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Sillas Duarte, Jr, DDS, MS, PhD
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Computational Photography: Future and Challenge for Dental Photography

One of the areas in which technology has made a significant impact is photography—more precisely, computational photography, a new term that we all should be aware of. This concept is being driven by smartphone manufacturers, not by the traditional camera manufacturers. The convenience of a relatively small device with impressive computational abilities has prompted the development of novel features that are revolutionizing how we take or make photographs. The megapixel camera war continues, as newer smartphones have cameras up to 108MP. Even though some smartphones may produce high-resolution files, many manufacturers default to the pixel-binned resolution to decrease phone storage. However, due to the small sensor size, noise is still an issue with smartphone cameras. Thus, digital technology was employed to improve this shortcoming, but it went even further. Computational technology is now able to control the illumination of a scene through algorithms that can relight, enhance, and/or blur the whole or parts of an image. With some smartphone cameras, by the time one presses the shutter button the camera has acquired numerous frames at long exposure, fast shutter speed, and standard speed, in addition to the intended shot. All those files are then merged, analyzed, and processed for noise and details, pixel by pixel, to generate the final image. Human skin/hair receives the highest level of detail, whereas other areas of the image receive less attention. Apps are now available with the power to access, modify the original depth of field, and refocus almost any image. All of us who do intraoral photography understand clearly how all the aforementioned features would be a great ally to our photographic skills.

The quality of smartphone videos also has significantly improved, with 4K video resolution now available for most smartphones. But more impressive is the extended dynamic range and the cinematic-like in-body video stabilization that some smartphones have available. In extended dynamic range mode, the camera is actually taking dual-exposure videos at a normal exposure frame together with a short exposure frame (for instance, 120 and 60 frames per second) and combining them on the spot to create a single frame without any further processing. Moreover, smartphone apps are capable of creating 3D face scans that can be exported as STL or OBJ files.

With all this technology in everyone's hands, it is no wonder that the digital camera market continues to shrink. The Camera & Imaging Products Association (CIPA) has reported a huge drop in global digital camera shipments from 2017 to 2019, as well as a decline in sales for all major camera manufacturers.[1]

Despite its features and convenience, photographing extra- and intraorally with a smartphone poses an ethical dilemma: Is it permissible to store patients' electronic protected health information (ePHI) on a personal device? In the United States there are strict regulations that safeguard patient health information (Health Insurance Portability and Accountability Act, HIPAA[2]), and dental practices are responsible for implementing policies to protect personal information. In 2006, the Health Information Technology for Economic and Clinical Health (HITECH) Act[3] expanded the concept of ePHI protection and places liability on the practice to maintain HIPAA and HITECH compliance. The US Government has created a webpage with more information on privacy and security of using mobile devices, and it is worth your time to take a look.[4]

The digital disruption affects our personal and working lives almost every day, and the understanding of its power and, more importantly, its limits can only benefit our practices, patients, and treatments. I welcome you to experience the magnificent collection of opinions and techniques that challenge the boundaries between digital technology and dental art.

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[1]http://www.cipa.jp/stats/documents/e/dw-201910_e.pdf
[2]https://www.hhs.gov/sites/default/files/privacysummary.pdf
[3]https://www.hhs.gov/sites/default/files/ocr/privacy/hipaa/administrative/enforcementrule/enfifr.pdf
[4]https://archive.healthit.gov/providers-professionals/your-mobile-device-and-health-information-privacy-and-security

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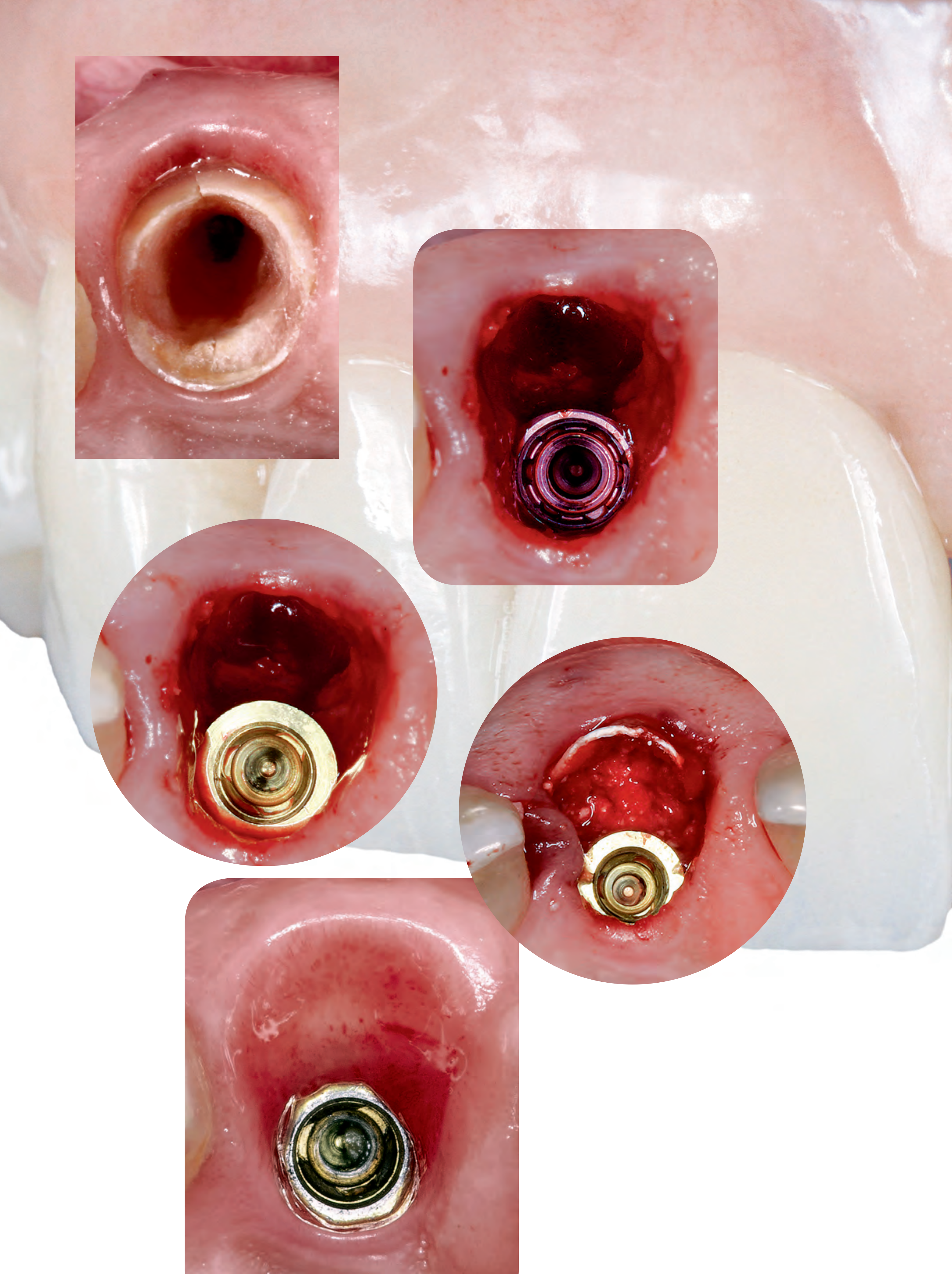

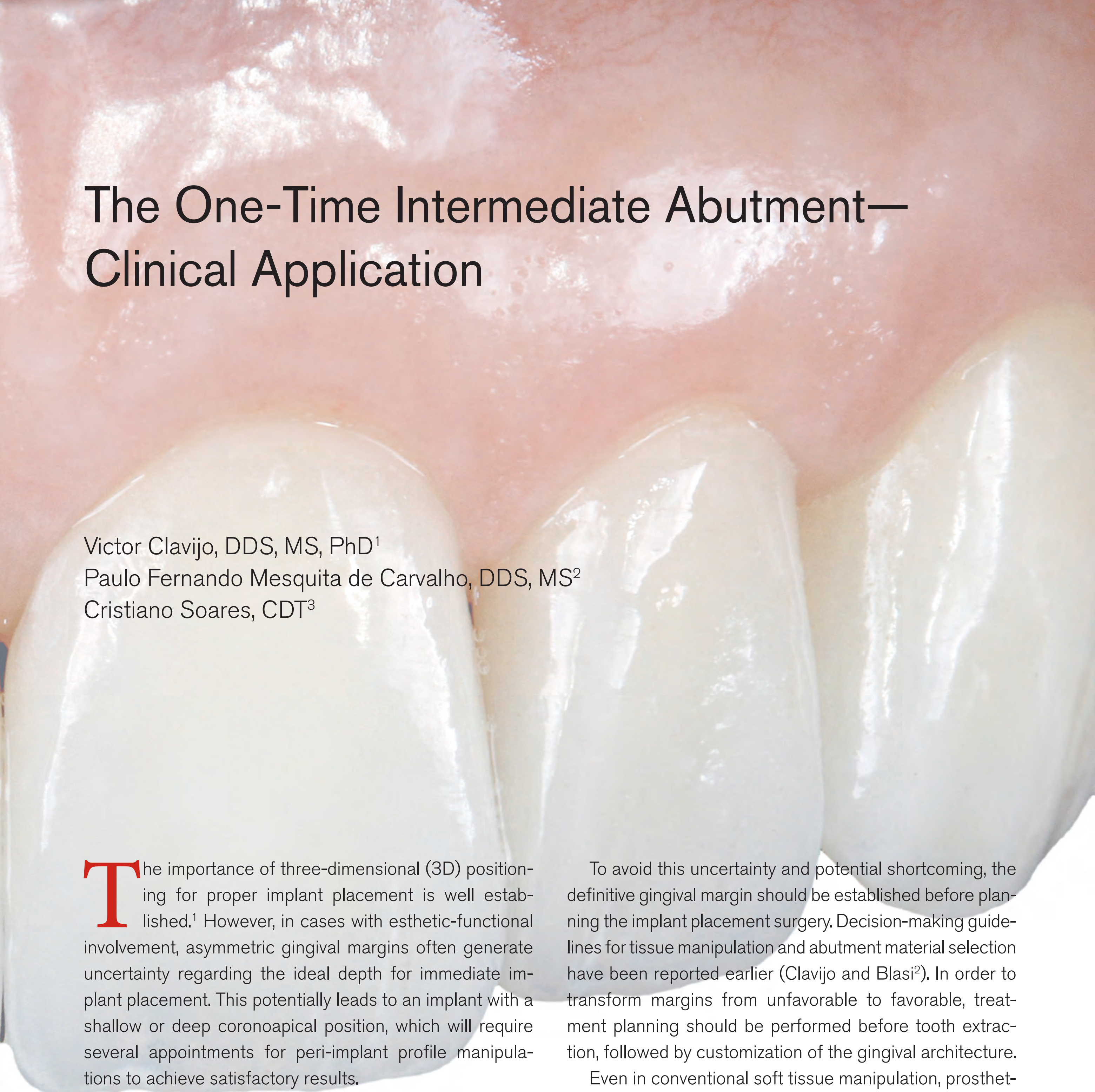

The One-Time Intermediate Abutment—Clinical Application

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Cristiano Soares, CDT[3]

The importance of three-dimensional (3D) positioning for proper implant placement is well established.[1] However, in cases with esthetic-functional involvement, asymmetric gingival margins often generate uncertainty regarding the ideal depth for immediate implant placement. This potentially leads to an implant with a shallow or deep coronoapical position, which will require several appointments for peri-implant profile manipulations to achieve satisfactory results.

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To avoid this uncertainty and potential shortcoming, the definitive gingival margin should be established before planning the implant placement surgery. Decision-making guidelines for tissue manipulation and abutment material selection have been reported earlier (Clavijo and Blasi[2]). In order to transform margins from unfavorable to favorable, treatment planning should be performed before tooth extraction, followed by customization of the gingival architecture.

Even in conventional soft tissue manipulation, prosthetic reconnections[3–5] are necessary due to removal of the provisional. This may lead to some bone resorption and subsequent tissue recession from repeated injury to the tissue seal and to the biologic equilibrium around the implant and abutment connection. The one-abutment, one-time concept has been described to improve stability of the bone-implant interface,[6–9] but such a technique would be hard to reproduce given the difficulty to manipulate the peri-implant tissue when the abutment cannot be removed and in cases of cement-retained prostheses.

BOX 1 Advantages and Disadvantages of the One-Time Intermediate Abutment

Advantages
- No reconnection around the implant neck; no aggression of the gingival seal formed around this area with the prosthetic connection
- More stable bone remodeling and more predictable maintenance of tissues around this connection
- Improved patient comfort during tissue-manipulation appointments
- Single body without access screw, platform switch, and gold coloration, allowing for increased amount of gingival tissue and superior esthetic quality (in terms of light reflection through thin gingiva)
- Reversibility and retrieval of component if necessary

Disadvantages
- The higher the intermediate abutment, the lower the possibility of peri-implant tissue manipulation
- Need for additional prosthetic components for fabrication of the restoration

A clinical alternative to keep both the bone-implant interface and peri-implant epithelium intact is the one-time intermediate abutment approach following placement of immediate implants or placement of implants with a tapered internal connection in healed sites. This allows for peri-implant tissue manipulation with more favorable bone remodeling and fewer reconnections that can damage the peri-implant tissue (Box 1). Key factors for the use of the immediate implant protocol after extraction include the residual bone, gingival margin position, buccal bone characteristics, and tissue biotype.[10] This article presents a case to describe the step-by-step application of the one-time intermediate abutment.[11]

CASE PRESENTATION

A 46-year-old woman came to the dental office reporting mobility of the maxillary right central incisor. The tooth had an all-ceramic crown with a fiberglass anatomic post-and-core composite resin restoration that had been fabricated approximately 10 years earlier. In addition, the patient was unhappy with the esthetics of her teeth, particularly their size and color, as well as the black spaces.

After clinical (Figs 1a to 1d), radiographic, and tomographic (Fig 1e) examinations, a fistula in the buccal area of the tooth (with suppuration and 9.0-mm probing depth) was observed, demonstrating partial loss of the buccal wall (confirmed by tomography) and suggesting longitudinal root fracture.

Treatment Plan

The six-step treatment plan was carried out as follows:

1. Pre-extraction planning to define the final height of the gingival margin of the failing tooth through Digital Smile Design (DSD), initial impression-taking, and planning of the guided surgery
2. Surgical and prosthetic procedures for immediate implant placement, one-time intermediate abutment, and maintenance of the gingival and bone architecture of the tooth site
3. After 6 months of peri-implant tissue stability, peri-implant manipulation until margins are stable
4. Removal of unsatisfactory restorations, preparation of teeth, and final impression of teeth and implant
5. Laboratory steps for fabrication of abutment and ceramic restorations
6. Delivery of tooth-supported and implant-supported ceramic restorations

1a

1b

1c

1d

1e

Figs 1a and 1b Preoperative intraoral views.

Figs 1c and 1d Views of the root fracture.

Fig 1e Initial cone beam computed tomography (CBCT) image.

Fig 2 Final implant depth using Digital Smile Design references.

2

Step 1

After decoronation of the maxillary right central incisor and clinical confirmation of the root fracture, an impression was taken for planning and laboratory preparation of the surgical guide.

The buccal volume of the extracted ceramic crown was reduced from its emergence profile, along with any occlusal contacts (at maximum intercuspal position and excursive movements) to prevent displacement during healing of the fistula through medication. The ceramic restoration was reseated with zinc phosphate cement, and the patient was provided instructions and dismissed.

The DSD was performed from the extraoral and intraoral photographs. The cementoenamel junction of the maxillary left central incisor was the reference for the final gingival margin (Fig 2) to achieve an optimal esthetic result in terms of tooth proportion.

The patient's files (DICOM and STL) were sent to the planning center (MCENTER, MSOFT Virtual Planning Process, Israel) to fabricate the surgical guide for implant placement. Implant placement was planned according to the 3D positioning and at 5 mm from the planned gingival margin of the adjacent tooth (in this case, the cementoenamel junction of the maxillary left central incisor) (Fig 2).

Fig 3a Ten days after crown cementation with zinc phosphate. Observe the coronal migration of the tissue. This gingival margin improvement was the result of reducing the crown's emergence profile.

Fig 3b Probing before tooth extraction.

Fig 3c Tooth extraction.

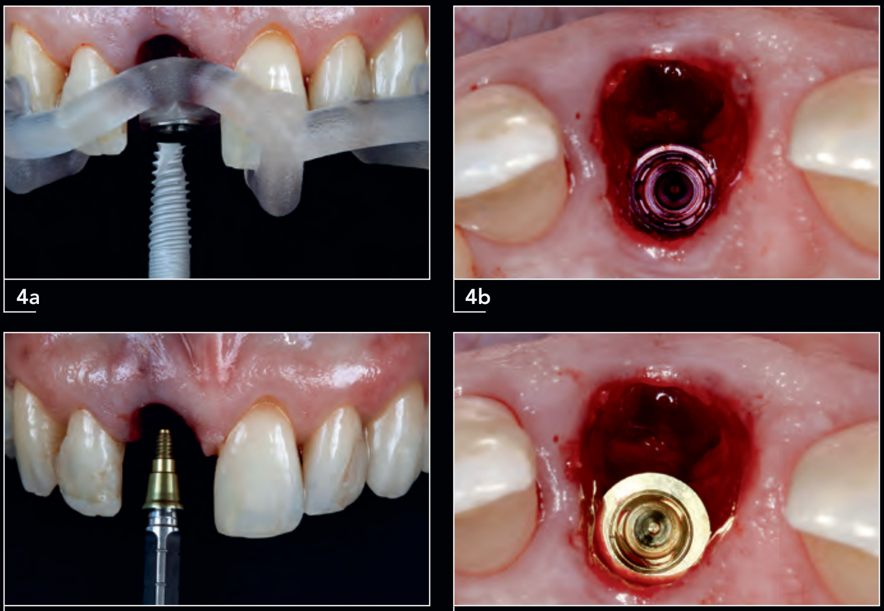
Fig 3d Decontamination of the socket.

Figs 3e and 3f Determination of the bone defect.

Step 2

After the ceramic crown was removed, minimally traumatic extraction was performed upon visual confirmation of the root fracture (Figs 3a to 3c), followed by careful cleansing of the socket (Fig 3d) and buccal soft tissues. With the aid of a periodontal probe (Figs 3e and 3f), it was possible to carefully determine the extent of the bone defect in the buccal wall[12,13] (classified as wide/deep according to the immediate implant placement protocol of Joly et al[14]).

Guide drilling (MGUIDE) and implant placement procedures were performed according to the digital planning. The implant (V3, 3.9 × 13 mm, MIS Implants) was inserted, achieving a primary stability of over 45 Ncm (Figs 4a and 4b), which allowed for immediate provisionalization and placement of the one-time intermediate abutment (MIS Connect) (Figs 4c and 4d) with a 30-Ncm torque. The aim was to place the intermediate abutment at least 1 mm away from the future bone margin to improve the bone remodeling, since disconnection will take place above the bone level. Pick-up of the provisional was performed by joining the ceramic crown and the provisional metallic abutment. Criteria used for defining the peri-implant profile are described in Fig 5. As previously mentioned, the one-time abutment was placed in the subcrestal peri-implant area to create space between the connection and the bone-implant interface, thus optimizing bone remodeling. In the subcritical area, a concave profile was planned approximately 1 mm below the gingival margin to create space for the connective tissue graft and the clot. The critical cervical contours of the crown were maintained mesiodistally by slight reduction of the buccal and lingual emergence angle in an attempt to migrate the gingival margin coronally, following the decision tree on how to determine the critical or cervical contour of the provisional in immediate implants (Fig 6).

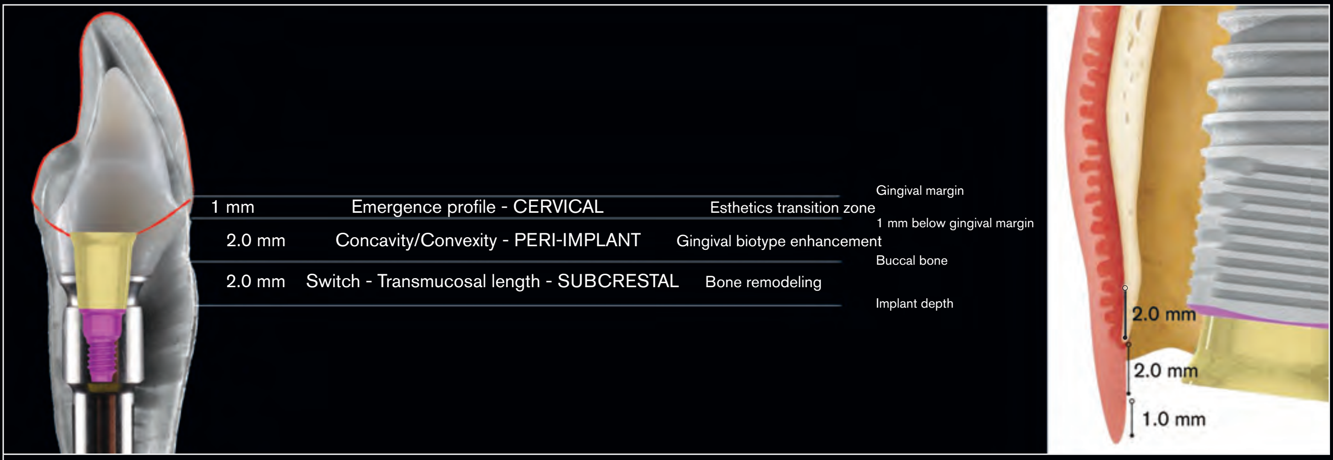


4a 4b 4c 4d

Fig 4a Guided implant placement.

Fig 4b Palatal approach from the digital implant treatment planning.

Figs 4c and 4d Delivery of one-time intermediate abutment.



5

Fig 5 Implant depth and function at each millimeter. An implant is usually placed 4 to 5 mm from the gingival margin in an ideal situation, which provides 1 to 2 mm subcrestal positioning. Within the 5 mm between the gingival margin and the implant head, there are three areas of importance:

1—*Area of the esthetic contour of the crown.* This area has the function of maintaining the gingival tissue, providing support for it and the correct sealing of the socket after extraction. This contour can be changed by removing its buccal volume, depending on the desired final gingival margin height after healing.

2—*Transmucosal area responsible for tissue volume around the implant.* This area should be very concave at the baseline to create space for the connective tissue that will change the thin tissue biotype around the tooth, close to the clot, into a thick tissue biotype around the implant.

3—*Area responsible for bone remodeling around the implant.* This area is usually subcrestal and is therefore important for bone remodeling. This area usually is polished titanium with a platform switch with a standard height. Bone remodeling may cause injury to the final result, so attention should be paid to this area. Components with transmucosal height of at least 1.5 to 2 mm should be used to avoid any pressure exerted on the bone around the implant.

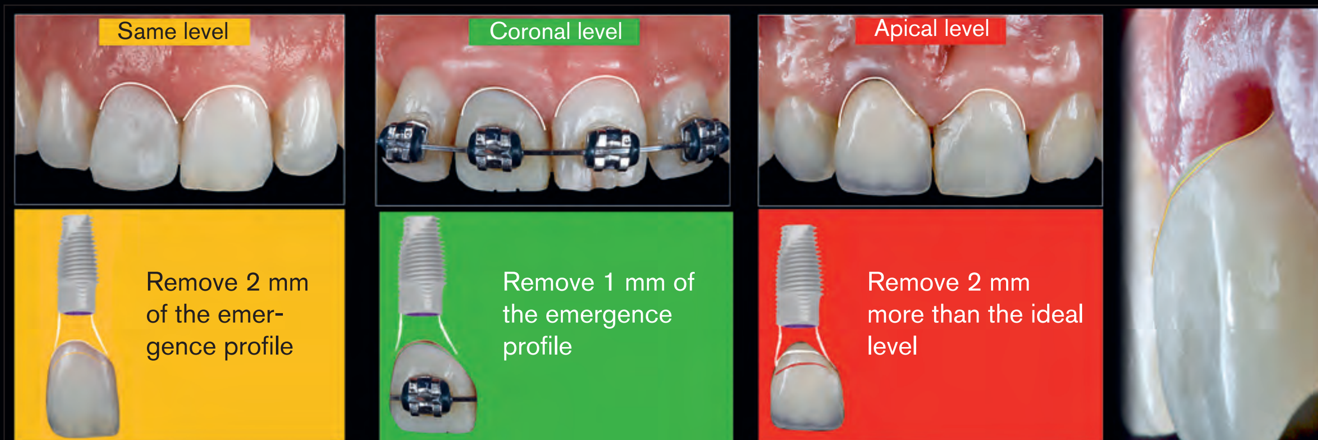


Fig 6 Reduction of the provisional restoration emergence profile according to the initial gingival margin in relation to the adjacent tooth. At the time of provisional finishing, a less convex emergence profile is always required to generate an overcorrection of the gingival margin around the restoration to ultimately improve the predictability during peri-implant tissue manipulation.

—*Margin at same level.* After provisional finishing, remove 2 mm from emergence profile below desired future gingival margin.
—*Coronal margin.* After provisional finishing, remove 1 mm from emergence profile.
—*Apical margin.* After provisional finishing, remove 2 mm from emergence profile below desired future gingival margin.

The provisional restoration was polished and cleaned following a protocol published elsewhere.[15]

The provisional restoration was delivered, after which a mixed flap was performed using the tunnel technique at the site of the maxillary central incisors (Fig 7a) in order to create space for a connective tissue graft and allow for the flap to cover the recessions of the involved teeth. A properly sized connective tissue graft (Fig 7b) was removed from the palatal region for the treatment of both teeth. The graft was positioned subgingivally, close to the gingival margin, and stabilized by sutures at both ends (Figs 7c to 7e).

A resorbable membrane (Geistlich Bio-Gide Shape) was then inserted in the external portion of the socket, beneath the periosteum (Figs 8a and 8b). The membrane should be supported by healthy bone at least 3.0 mm laterally and apically. Excess membrane should be maintained to facilitate positioning and stability until the biomaterial is packed.

The biomaterial (Geistlich Bio-Oss Collagen) was trimmed and adapted to the shape of the defect. The first portion should be inserted below the membrane, reconstructing the lost wall portion. Other portions should be placed over any existing spaces so that they may be filled. The membrane can be trimmed close to the gingival margin or folded and placed toward the buccal aspect (Figs 8c and 8d).

The provisional restoration with the properly defined contour was screwed with a torque of 30 Ncm, allowing for the support of the papillae and sealing of the reconstructed socket. Flap and graft tension sutures anchored at the contact points were accomplished at the proximal spaces, allowing for the coronal advancement of both the flap and graft (Figs 8e and 8f).

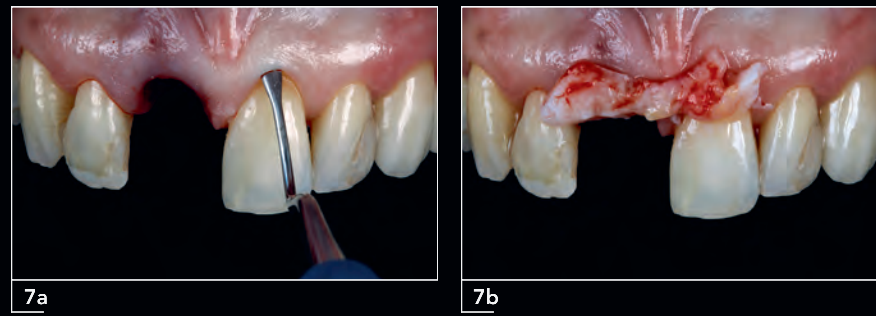
Step 3

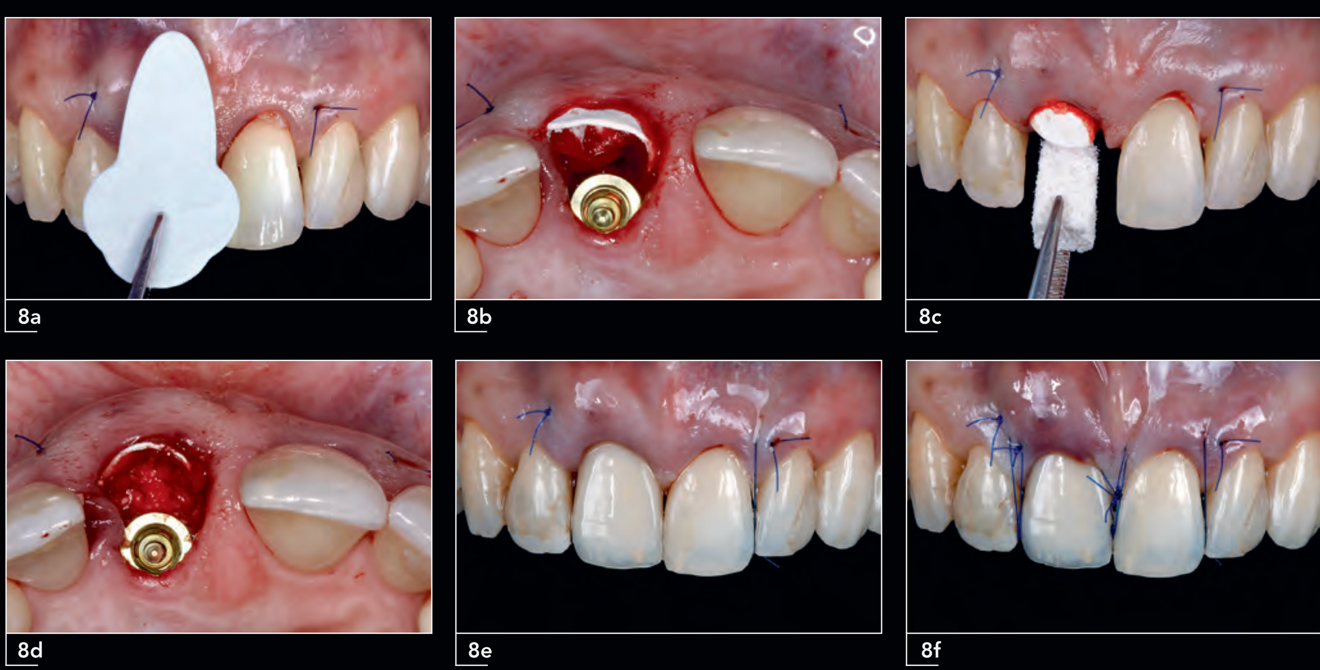
Six months after the graft placement, peri-implant tissue stability was achieved (Figs 8g and 8h) and peri-implant tissue manipulation was initiated. The surgical protocol was performed to obtain a margin coronal to adjacent tissue with a volume greater than 2 mm, limiting the prosthetic manipulation only to the restoration of the cervical contour or critical contour[16] with volume addition in this area.[2] For a precise determination of this margin, the technician performed the diagnostic wax-up, defining the correct gingival margin height (Figs 9a to 9e). The provisional was removed and flowable composite resin was added for manipulation of the margin.

Fig 7a Tunnel technique.

Fig 7b Connective tissue graft in position.

Figs 7c to 7e Graft is positioned subgingivally and stabilized by sutures at each end.





Figs 8a and 8b Resorbable membrane.

Fig 8c Bio-Oss Collagen.

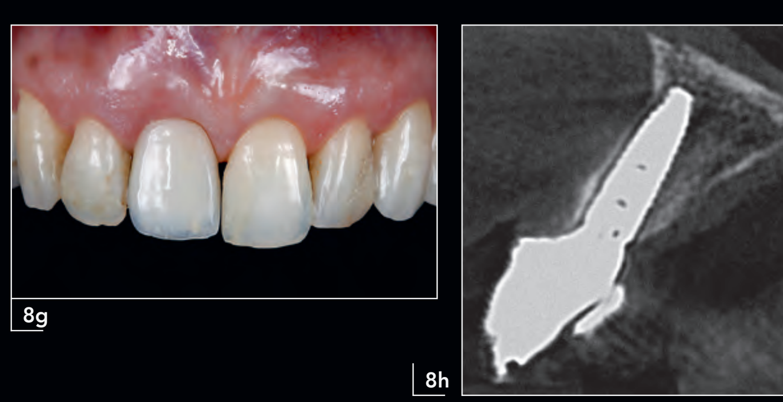
Fig 8d Bio-Oss Collagen in position.

Fig 8e First suture.

Fig 8f Second suture.

Fig 8g Six months after implant placement.

Fig 8h CBCT 6 months after implant placement.




9a


9b


9c


9d

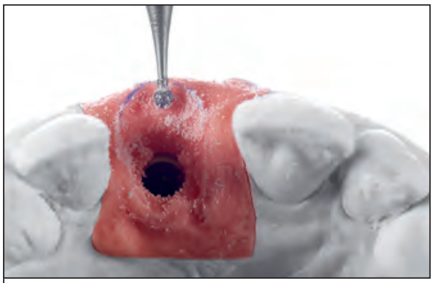

9e

Fig 9a Silicone guide of the ideal wax-up. Note the ideal zenith in blue color.

Fig 9b Placing the silicone guide on top of the stone model to visualize the ideal zenith.

Fig 9c Note the area that needs to be trimmed.

Figs 9d and 9e Removing the excess of the soft tissue guided by the ideal wax-up reference.


10a


10b


10c


10d


10e

Figs 10a and 10b Guided teeth preparation creating 0.5 mm of thickness for the future veneers.

Fig 10c Placing new composite buildup.

Figs 10d and 10e Finishing of the teeth preparations.

Fig 10f Final teeth preparations with the zirconia abutment try-in.


10f


11a


11b


11c


11d

11e


11f

Fig 11a Stone model with the zirconia abutment before shape and color customization.

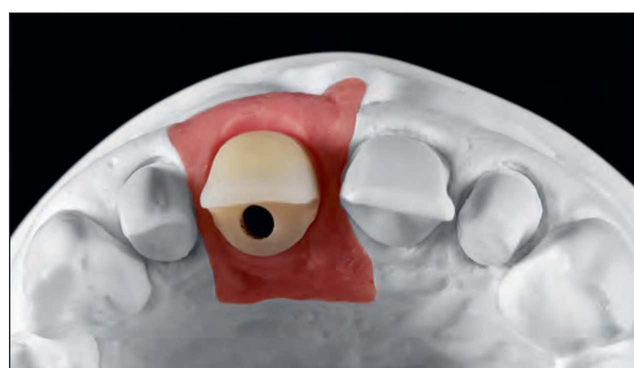
Fig 11b Reduction of buccal volume.

Fig 11c Ceramic buildup.

Figs 11d and 11e Finishing of the customized color and shape of the abutment.

Fig 11f Bonding the zirconia abutment into the titanium-base structure following the APC concept technique from Blatz et al.[18]

Fig 11g Final check of the shape and volume.


11g

Step 4

The unsatisfactory restorations were removed and composite resin restorations were placed. The teeth were prepared for ceramic veneers following the vertical axis of insertion in order to favor the closure of the black spaces and manipulation of the papillae (Figs 10a to 10f). Transfer digital and analog impressions were obtained and sent to the laboratory with shade and shape information.

Step 5

After the cast fabrication, a digital workflow in the laboratory was undertaken. First, a zirconia abutment was fabricated on the titanium link (MIS Ti-Base CONNECT), replicating the preparation shape with a slight labial reduction for subsequent ceramic application to mimic the shade of the adjacent teeth and to create a bonding area on the abutment (Figs 11a to 11g). This procedure favors the

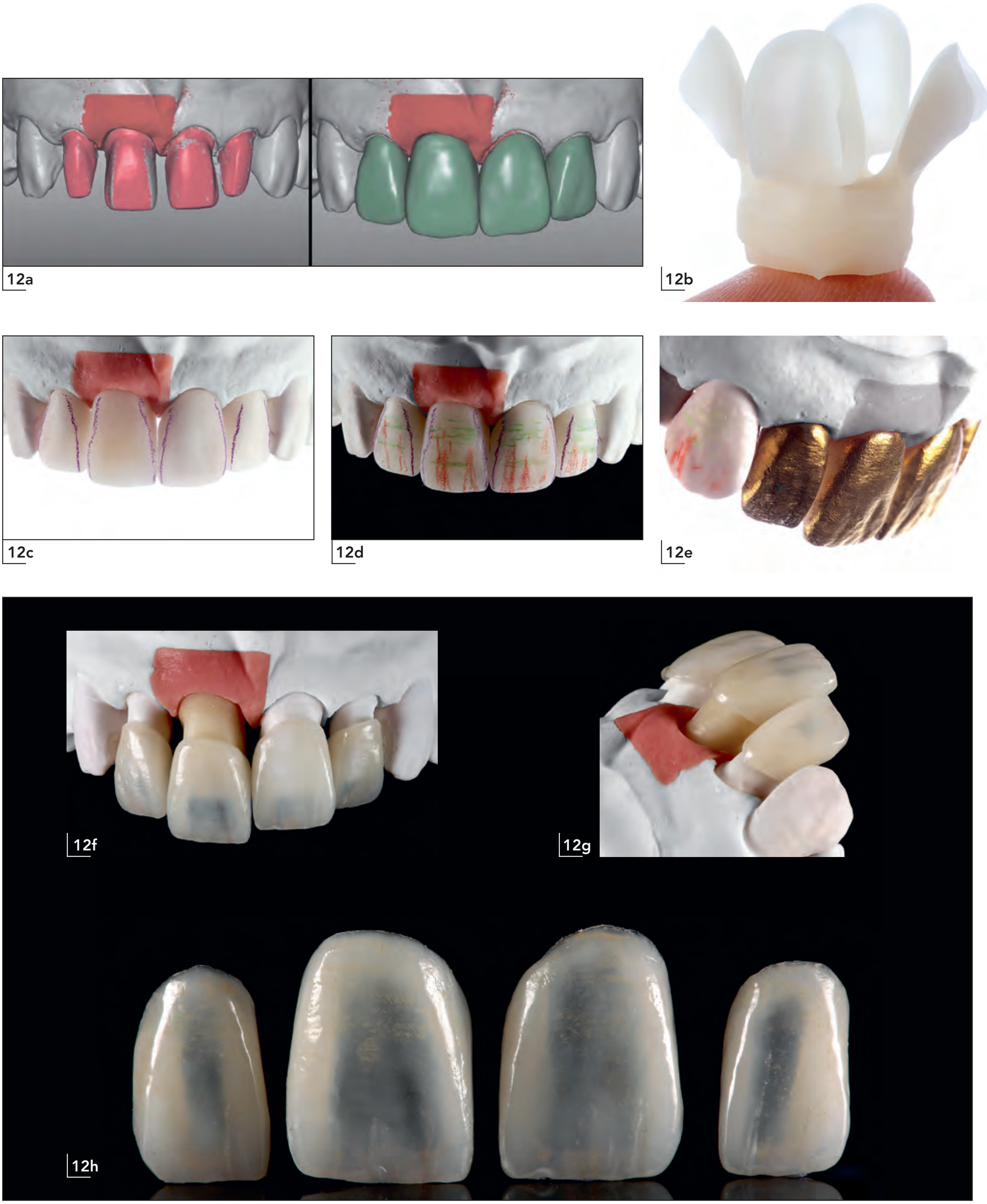


Fig 12a Digital design from the final veneers.

Fig 12b Pressable lithium disilicate (e.max Press) veneers.

Fig 12c Finishing the lithium disilicate veneers.

Figs 12d and 12e Final texture.

Figs 12f to 12h Final veneers.


13a


13b


13c

Figs 13a and 13b Customized abutment try-in.

Fig 13c Veneers try-in.

adhesive cementation and matching of the substrate. After the shade and shape equilibrium was achieved, the teeth and abutment were scanned again to obtain the digital design of the ceramic veneers (Fig 12a) following the reference of the initial diagnostic wax-up.

The ceramic veneers were milled in wax and then injected with lithium disilicate (e.max Press, Ivoclar Vivadent). After finishing, the veneers were characterized and glazed, and the final polishing was performed (Figs 12b to 12h).

Step 6

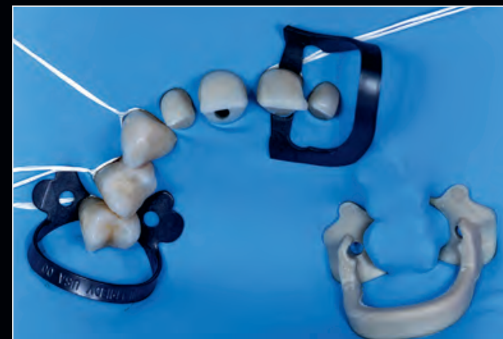
After removal of the provisional, any residues of temporary cement were removed, the abutment was placed, and the ceramic veneers were individually tried-in for their adaptation (Figs 13a and 13b). All the veneers were then placed to check the contact points (Fig 13c). After the "dry" test, a glycerin-based paste (Variolink Esthetic LC, Ivoclar Vivadent) was used to perform the try-in. The patient approved the shape and color, and the cementation of the ceramic veneers proceeded.

Rubber dam isolation was performed with thick rubber sheets (Nictone), a rubber dam adult frame, and 212 Hu-Friedy clamps (Figs 14a and 14b).

The veneers were individually bonded using light-cured resin cement (Variolink Veneer, Ivoclar Vivadent) following the etching protocol for lithium disilicate with 5% hydrofluoric acid for 20 seconds, followed by rinsing and drying. To remove glass particle debris, 37% phosphoric acid was applied, followed by rinsing and drying. Silane was subsequently applied for 60 seconds and air dried, after which a thin layer of adhesive was placed, air-thinned, and left uncured. Enamel was etched with 37% phosphoric acid for 30 seconds, and dentin areas were etched for only 15 seconds. Etched enamel and dentin were thoroughly rinsed and dried with a gentle airflow and absorbent paper. A thin layer of adhesive was applied using a disposable applicator, followed by gentle airflow to remove the excess and promote solvent evaporation. The adhesive resin was light cured for 20 seconds.

The luting material was placed inside the veneers, which were positioned on the tooth surfaces. Excess cement was removed, and light curing was performed for 40 seconds.


14a


14b

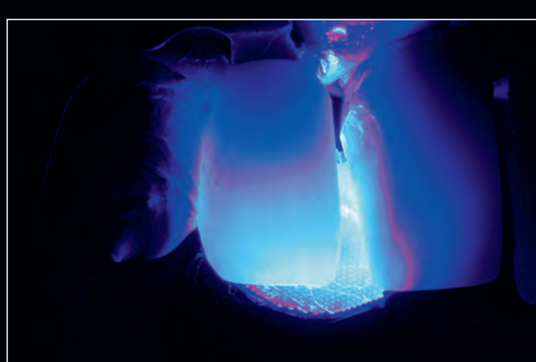

14c


14d


14e


14f


14g


14h

Figs 14a and 14b Rubber dam placement.

Fig 14c Checking the veneer fit after rubber dam placement.

Fig 14d Sandblasting with 27-µm aluminum oxide.

Fig 14e Phosphoric acid at 37% per 30 seconds in enamel and 15 seconds in dentin.

Figs 14f to 14h After a thin layer of adhesive, excess was removed with air and the veneer was placed with a resin cement and light cured.

Glycerin was placed at the tooth-ceramic interface to prevent oxygen inhibition and improve the polymerization process at the veneer margins (Figs 14c to 14h).

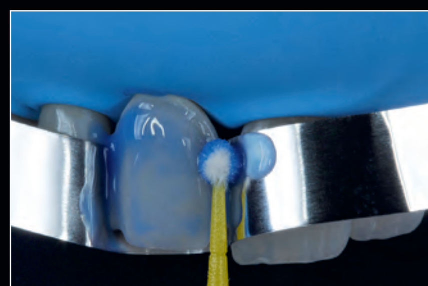
The veneer on the implant abutment was bonded following the protocol described by Clavijo et al[17] for bonding feldspathic ceramic with lithium disilicate structure (Figs 15a to 15i).

After cementation, the excesses were removed with a #12D scalpel, and margins were polished with composite resin rubber polishers. Occlusal adjustments were performed and radiographs were taken for control. One-week and 2-year follow-up images are shown in Figs 16 and 17.


15a


15b


15c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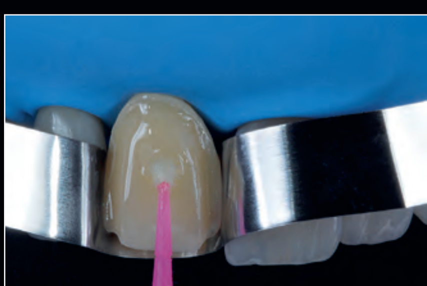

15f


15g


15h


15i

Fig 15a Implant veneer in position after bonding.

Fig 15b Sandblasting with 27-µm aluminum oxide.

Fig 15c Application of 10% hydrofluoric acid for 90 seconds.

Fig 15d Application of 37% phosphoric acid for residual removal.

Fig 15e Silane application for 60 seconds.

Fig 15f Thin adhesive layer application.

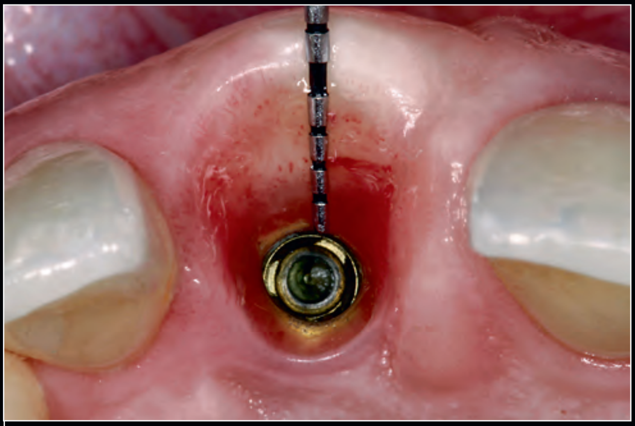
Fig 15g Excess adhesive removed after air jets.

Fig 15h Veneer in position.

Fig 15i Final light cure for 40 seconds.

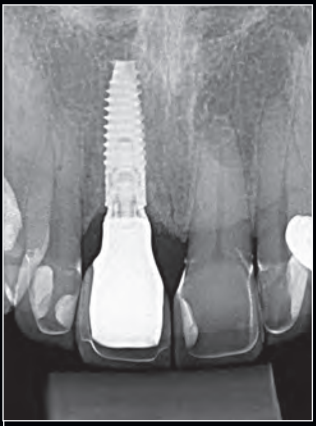
16

17a



17b

17c



17d

Fig 16 One week follow-up.

Fig 17a Two-year follow-up after implant and one-time intermediate placement.

FIg 17b Peri-implant tissue after 2 years.

Fig 17c Screw-retained crown removed after 2 years. Observe the zirconia and lithium disilicate areas.

Fig 17d Two-year radiographic follow-up. Observe the bone surrounding the intermediate abutment after immediate implant placement.

CONCLUSION

The one-time intermediate abutment is a new option to optimize bone remodeling and to increase the amount of tissue volume around implants. The abutment should be placed at least 1 mm above the future bone margin with a torque of 30 Ncm. With the one-time immediate abutment it is possible to protect the interface surrounding the peri-implant bone and mucosa, while providing the opportunity to customize the emergence profile using a screw-retained prosthesis.

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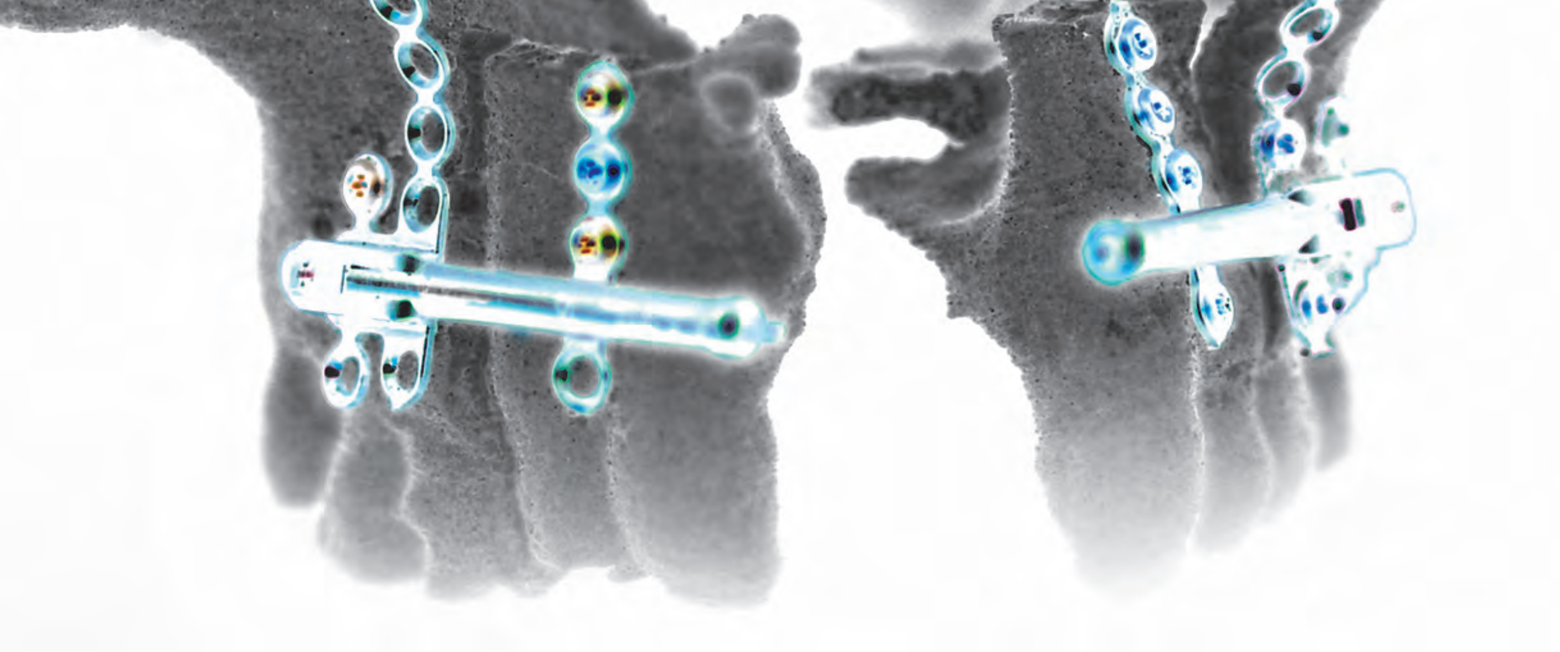

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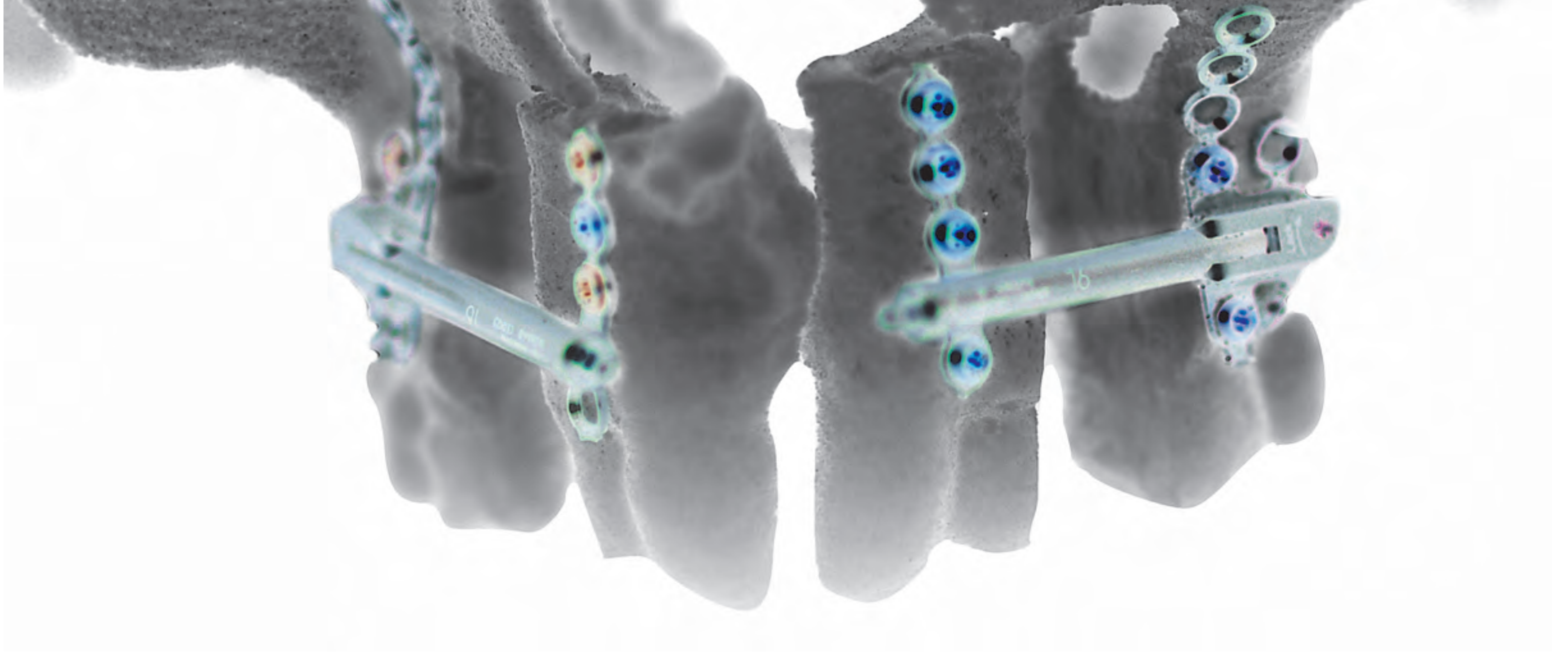


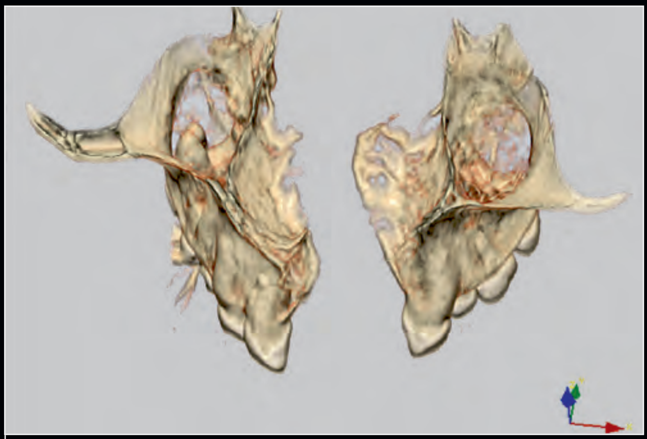
Bilateral Cleft Palate with Palate Involvement: Putting All in Place for an Esthetic Restoration

The patient presented in this article was referred for restorative finalization after treatment by an oral and maxillofacial surgeon and orthodontist for bilateral cleft palate with palatal involvement. Upon referral, the esthetic situation was extremely poor due to the patient's gingival recession and the implant positioning. The surgical and orthodontic treatment are described, followed by the treatment to provide an acceptable esthetic solution for this complex situation.

INITIAL PRESENTATION

Prior to the surgical and orthodontic treatment, the patient presented as follows (Figs 1 to 3):

- Skeletal Class III, Class I right molar, and Class II left molar, bilateral cleft palate with palate involvement
- Missing teeth: Maxillary right central incisor and first premolar; maxillary left central and lateral incisors and second premolar (#14,11,21,22,25)
- Removable partial denture for the anterior edentulous area
- Anterior crossbite


1a


1b

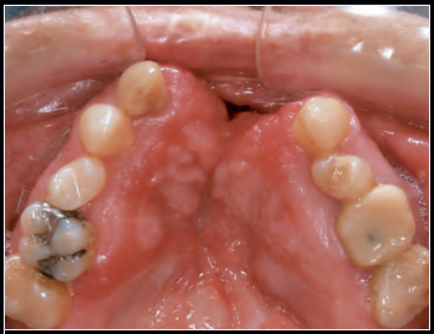

2

Figs 1a and 1b CBCT of the maxillary defect of the cleft palate patient. *(a)* Apical and *(b)* frontal views.

Fig 2 Initial panoramic radiograph.

Figs 3a to 3c Initial intraoral photographs of the defect.


3a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3c

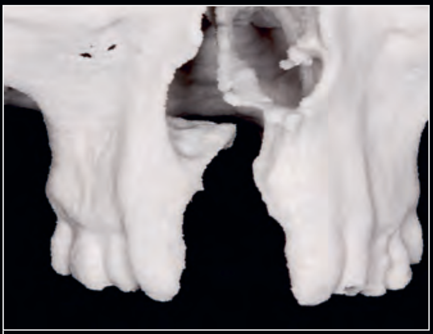
SURGICAL AND ORTHODONTIC TREATMENT

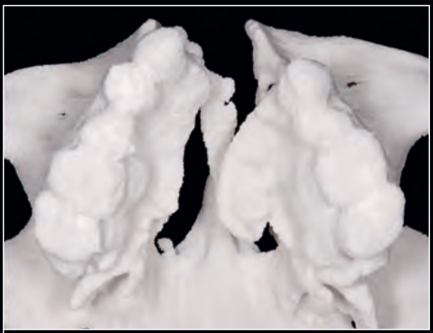
Bone distraction osteogenesis was performed first on printed models, to visualize the surgical strategy and select the adequate hardware (Figs 4 and 5), and then on the patient. On the day of the surgery, the segmental osteotomies were performed with piezosurgery based on the preplanned surgery on the printed model (Fig 6). A week after the surgery, the patient started with the distraction sequence by moving both lateral segmental osteotomies 1 mm a day, 0.5 mm in the morning and 0.5 mm at night, until both sides touched at the central midline of the face. The severe arch discrepancy (Figs 7a to 7c) was due to the patient's initial Class III malocclusion as well as the anterior movement into the large bone defect.

Orthodontics was then performed to realign the teeth to create a nice arch form and best position the torque of the teeth prior to opening the vertical dimension with the help of posterior implants (Fig 8). Six months after the comple-

Figs 4a and 4b Frontal and occlusal views of the 3D-printed model of the CBCT.

Figs 5a to 5c Distraction osteogenesis surgical mock-up on 3D-printed models: *(a)* frontal, *(b)* right lateral, *(c)* left lateral.

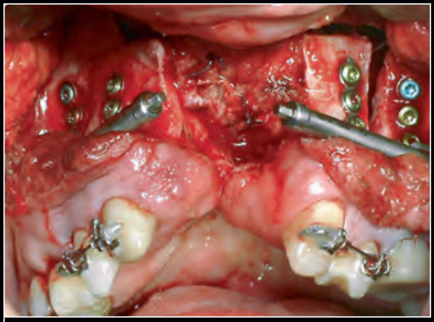

4a


4b


5a


5b


5c


6


7a


7b

Fig 6 Day of segmental osteotomy: Refreshing of the bone blocks that were cut with piezosurgery for precision with the corresponding distraction hardware in place.

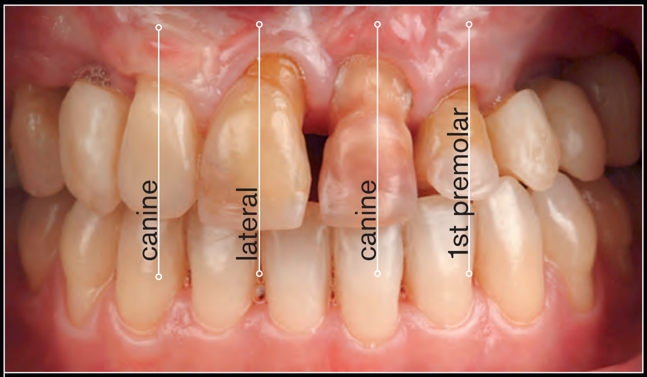
Figs 7a to 7c Distraction osteogenesis movements were started 1 week after the surgery.

Fig 8 Orthodontic treatment was undertaken to open the vertical dimension and provide torque and arch alignment on the four anterior teeth.


7c


8

tion of the distraction osteogenesis, implants (Nobel Replace, Nobel Biocare) were placed by the surgeon to fill the posterior distal edentulous spaces (tooth sites 13, 23, 24, 25) created by the mesial movement of the segmental osteogenesis. After implant osseointegration, screw-retained provisional restorations were fabricated to use as anchorage and to increase vertical dimension in order to obtain the best anterior guidance.



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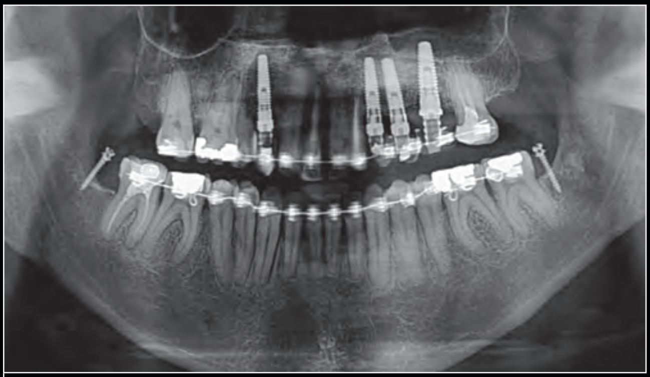

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Fig 9 Note the gingival recession with vertical and horizontal components in the areas of the four anterior teeth and the posterior implants. Also note the difficult tooth relationship interdentally and in width to the new tooth position.

Fig 10 Panoramic radiograph demonstrates the provisional restoration placed as well as the implants and the tooth resorption on #14. Orthodontics was used as an anchorage to fine tune the anterior teeth relationship.

PRESENTATION UPON REFERRAL

The patient presented for prosthetic treatment with a transverse discrepancy in the maxillary left quadrant with a large (16 mm) interproximal bone defect between #11 (lateral incisor) and #21 (canine) as well as a 9-mm bone defect distal of #12 (which is a canine), due to the extremely palatal and deep placement of the implant (Nobel Replace NP) in that area (#13). Other findings included root resorption on #14, which needed to be extracted and replaced by an implant, large discrepancies of gingival levels across all six anterior teeth, with implants for both canines having different depths and positions, as well as lack of soft tissue volume not only vertically but also horizontally (Figs 9 and 10). All areas of the implants at #23, #24, and #25 were too coronal, with full heads above the soft tissues at different heights and lack of buccal and vertical tissue volumes. Repositioning the tissue to align all the gingival margins would be challenging, as would transforming root diameters to the new prosthetic tooth forms—the #12 canine into a lateral incisor, the #22 first premolar into a lateral incisor—and the implants on #13 and #23 at the corresponding tissue levels with their respective defects.

PLANNING

Alginate impressions were taken and a full-contour wax-up was performed to evaluate the ideal incisal edge and occlusal plane related to the malocclusion present and mesiodistal space that remained, as well as to recreate the ideal tooth form and then the ideal tissue level position with pink wax (Figs 11 and 12). It was a conventional facially generated analysis of the situation to visualize the end result of this difficult case in order to achieve the ideal plan. An orthodontic set-up was also done at the same time to visualize the best occlusion possible given the limitation of the skeletal and tooth positions, with a saddle lingual torque of the mandibular left quadrant, especially on #32, #33, and #34, due to the transverse discrepancy in the corresponding maxillary area.

Silicone matrices were fabricated to visualize the necessary space for the completion of the mock-up in the patient's mouth (Figs 13a and 13b). Once this evaluation was performed, provisional restorations and composite-veneered titanium abutments were fabricated for teeth and implants in the full arch. Care was taken while preparing the teeth to perform a supracrestal margin for a flatter gingival scallop in the provisional restoration (Figs 14a to 14c). This procedure was done to maximize tissue thickness coronally as much as possible and then, through the final provisional restoration, to shape the desired gingival scallop to a height of around 4.5 mm from the tip of the interproximal papillae to the most apical position on the gingival margin.

11

12

13a

13b

14a

14b

14c

Fig 11 Mounted casts.

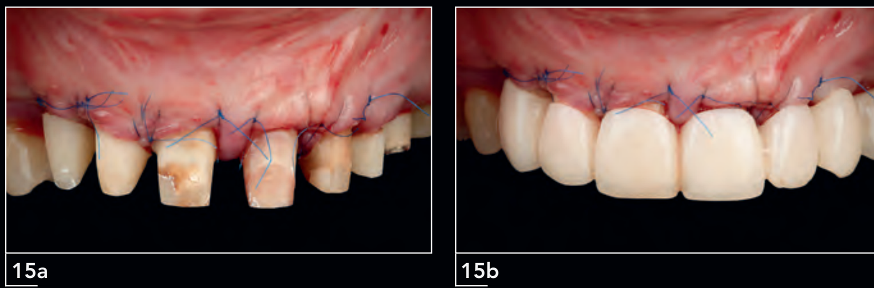
Fig 12 Full-contour wax-up with white wax for tooth proportion as well as pink wax for the soft tissue recessions and volume discrepancies. Orthodontic set-up was performed in the mandibular left quadrant to solve the transverse problem by torquing teeth #32, #33, and #34. In this way, the emergence profile on the maxillary arch could be straight for better esthetics and occlusion.

Figs 13a and 13b Silicone matrices for preparation of teeth and performing an esthetic mock-up before provisional restoration fabrication.

Figs 14a to 14c *(a)* Mock-up teeth and their correct orientation were checked, *(b)* teeth were prepared, and *(c)* provisional composite abutments were screwed in on implants and the full-arch provisional restoration was relined.

PERIODONTAL SURGERIES

Two connective tissue graft surgeries were necessary to satisfy the prosthetic expectations. The two surgeries were performed 4 months apart for healing purposes and tissue maturation. The first periodontal surgery involved different flap elevations to limit the risk of failure. Central papillae were elevated uncut to limit any papilla loss and tunneled to preserve as much of the anatomy as possible and improve the site due to the large vertical bone defect related to the distraction approximation of both segmental osteotomies on the midline. The flap was mainly tunneled around implants #13, #23, #24, and #25 through a full-thickness flap to avoid the thin tissues from jeopardizing the flap-elevation procedure. The papillae between the central and lateral incisors on both right and left sides were cut through a partial-thickness flap elevation, to allow an entrance to the tunnel side all the way to the maxillary arch, that extended 3 mm vertically above the fornix from posterior to anterior teeth in order to coronally advance the



Figs 15a to 15d Results of first connective tissue grafting before and after placement of provisional restorations at *(a and b)* day 0 and *(c and d)* 3 months.

Figs 16a to 16d Second connective tissue grafting performed to satisfy the prosthetic demands. *(a and b)* At day 0 before and after provisional restoration. *(c)* Occlusal view of the donor site. *(d)* Result after 3 months of healing.

flap to meet the desired prosthetic flap scallop. At this stage of the surgery, and as the flap was passive, care was taken to deflect the tissue and perform the root remodeling of the four anterior teeth to blend the tissue support and emergence profile despite the root discrepancies among them. Care was taken to reduce the roots above the crestal bone in order to avoid any height loss during the procedure, but the main objective was to blend the diameters of each contralateral tooth, reducing their buccal emergence but even more important their mesiodistal root distance. This root reduction improved the crestal space not only interproximally but also buccally, providing a larger space for connective tissue grafting to provide more crestal soft tissue thickness.

Once the flap incisions, passivation, and root remodeling were completed, the tissue grafting template was tailored to the full-arch maxillary site in order to harvest all the desired tissue to overcome the root, implant, and defect dehiscence. Several donor sites were specifically selected based on the type of defect and tissue density desired. Both tuberosities, as well as the superficial hard palate involving only the lamina propia, were removed in order to target the higher concentration of dense collagen fibers for the connective tissue grafts for the multiple recessions present (Figs 15a to 15d).

After 3 months of healing, a second connective tissue grafting procedure was required to improve tissue height and width, especially around the dental implants that were

17a

17b

Fig 17a New mock-up tried in patient's mouth to evaluate the tooth proportion, gingival scallop, incisal edge, and occlusal plane.
Fig 17b Final full-contour wax-up.

placed by the previous surgeon and around the NobelActive 3.0 implant on #14. Special details were addressed when elevating the partial-thickness flap for the second time, such as modifying the emergence profiles of the teeth and composite abutments to flatten them in order to advance the maximum amount of tissue coronally. Care was taken to harvest the graft from the same site of the superficial hard palate to retrieve the densest (scar) tissue available from the donor sites. Before provisional cementation, the buccal emergence profile was flattened to almost the interproximal contact level in order to avoid any pressure on the grafted coronally advanced flap. Note the flat scallop designed on the provisional restorations across the entire maxilla to allow maximum healing in the most coronal position without any pressure on the grafted site (Figs 16a to 16d).

PROVISIONAL, REEVALUATION, AND TISSUE REMODELING

After another 3 months of healing from the second connective tissue graft procedures around teeth and implants, a new mock-up was tried in the patient's mouth to evaluate tooth proportion, desired gingival scallop, incisal edge, and occlusal plane. Information was then recorded and transferred to the final full-contour wax-up (Figs 17a and 17b). A polyvinyl siloxane impression was taken to fabricate the second and final provisional restoration, creating the desired scallop, tooth proportion, and tissue support. Once the master cast was created, verification jigs were fabricated for both implant segments to guarantee the accuracy of the master model before fabrication and delivery. The patient was scheduled as soon as the verification jigs were fabricated and impression copings were glued together with low-shrinkage Pattern Resin (GC America).

The master cast accuracy was verified with the jigs in the laboratory. Heat-cured polymethyl methacrylate provisional restorations were fabricated, splinting teeth and implants even though both segments would be separated in the final restorations. Care was taken to modify the master stone model, carving the emergence profile of all individual teeth and implants to mold the tissue for the specific desired prosthetic tissue support. Rotational titanium temporary abutments were selected to restore the Replace Select and NobelActive implants (Figs 18a to 18h).

The provisional restoration was relined in place in the clinic, and the intracrevicular margin was located to meet the desired ideal gingival scallop and tissue support with the help of tissue retraction with retraction cords. When ideal margin locations were reached, the provisional acrylic reline was performed followed by an occlusal adjustment before removal from the patient's mouth (Figs 19a to 19c).

In the laboratory, the provisional restoration was polished and refined to create the desired esthetics and smoothness to satisfy the patient. The provisional was cemented with Temp-Bond cement (Kerr) and screw retained at the same time. It was left for 6 months until the desired esthetic outcome and tissue maturation were attained. The


18a


18b


18c


18d


18e


18f

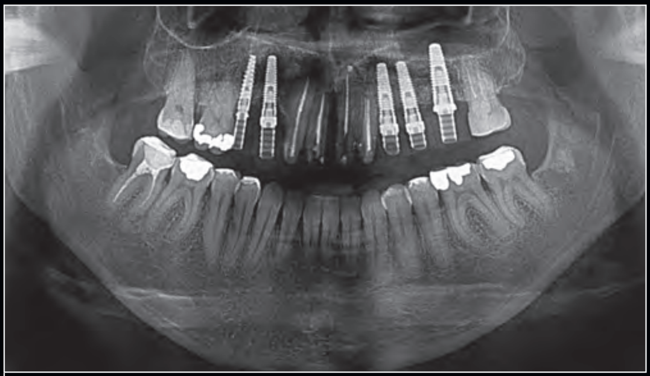

18g


18h

Figs 18a to 18h Heat-cured polymethyl methacrylate provisional restorations were fabricated as one piece on titanium temporary abutments. *(a)* Emergence profile was carved into the stone to support the soft tissue grafts and create the desired scallop intraorally. *(b and c)* Titanium abutments in place. *(d to f)* Views of the provisional on and off the model. *(g)* Polishing of the provisional restoration. *(h)* Frontal view on model.


19a

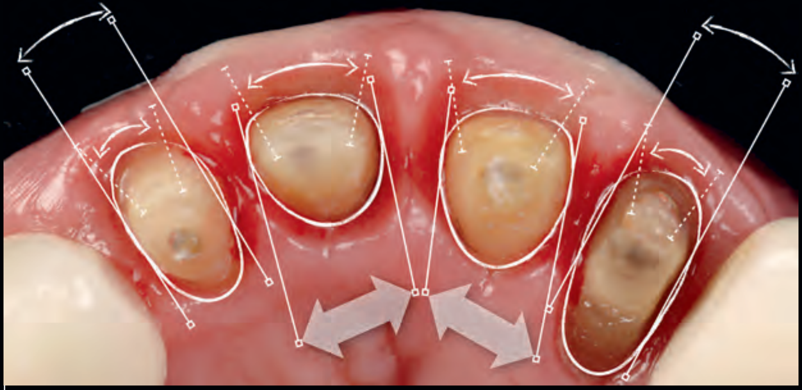

19b


19c

Figs 19a to 19c *(a)* Second provisional restoration 3 months after placement compared to *(b)* the initial situation and *(c)* its corresponding panoramic radiograph.

20a

20b



20c

Figs 20a to 20c *(a)* Final preparations and *(b)* occlusal full-arch view of the treatment before the delivery of the final prosthesis. *(c)* Note the root remodeling achieved during the surgeries to provide the ideal mesiodistal root support interproximally as well as the buccal contour.

patient was seen on a regular monthly basis for evaluation and tissue remodeling to camouflage the scars from previous incisions.

After the 6 months of perioprosthetic reevaluation and the patient was satisfied (Figs 20a to 20c), the final impression for the rehabilitation phase was taken. The conventional polyvinyl siloxane double-cord technique was used, and a new verification jig was performed at the same time as the provisional reline. Porcelain layered zirconia (NobelProcera) was selected for the rehabilitation of this case in three different segments. Implants at sites #13 and #14 as well as #24 to #26 were splinted. As was decided from the start, the four anterior teeth were splinted in order to prevent any dental migration that might occur in time due to the extensive surgical distraction osteogenesis and orthodontic treatment, in addition to the large bone defect between the central incisors.

FINAL DELIVERY AND RESULT

After bisque bake try-in and occlusal adjustment were performed, the final restorations were ready to be delivered. First the tooth restorations were cemented using resin-modified glass-ionomer luting cement (FujiCEM 2, GC America) in order to guarantee the best fit on the prepared teeth. Then posterior implant segments were tried-in to verify the accuracy of the interproximal surface contact areas against teeth. All four interproximal contacts were verified, and the implant prosthesis was screwed in place. Teflon and composite were used to seal the screw access channels of the prosthesis (Figs 21 to 25).


21a

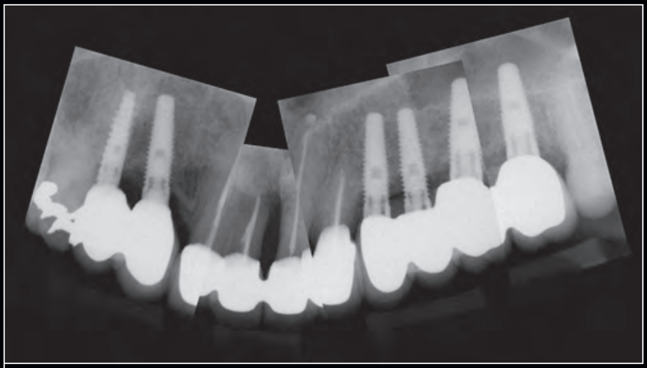

21b


21c


21d

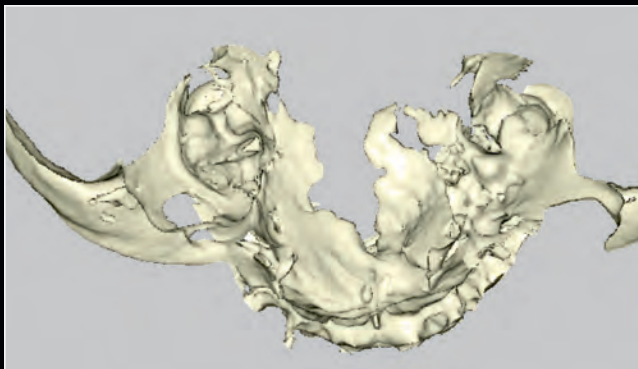

22a


22b

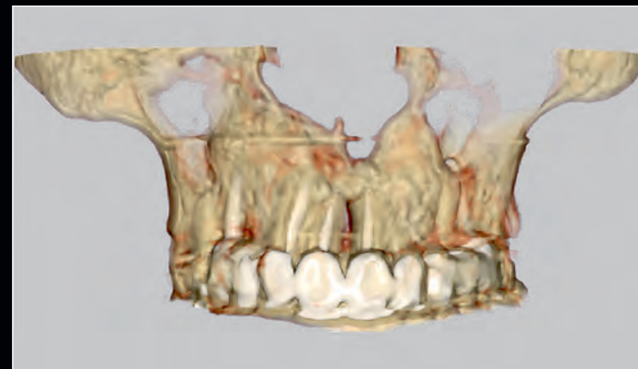

22c

Figs 21a to 21d Final delivery of the splinted segment on natural teeth as well as the posterior splinted segments to the corresponding implants. Note the blanching and tissue support of the final prosthesis with its final delivery.

Figs 22a to 22c *(a)* Three years posttreatment. *(b)* The keratinized tissue as a result of the grafting procedures and the tissue response from the tissue remodeling procedures can be appreciated. *(c)* Periapical radiographs demonstrate the result achieved 3 years after delivery.



23a



23b

24a

24b

Figs 23a and 23b CBCT from the final treatment shows the fusion at the basal aspect of the maxillae and the bone interproximal defect between the central incisors.

Figs 24a and 24b Before and after intraoral views.

Figs 25a and 25b Before and after smile views.

25a

25b

ACKNOWLEDGMENTS

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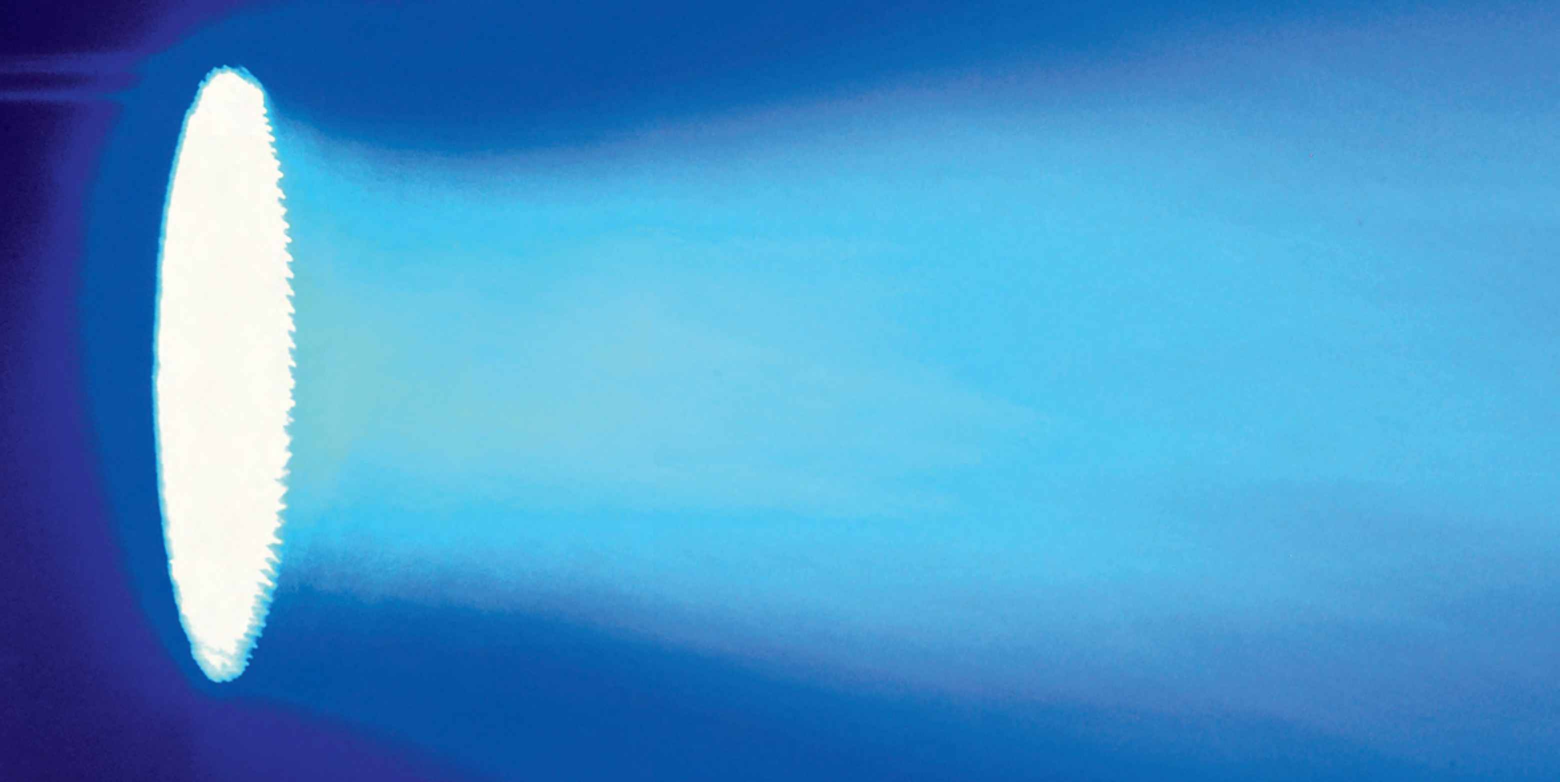
BIOMATERIALS UPDATE



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Photopolymerization: Scientific Background and Clinical Protocol for Light Curing Indirect Bonded Restorations

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Polymerization of resin-based materials is determined by several parameters, the most important being the composition of the resin-based materials and the curing light used for their polymerization. Through the years, curing lights have been developed and improved along with the dental materials for which they are used. The proper choice of material and curing light for particular restorations, along with clinician's knowledge and skills, will have a great impact on achieving long-lasting restorations. This review highlights the impact of photopolymerization on indirect-bonded restorations.

Photocuring of resin-based dental materials is an essential step in clinical practice. It is assumed that light delivered from the light-curing unit is uniform and will provide an optimal polymerization reaction and complete curing of the resin-based restoration. If an inadequate radiant exposure (irradiance × exposure time) is delivered to the restoration, the physical and mechanical properties of the restoration and its clinical and esthetic longevity could be compromised. Poorly polymerized restorations will suffer from premature clinical failure due to marginal defects, discoloration, secondary caries, or fracture. Biocompatibility due to the leaching of uncured monomers will be negatively affected as well.[1,2]

FACTORS AFFECTING POLYMERIZATION

Photopolymerization is the conversion of monomers into polymers initiated by photoinitiators after exposure to the light of compatible wavelength. In contemporary light-curing units, this light is usually blue. Resin-based materials create highly cross-linked networks during polymerization and usually achieve up to 70% of conversion. There are several significant factors that have an impact on the degree of conversion of resin-based materials: *(1)* composition of resin-based materials (inorganic content type, shape, and size; organic matrix type and amount; photoinitiator type and amount); *(2)* light-curing unit characteristics; *(3)* operator knowledge and skill; and *(4)* restoration characteristics.[3,4] A 100% conversion of monomer into polymer is never achieved in resin-based materials. Even in a fully polymerized resin-based material, unreacted monomers can be leached and cause cytotoxicity.[4] Furthermore, insufficient polymerization can negatively affect the properties of a resin-based restoration, such as wear, quality of the margin, quality of the bonding interface, depth of cure, mechanical properties, and degree of conversion.[5]

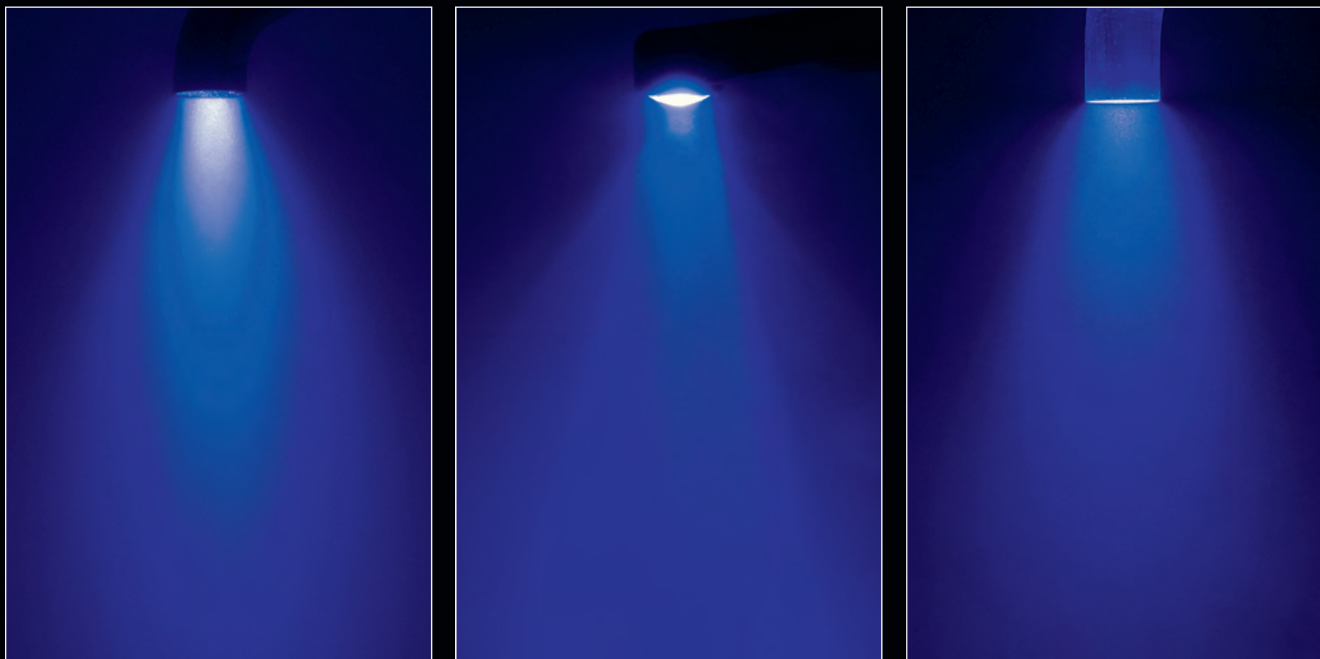
PHOTOINITIATORS OF RESIN-BASED MATERIALS

To ensure optimal photopolymerization, the radiant exposure and spectral distribution requirements of the resin-based material must be fulfilled by the radiant output from the light-curing unit.[6] The most common photoinitiator present in resin-based materials is camphorquinone (CQ) in association with tertiary amine as a co-initiator. CQ belongs to the Norish Type II photoinitiators, as it needs a co-initiator to be activated and undergoes a bimolecular reaction upon irradiation. It has maximum absorption of blue light at 468 nm wavelengths, although it is activated by a broad range of light between 360 and 510 nm.[7,8] The main disadvantage of CQ is its bright-yellow color that only partially photo bleaches after the relevant light-curing exposure time.[7] In order to formulate bright white and translucent shades of resin-based materials, some manufacturers use less CQ and/or alternative photoreactive species, such as PPD (1-phenyl-1,2-propanedione) and Lucirin TPO (2,4,6-trimethylbenzoyl-diphenylphosphine oxide). PPD has a maximum absorption peak in lower wavelength (around 390 nm) and is used in combination with CQ to decrease its yellowish effect and to improve curing efficiency of the polymerization process. Together with CQ, PPD belongs to the Norish Type II photoinitiators.[9]

Alternative photoinitiators, such as Lucirin TPO or derivatives of dibenzoyl germanium (eg, Ivocerin), are lighter in pigment, and they are very sensitive to light below 420 nm and are not activated by light above 460 nm. Ivocerin is present in Ivoclar Vivadent products, and along with TPO belongs to the Norish Type I photoinitiators, which do not need a co-initiator and undergo a unimolecular reaction upon irradiation. While Norish Type I photoinitiators are more reactive than CQ, light with a shorter wavelength has a decreased penetration depth into the material.[8] Besides adding more reactive alternative photoinitiators to overcome the issue of shallow penetration depth of short-wavelength light, manufacturers have used different strategies, including improving the translucency of resin-based materials by reducing the amount of filler particles or by improved match of the refractive indices of the fillers and the resin matrix.[10]

LIGHT-CURING UNITS

The quartz-tungsten halogen curing unit (QTH) was the most widely used light-curing unit for resin-based material polymerization for a long time. However, due to its several drawbacks, it was replaced by light-emitting diode (LED) curing units. There are two types of LED units: the "monowave" (first and second generation) LED units, which can emit only blue light, and the "polywave" (third generation) LED units, which can emit blue and violet light. The main disadvantage of the first two generations of LED units was the lack of polymerization of resin-based materials containing PPD, Lucirin TPO, or Ivocerin, since those



1a 1b 1c

Figs 1a to 1c Light dispersion of different LED curing lights. *(a)* cylindrical (collimated), *(b)* conical (divergent), and *(c)* mixed beam (cylindrical and conical). Note the all curing tips shown in this example produce some scattering and diffusion of light at the extremities of the curing tip. Light irradiance decreased with the distance, and for each curing light the decrease of irradiance is different.

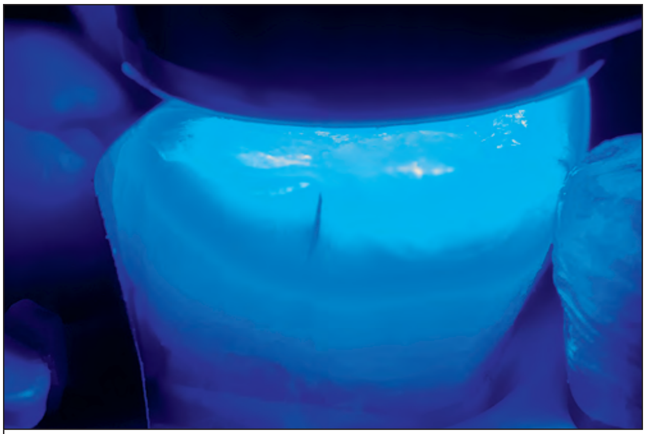
photoinitiators are activated in the short blue and violet range of the light spectrum.

There are two main parameters that characterize a light-curing unit: light irradiance and radiant exposure. Irradiance (power density or intensity) is the total power of wavelength divided by the area of the optical guide, while radiant exposure (energy density or total energy) is the irradiance multiplied by exposure time. Two other parameters have to be taken into account when assessing the effectiveness of the light-curing unit: beam profile and tip diameter.

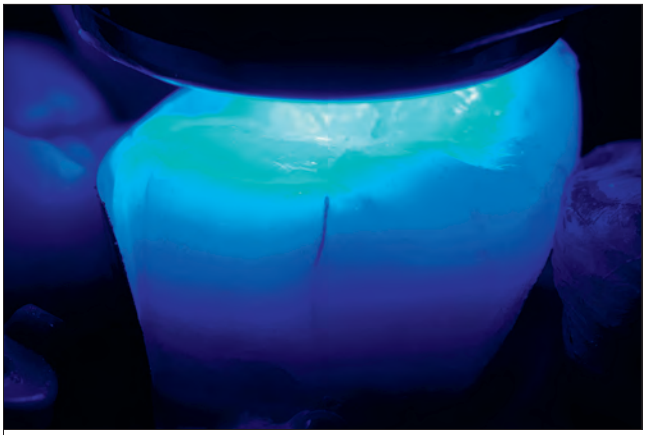
It is often assumed that the entire surface area at the tip of the light-curing unit emits light that is uniform or at the same levels (same power and wavelength). However, in some LED curing units, especially in those that emit both blue and violet light, the spectral emission is not uniformly distributed across the light tip, which means that some areas of the resin-based material may not receive the required irradiance or radiant exposure. Some areas of the resin-based material will be exposed to less and others to more energy. On the beam profile this can be seen as a presence of "hot" and "cold" spots.[11] Hot and cold spots will result in inhomogeneous resin-based material polymerization with different degrees of conversion and temperature increase, poor physical properties, different stress distribution, and premature failure of the restoration.[12] Therefore, it is recommended to move the light tip around by a few millimeters with each curing cycle. Movement of the light-curing tip should compensate for the non-uniform irradiance and spectral distribution from the light-curing unit.[6,13] This has to be managed very carefully or the light exposure time will have to be increased at the risk of thermal pulp or soft tissue injury.

The diameter of the light tip can have a significant impact on the amount of light and energy delivered to the restoration as well.[14] Disproportion between the external diameter of the light tip and the active beam diameter can lead to non-uniform polymerization of a resin-based material restoration with the same consequence as inhomogeneous beam profile (Figs 1a to 1c).

2a



2b



2c

Fig 2a Photopolymerization of a CAD/CAM resin nanoceramic onlay restoration.

Fig 2b The tip of the light-curing unit must be placed as close as possible to the restoration. Ideally, the tip needs to touch the restoration.

Fig 2c Placing the light-curing unit at a 45-degree angle to the surface of the resin-based material will result in 56% reduction of light radiant exposure and decrease the depth of cure.

EFFECT OF CURING THROUGH DIFFERENT SUBSTRATES

It is well established in the literature that resin-based materials need to receive a certain amount of energy, usually between 16 and 24 J/cm^2, in order to be properly cured. How much energy will be delivered to the restoration is determined by the parameters of the light-curing unit. Curing time is dependent on the irradiance—usually the higher the irradiance level is, the shorter curing time can be.[15] However, the quality of polymerization will be influenced as well by the composition and thickness of the resin-based material, the cavity configuration, and the operator's skills.

It is recommended to position the light-curing optical guide directly over the resin-based material (Figs 2a and 2b). The placement of the light-curing unit at a 45-degree angle to the surface of the resin-based material will result in 56% reduction of light radiant exposure[16] (Fig 2c). However, in some clinical conditions, light polymerization of the resin-based material cannot be achieved directly and so it has to be done indirectly through a layer of dental hard tissues, such as dentin and enamel, or layers of resin-based materials or ceramics.[17] The indirect polymerization of resin-based materials through any kind of substrate significantly reduces the amount of energy delivered to the resin-based material. The amount of reduction will depend on the composition, thickness, and translucency of the substrate through which light has to pass before it reaches the resin-based material.[18,19] Since different curing units deliver different light irradiance at different levels or different depths of the restoration, the clinician has to be familiar with the characteristics and abilities of the curing unit that is being used and adjust it appropriately to each clinical condition or situation.

Light Curing Through Tooth Substrate

The light-attenuation effect of enamel and dentin significantly diminishes the depth of cure and hardness of the cured resin restoration.[20–22] However, it is still not clear if light attenuation by enamel and dentin tissues significantly affects the mechanical properties and degree of conversion of resin-based materials. It is known that light transmittance through dentin is less than light transmittance through enamel and that wet dentin and enamel show better transmission than dry substrates.[23]

Light Curing Through Resin-Based Materials

Resin-based materials are heterogeneous substances and when exposed to the light, the light can be reflected, transmitted, scattered, or absorbed. All of these phenomena will occur to different extents depending on the composition of the resin-based material. Scattering of the light delivered from light-curing units is greater when the resin-based composite filler particle size is almost one-half of the curing light wavelength.[24,25]

There will be less light transmission through thicker resin-based material layers and through darker shades, where transmittance is diminished due to the greater opacity and absorption within the material in comparison with lighter shades.[26] Transmission is described as the amount of light that successfully passes through a material, while transmittance refers to the amount of light energy that the material absorbs, scatters, or reflects. In general, resin-based materials exhibit increased light transmission as the curing process progresses, which may improve depth of cure. Further, the light transmission of resin-based materials will increase when the difference between the refractive index of the matrix and filler becomes smaller.[27]

By changing and modifying the chemistry of organic matrices and inorganic fillers, manufacturers try to optimize and improve light transmission through resin-based materials.[27,28] The closer the refractive index or organic matrix and inorganic filler is, the better light transmission and translucency of the resin-based material will be. The initial refractive index of the monomer is lower than that of the filler particles. During polymerization, the refractive index of the polymer becomes more similar to the refractive index of the fillers. Therefore, the amount of light transmitted through the resin-based material will increase, which will potentially result in enhanced curing depth. Subsequent or continued light exposure in this case will have a significant impact on the irradiance on the bottom of the resin-based material.[27]

Resin-Based Luting Materials

Transmittance of the light plays a crucial role for setting resin-based luting materials used for placement of ceramic or resin-based inlay/onlay CAD/CAM restorations, crowns, or veneers. Luting materials can be classified as autocured, dual-cured, or light-cured. According to their surface preparation, resin-based luting materials can be classified as: *(1)* etch and rinse adhesive resin–based luting materials, *(2)* self-etch adhesive resin–based luting materials, or *(3)* self-adhesive resin–based luting materials that require no surface pretreatment at all.[29]

Dual-Cured Resin-Based Luting Materials

Most of the dual-cured resin-based luting materials have incorporated a self-cured peroxide/amine system. In light-cured materials, CQ is the most widely used photoinitiating system; therefore, the final color of a luting material can be influenced by its initiator system. Regardless of which photoinitiating system is used, the wavelength of photoinitiators present in resin-based luting material should match with the emitted spectrum of the light-curing unit used.[30,31] The influence of light on dual-cured resin-based luting material has been shown to be affected by the material's properties. However, many dual-cured resin-based luting materials are dependent on blue light, because they achieve significantly higher mechanical properties after blue-light exposure in comparison to only autocured luting materials.[32,33]

Light curing of dual-cured resin-based luting materials generally leads to improved properties compared to self-curing alone: better micromechanical properties, higher degree of conversion, decrease in marginal wear and discoloration, and increased biocompatibility.[29] Dual-cured or visible light-cured resin-based luting materials are exposed to the curing light indirectly, after attenuation of the light through the tooth structure or restoration material.[19] The autopolymerization step in a dual-cured system seems insufficient to ensure optimal polymerization of resin-based luting materials. Some authors recorded a higher bond strength after dual-curing as compared to solely self-curing resin-based luting materials.[34,35]

Light-Cured Resin-Based Luting Materials

The advantages of light-cured resin-based luting materials are longer working time and easier clean-up of residual luting material. However, the light has to pass through the different compositions and thicknesses of the restoration before it reaches the luting material; therefore, the main disadvantage of this type of luting material is incomplete setting due to the limited light transmission through the restoration.[36]

The composition and thickness of the restoration, type of organic matrix and inorganic fillers, as well as the photoinitiator system in light-cured resin-based luting materials—along with the exposure time and light-curing unit characteristics—will significantly influence the degree of conversion.[36] Exposure time is the most critical parameter for optimizing the degree of conversion of the resin-based luting material.[37] A higher degree of conversion will usually have a higher cross-linking density and, as a consequence, better mechanical properties as well as higher color stability and resistance to hydrolytic degradation.[38] Studies also show better performance of light-cured resin-based luting materials with Lucirin TPO as a photoinitiator than light-cured resin-based luting materials with CQ/amine-based photoinitiator due to the polymerization and color stability. The better color stability of light-cured resin-based luting materials is especially important in cases of thin bonded veneers, since the final color of restorations after polymerization is influenced by the shade of the underlying structures including the luting system.[39]

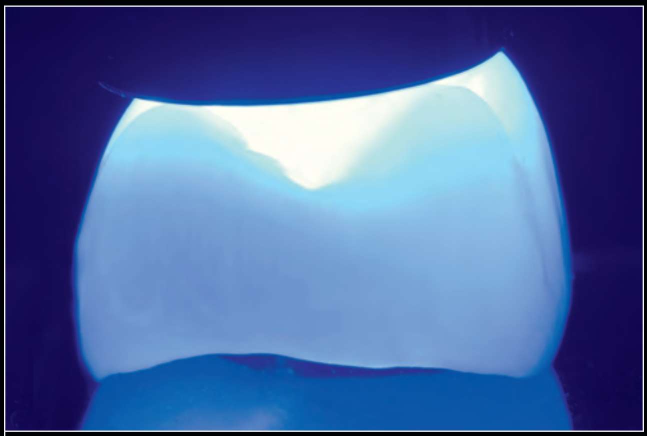
Light Curing Using Resin-Based Restorative Materials as Luting Material

There has been an increasing trend in the clinic to use flowable and regular-consistency resin-based restorative material as light-activated luting materials for adhesive luting of indirect restorations. Restorative resin-based materials have a firmer consistency that facilitates removal of the material excess. Depending on the viscosity of the resin material, heating may be indicated to reach better flow during seating of the restoration. Since restorative resin-based materials are mechanically stronger due to the higher filler content, it can be expected that they would maintain marginal integrity for longer periods of time and lower susceptibility to wear in stress-bearing occlusal areas.[40–42] It is assumed that the photopolymerization process of this type of resin-based material probably generates a higher concentration of free radicals. This will form more growth centers, which will lead to an efficient chain propagation and improved polymerization.[37,43,44] Ideally, homogenous monomer conversion should be achieved even when curing through the restorative material. Clinicians should also be aware that the thickness of the indirect restoration can be reduced by modifying the cavity with resin-based restorative material during the preparation.[43]

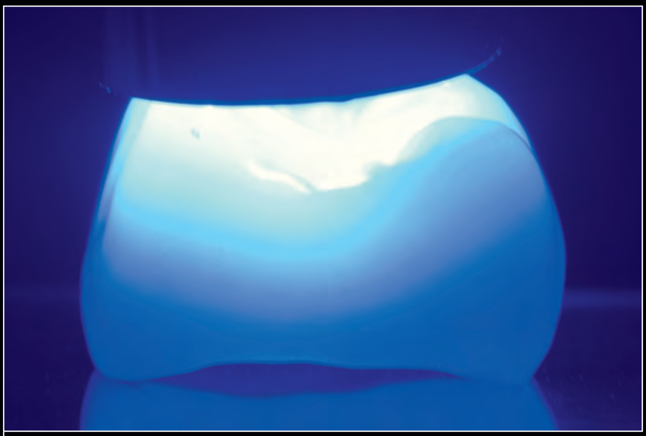
Light Curing Through Indirect Bonded CAD/CAM Restorations

Three main types of materials for CAD/CAM indirect bonded restorations are available on the market: CAD/CAM glass-ceramics (lithium disilicate, zirconia-reinforced lithium disilicate, leucite, and feldspathic), CAD/CAM-compatible polycrystalline ceramics (zirconia), and resin-based hybrid CAD/CAM materials (polymer-infiltrated ceramics, nano resin ceramic). Ceramic is a crystalline, inorganic material with metallic and non-metallic components bonded by ionic and/or covalent bonds.[45,46] Glass-ceramic is a type of material in which the glassy phase acts as the matrix, while the ceramic acts as the filler. Resin-based CAD/CAM materials consist of a polymeric matrix and fillers that could be inorganic (ceramics, glass-ceramics, or glasses) or organic.[45,47] The glassy matrix determines the esthetic properties of the ceramic. The higher the amount of glass, the greater is the translucency. The glassy matrix will permit the diffusion of light through the material/restoration. The nature of the filler present in the glassy matrix will determine the mechanical properties and prevent the development of microfractures.[46] Glass-ceramic/ceramic materials have superior properties in comparison to resin-based CAD/CAM materials.

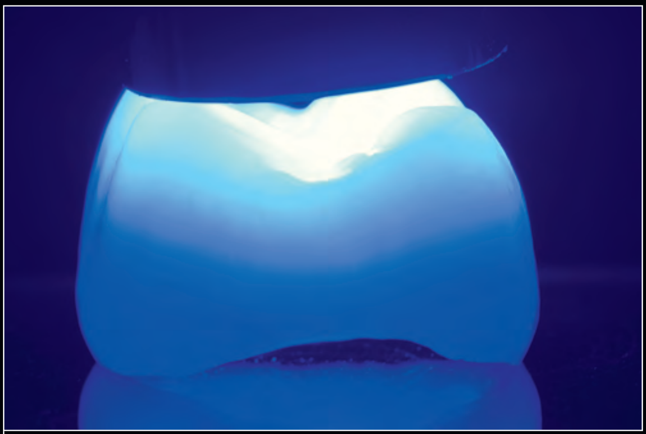
Material composition has a significant impact on light transmission. Depending on the shape and size of the filler particles in the material and their size and interaction with the wavelength of the light emitted from the light-curing unit, scattering and absorbance will be different.[40,48] If the ceramic phase forms a dense network with, for example, leucite clusters (1 to 5 μm) or has crystalline zirconia inclusions (200 to 400 nm), light absorbance and scattering will be increased.[40] Whether light reaches deeper layers of the restoration is determined by the parameters of the curing light as well. It has been shown that 24% to 44% of the incident blue light and 9% to 14% violet light is transmitted through a 2-mm resin-based material sample. This per-



3a



3b

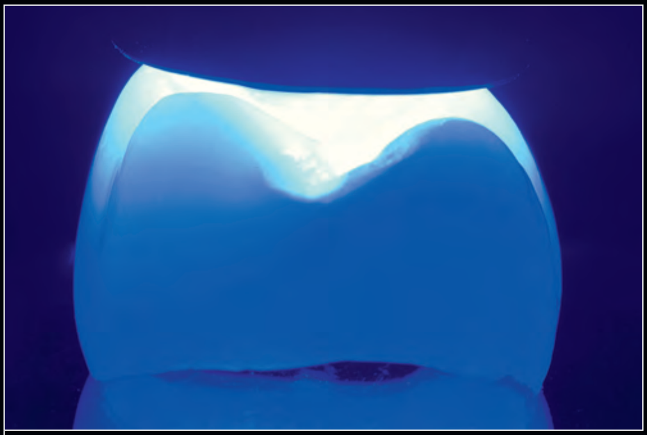


3c

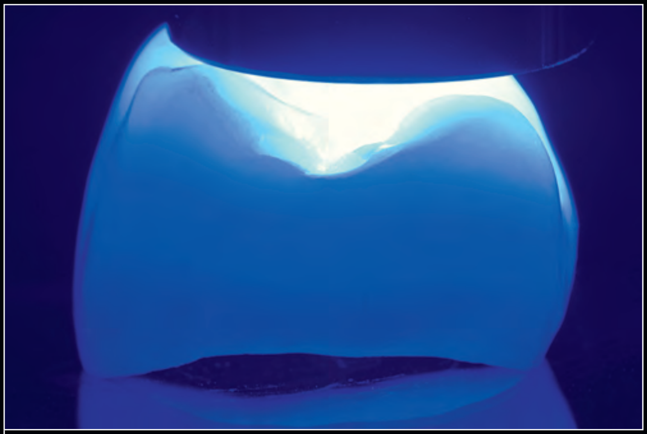
Figs 3a to 3c Light attenuation through lithium disilicate glass-ceramic (e.max CAD, Ivoclar Vivadent) at *(a)* 0.5 mm, *(b)* 1.0 mm, and *(c)* 1.5 mm. The transmitted irradiance is decreased with increased material thickness; therefore, the depth of cure is significantly diminished.

centage decreased even more at 4-mm depth: 9% to 24% and 3% to 9%, respectively.[4,49] Thus, when using luting materials of Norish Type I photoinitiators, polymerization might not occur at the bottom of indirect bonded restorations with low translucency or thicker than 2 mm.[32,50] Clinicians can overcome this issue by adapting the time of light exposure during the light-curing procedure. However, longer exposure will increase the temperature and might have a negative impact on vital pulp tissue. Thus, it is important to choose an optimal combination of light-curing unit parameters and photoinitiator present in a resin-based luting material.[50,51]

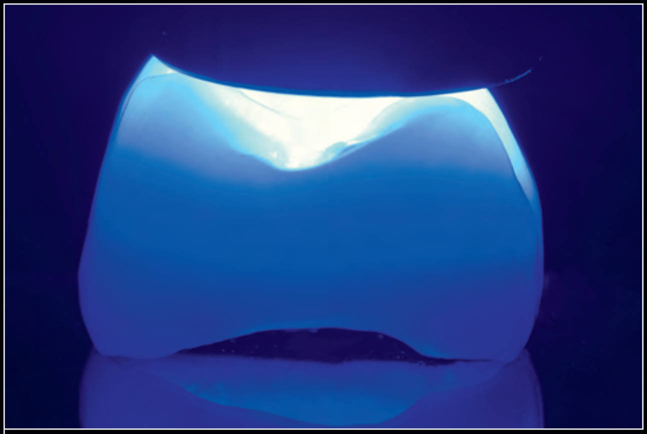
Transmitted irradiance is decreased with increased material thickness (Figs 3a to 3c). A decrease in irradiance of more than 80% can be expected when curing through 1.5-mm-thick CAD/CAM glass-ceramic and 95% or more when measured through 3-mm-thick glass-ceramic. Leucite-reinforced glass-ceramic has shown a smaller decrease in irradiance than lithium disilicate glass-ceramic, which can be related to the higher translucency of leucite-reinforced compared to lithium disilicate glass-ceramic material.[29,52] Variations in irradiance can also be attributed to the differences in crystal volume, grain size, and the refractive index. Less crystalline amounts in the material composition and refractive index closer to that of the matrix may cause less scattering of light and therefore better polymerization of the resin-based luting agent.[53]



4a



4b



4c

Figs 4a to 4c Light attenuation through 4 mol% yttria partially stabilized zirconia (4Y-PSZ) monolithic CAD/CAM restoration (Katana STML, Kuraray) at *(a)* 0.5 mm, *(b)* 1.0 mm, and *(c)* 1.5 mm. Note the decrease in transmitted irradiance as the thickness of the restoration increases.

Light Curing Through Feldspathic Porcelain

Veneers are usually fabricated with feldspathic porcelain, which possesses a relatively high translucency.[37] For bonding of porcelain veneers, a light-curing resin-based luting material is the preferred choice over dual-cured resin-based luting material due to its color and stability.

As for any bonded restorations, the chemical composition of a luting material can have a great impact on the esthetic outcome, especially if the luting material is used with a thin translucent ceramic veneer. In dual-cured resin-based luting materials, the color changes are mainly caused by the oxidization of the amine, which is a necessary component of the polymerization initiation system in the material.[54,55] To avoid discoloration caused by unpolymerized or degraded CQ/amine of photoinitiator-based luting materials, amine-free resin-based luting materials are recommended. Amine-free resin-based luting materials contain Ivocerin and Lucirin TPO as a photoinitiator and seem to be a better option than CQ/amine luting materials, while not reducing bond strength or degree of conversion. Unfortunately, these luting materials can change color over time as well.[56] When using amine-free luting materials, the restoration should not be thicker than 2 mm due to the scattering and low penetration of violet light, which is needed for Lucirin TPO activation and partially for Ivocerin.

Light Curing Through CAD/CAM Polycrystalline Ceramics (Zirconia)

The translucency of zirconia is influenced by the type and amount of additives, such as alumina dopant, which decreases its translucency. Compared to glass-ceramic, zirconia is less translucent; however, its translucency is less sensitive to the variation in material thickness. In other words, translucency decreases more slowly with increasing thickness of the material. Chairside CAD/CAM zirconia is yttrium cation-doped tetragonal zirconia polycrystal (3Y-TZP).[56] The light reflection differs in different shades of zirconia and results in significant differences in the translucency of various zirconia shades.[53] "High-translucent" zirconia was introduced to improve the esthetics of monolithic restorations. Due to the increased translucency and good mechanical properties, the "high-translucent" zirconia is an alternative to lithium disilicate for monolithic restorations. Ultra-translucent zirconia has more yttrium added (5Y-PSZ), which increases translucency but decreases mechanical strength.[57]

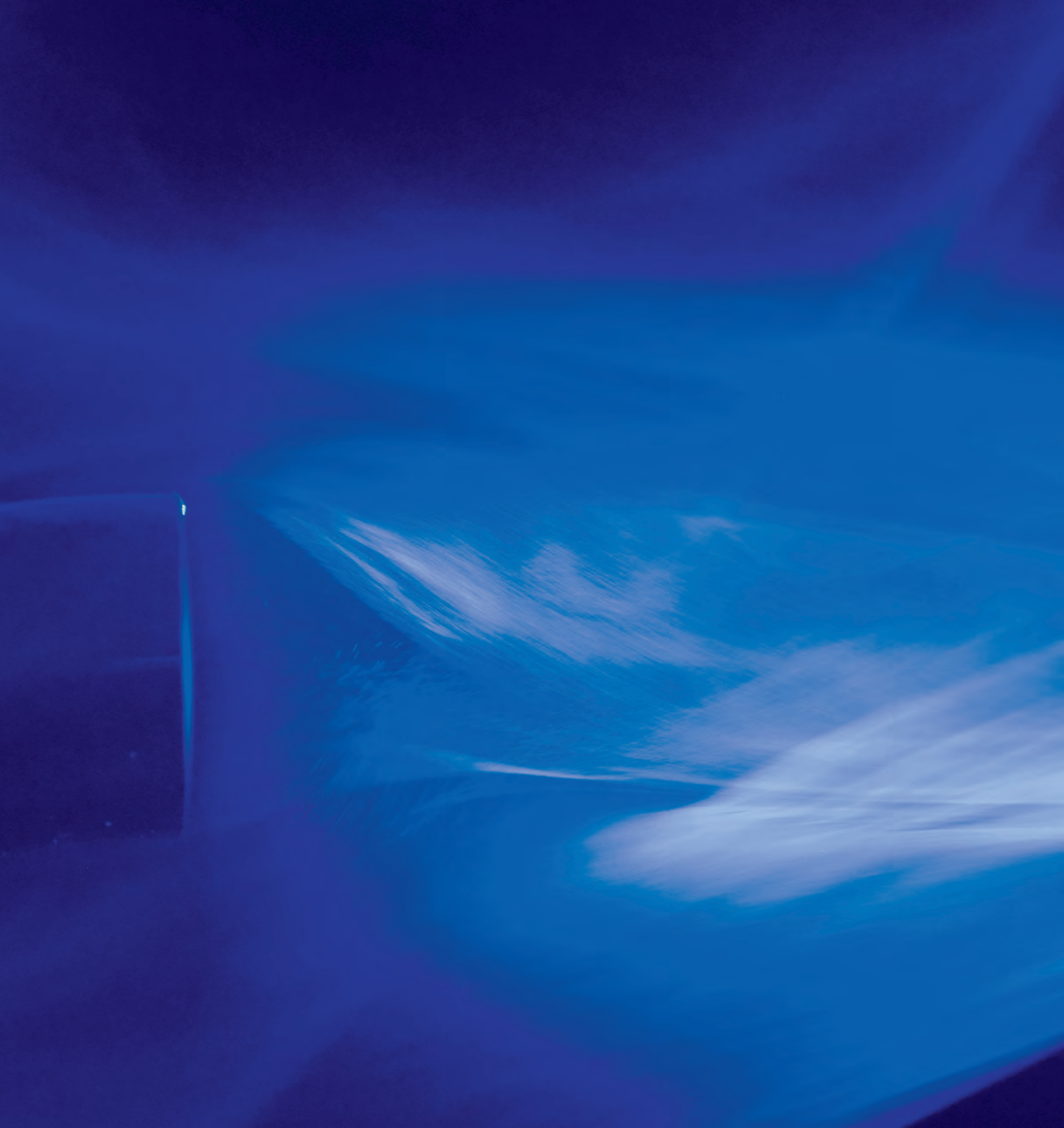
The adhesive luting of zirconia is possible only if the resin-based luting material possesses at least one acidic group (phosphate or carboxylate) that can chemically bond with zirconia.[58] For restorations thicker than 1.5 mm in lighter-shade zirconia and 0.5 mm in darker-shade zirconia, the use of less light-sensitive dual-cured resin-based luting material for zirconia cementation is recommended (Figs 4a to 4c).[7]

CURING TIME

Unfortunately, there is no consensus to date on the adequate radiant exposure that a material needs in order to be properly polymerized. Since there are no specific manufacturer-recommended curing times for different thicknesses and shades of the materials for indirect-bonded restorations, it has been suggested to increase the curing time to compensate for the decreased light transmission. This should be performed with caution due to the excess heat generated. Light overexposure unfortunately does not compensate for the attenuation in light intensity, and luting materials will most likely not reach the hardness values exhibited after direct light exposure.[59] However, complete light attenuation might not occur during luting of indirect bonded restorations. Clinically, light curing is always possible from occlusal and lateral aspects, which will ensure a proper seal of outer restoration margins. This will protect the luting material against external water damage, by which the degree of conversion at these more distant areas can increase over time when dual-cured resin-based luting materials (dark cure) are used.[35]

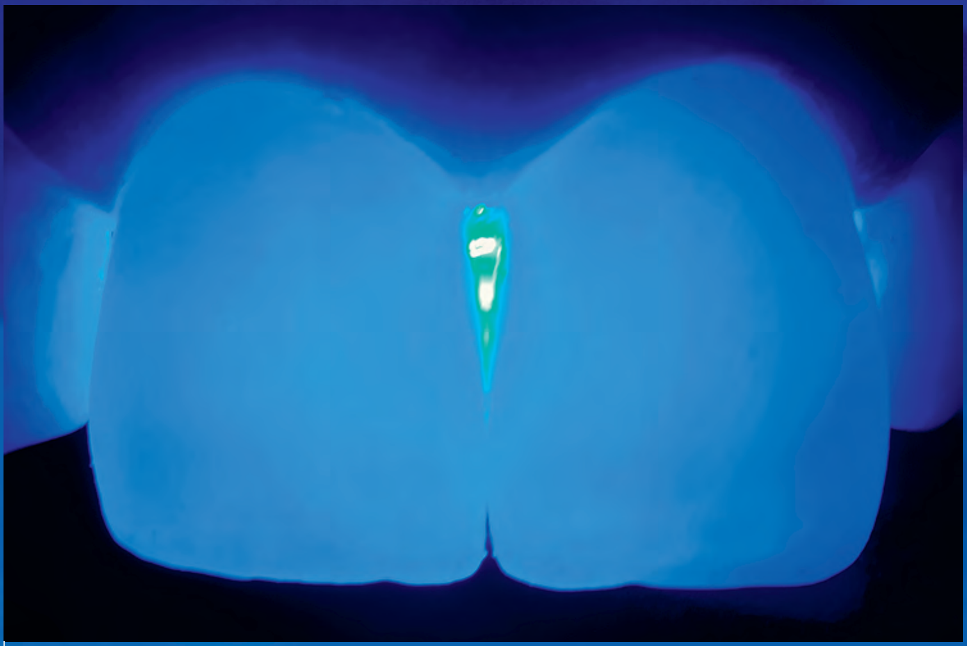
It has been recommended to increase the curing time (approximately 40%) for 0.5-mm ceramic restorations compared to resin-based restorative materials. For ceramic restorations with a thickness of 1 mm, it was recommended to double the curing time.[60] However, these recommendations are no longer valid; because of the influence of the luting material characteristics, material-specific recommendations for proper curing are required.[61]

Exposure time has the strongest influence on the mechanical properties of luting materials, followed by the ceramic type and ceramic thickness. Exposure of 20 seconds will produce significantly higher mechanical properties compared to 10-second exposure.[48] For achieving suc-

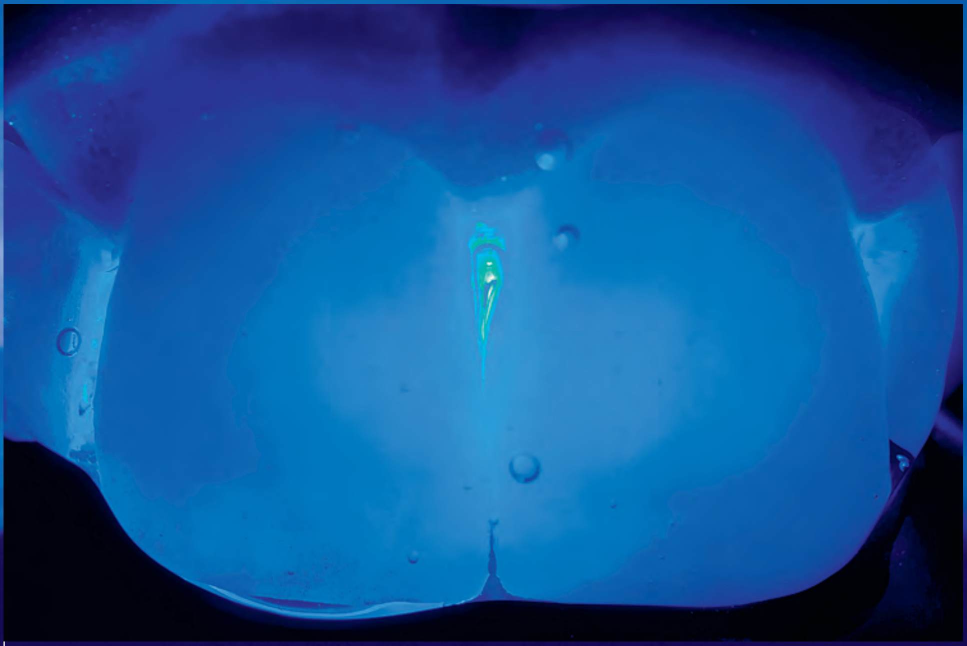


cessful restorations, it is crucial to know the material, the curing light, and the luting material properties. Using all three components from the same manufacturer would be ideal, but unfortunately is not always possible. That would ensure that the spectra of all photoinitiators present in the luting materials would be within the spectra emitted from the light-curing unit (Figs 5a and 5b).

Beam homogeneity and tip diameter of the curing light are important and require adjustment of exposure over the restoration surfaces accordingly. Although beam homogeneity and tip diameter are not related, more overlapping exposure will be necessary for both, especially when using smaller light tips or light-curing units with a nonhomogeneous beam.



5a



5b

Figs 5a and 5b *(a)* Each surface of the restoration must be light-cured for a minimum of 20 seconds (ie, occlusal, buccal, lingual; mesiobuccal and mesiolingual; distobuccal and distolingual) and *(b)* the same light-curing steps repeated through glycerin gel to prevent the formation of an oxygen-inhibited layer. Oxygen has great affinity toward radicals and forms peroxide radicals that are less active toward double bonds. In that way, polymerization is inhibited. To prevent this, it is recommended to apply glycerin over the restoration margins and additionally light cure each surface that is covered with glycerin.

Clinical Guidelines for Successful Curing of Indirect Bonded Restorations

- Carefully read the manufacturer's information about the restorative material and the luting material.
- Know the performance and parameters of your light-curing unit (irradiance, spectra, beam profile, tip diameter).
- Choose a proper luting material for the restoration.
- For restorations thicker than 2 mm, preferably use dual-cured resin-based materials.
- With amine-free resin-based luting material, use a light-curing unit that emits both blue and violet light.
- Maintain proper isolation at all times when using resin-based luting materials.
- Protect your light-curing unit with a protective barrier for infection control.
- Protect your eyes with an orange filter or light-blocking eye protection (orange-filtering goggles and/or paddles).
- Position the tip of the light-curing unit as close as possible to the restoration.
- Light cure each surface of the restoration for 20 seconds (occlusal, buccal, lingual; mesiobuccal and mesiolingual; distobuccal and distolingual).
- Start curing at the margins of the restoration to prevent any possible contamination and improve the marginal seal, then continue to other areas of the restoration.
- Increase curing time for restorations with higher chroma (A3, A4, B3, etc).
- For multiple light-curing exposures, take a short break between curing cycles to avoid overheating of the tooth.
- When using light-curing units that emit both blue and violet light, slightly rotate the tip by 45 degrees for each curing cycle to ensure uniform polymerization.
- Air-block with glycerin after the last curing cycle to remove the oxygen-inhibited layer.
- Keep your light-curing unit clean, regularly inspect the light output, and perform proper maintenance.

CLINICAL LONGEVITY OF INDIRECT BONDED RESTORATIONS

Unfortunately, there is a lack of clinical studies concerning the long-term effect of polymerization of resin-based luting materials under different ceramic indirect restorations. Clinical studies of ceramic inlays show bulk fractures as a major reason for failures of all commercially available ceramic indirect bonded systems. Significantly fewer bulk fractures were recorded for restorations luted with dual-cured resin-based materials. All catastrophic fatigue fractures usually occurred between 2 and 4.5 years of clinical function.[62,63] One study found 13% initial hypersensitivities, which were reduced rapidly afterwards in the majority of cases; this might be due to the use of dentin adhesive in addition to a glass-ionomer lining. Enamel cracks were visible in CAD/CAM inlay/onlays in 89% of cases after 12 years of observation. Chipping of the restorations can usually be detected after the second year of clinical use, most often at occlusally loaded lateral ridges. When occlusal adjustments are made with rotary instruments and the surface is not properly repolished, microcracks can occur, which can lead to further catastrophic fractures.[62,63]

CONCLUSION

As has been described, many parameters determinate the final quality of the polymerization and clinical outcome of the final restoration. Clinicians need to have sufficient knowledge about the restorative material that is used, the luting material, as well as the parameters of the light-curing unit in order to achieve appropriate physicomechanical, esthetic, and long-lasting clinical restorations.

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Masterpiece
- Harmony with Biology -

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:: CASE 1 Single Central Laminate Veneer

CASE 1

CERAMIC LAYERING

BUILDUP 1

- NW 0.5B
- E1
- LT Super Luster
- LT Coral
- LT Super Luster (90%) + LT Royal Blue (10%)
- Incisal Aureola (30%) + Creamy Enamel (70%)

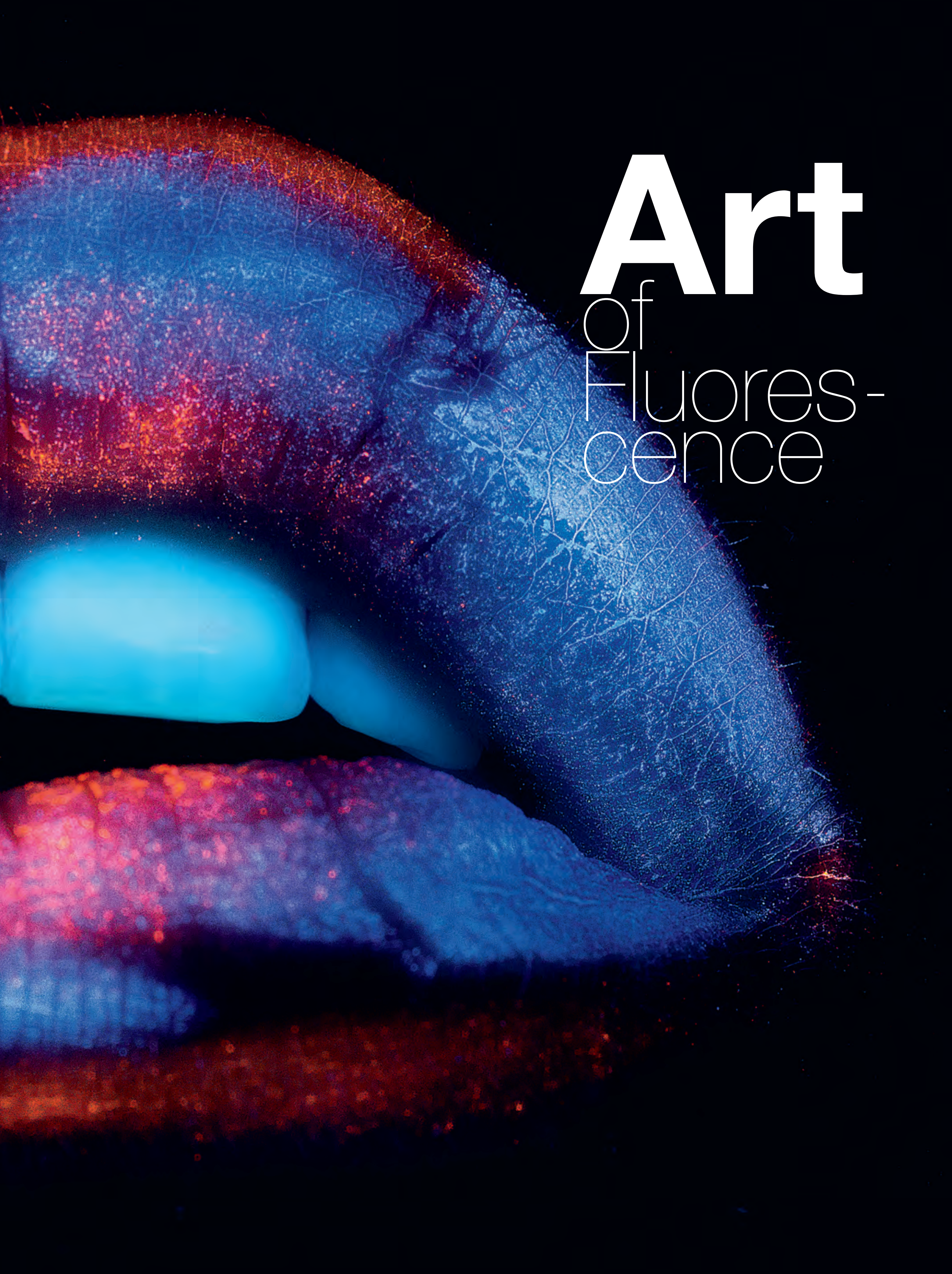
INTERNAL STAIN

- Bright (Dilution) (75%) + Mamelon Orange 2 (5%) + White (20%)
- A+

BUILDUP 2

- OB White (75%) + White (25%)
- NW 0.5B
- E1
- LT Super Luster
- Incisal Aureola (30%) + Creamy Enamel (70%)
- LT Coral
- T Clear (50%) + LT0 (50%)
- TX

Art of Fluorescence



Hello!

new smile

Noritake EX-3
Central Incisor
Feldspathic Laminate Veneer

Collaboration with Michael J. Welcome, DDS

CASE 2. - Combination -

#21 Cement-Retained Implant & Layered Zirconia Crown

#11 & #22 Feldspathic Laminate Veneers

1 and 2. Preoperative situation.

3. Diagnostic wax-up.

4. Soft tissue is reshaped with provisional restoration.

5. Completed zirconia abutment.

6. Zirconia abutment in place.

7. Porcelain is built up on the zirconia coping #21 to reproduce the same condition of preparation design of #11.

8. Completed implant-supported crown and laminate veneers.

1

2

3

4

5

6

7

8

CASE 2

- Combination -

#21
Cement-Retained Implant & Layered Zirconia Crown

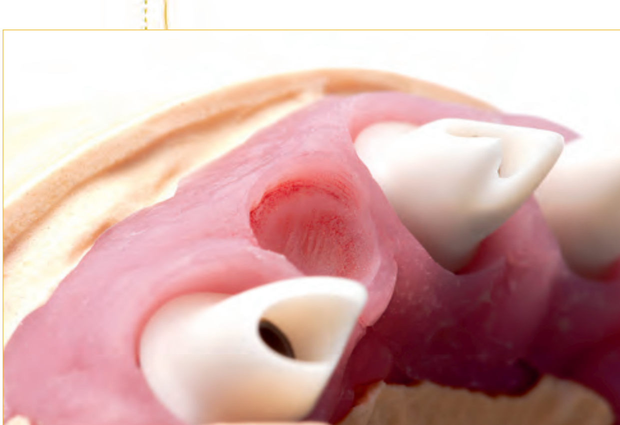
#11 & #22
Feldspathic Laminate Veneers

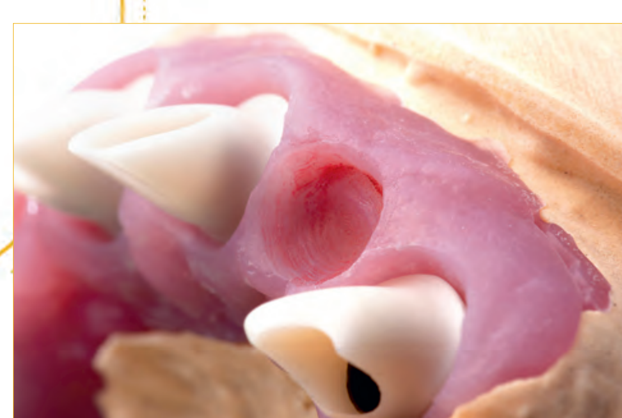
Collaboration with Marco Gresnigt, DDS, PhD

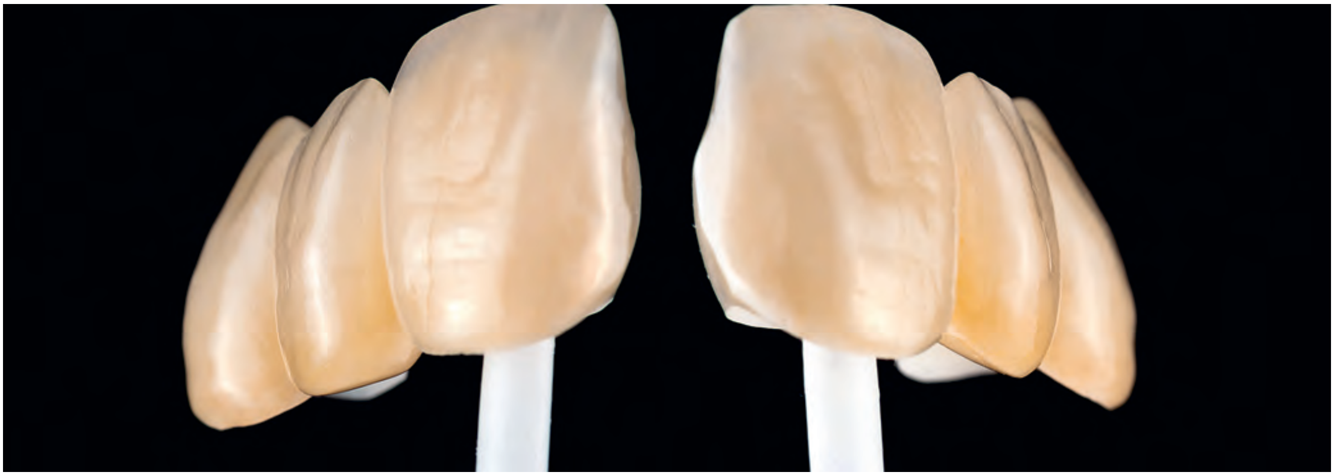
CASE 3

INITIAL CONSULTATION

SHAPE OF PONTIC BOTTOM & SUBGINGIVAL







CASE 3

3-mo FOLLOW-UP

"Esthetic pontic" tissue-bearing area shape & custom subgingival esthetic shape

Collaboration with Bach Le, DDS, MD, FICD, FACD & George Chakmakjian, DDS

CASE 3

3-mo FOLLOW-UP

Smile couture: Never stop exploring

CASE 4

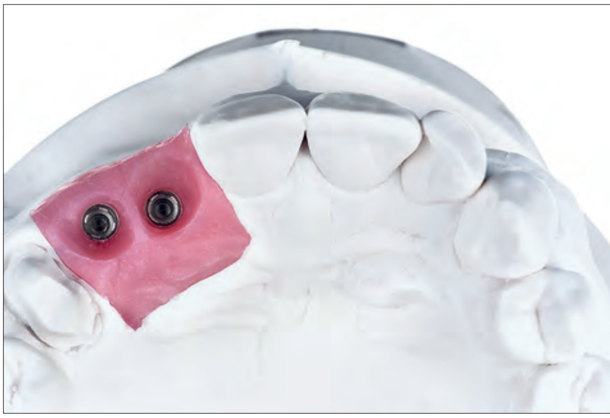
Reconstruction of dental esthetics and function

Kuraray Noritake KATANA with CZR layering

CHALLENGE TO RECREATE
NATURE'S BEAUTY
MORPHOLOGY | COLORS | STRUCTURE

- CASE 5 -

#14 Layered crown & #12, #13 Cement-retained implant



SYMMETRICAL, MIMICKING NATURE

- CASE 5 -

Collaboration with Gianmarco O'Brien, DDS

- CASE 6 -

#21 Nobel Biocare screw-retained implant with ASC
and layering with Kuraray Noritake CZR

Collaboration with Wayne Wu, DDS

NATURE

2 0 2 0

We must develop a greater understanding of nature for technology to advance

In this Masterpiece, I have selected six functional and esthetic maxillary anterior cases, ranging from a simple single crown to a complex combination of implant prosthesis, crowns, and laminate veneer restorations. Despite the variety of these cases, there is common thread running through all of them—that is, my greatest focus is the seamless integration of the prosthesis with natural elements, including natural teeth, gingiva, and the bone, thus achieving oneness with nature.

In recent years, digital dentistry has been the prevailing trend in the dental world, and I notice many articles and presentations that emphasize the use of digital technology in dentistry. To be sure, the integration of digital technology in dentistry is a welcome trend, and undoubtedly, my work has also greatly benefited from it. However, now, more than ever, it would seem to be the right time to take a moment and carefully examine our use of digital technology in present-day dentistry—particularly in the laboratory setting.

Notably, some dental laboratories handle management, as well as all stages of fabrication, solely via digital technology. Dentistry, however, is inherently based on human interaction, and thus should not rely on digital manufacturing alone—I would argue that the "human touch" is necessary, even crucial. We must never forget that the patients we are treating are beings who originate with nature.

As a Japanese native, I was intrigued to learn that the word "nature" is said to have not existed in Japan until 1603. And it was not until around 1868 that the Japanese word "Shizen" came to be recognized as the translation of the English word "nature," thus leading to the term becoming widely used in Japan. One could say that until then, nature had been so ingrained in Japanese life that it had not been necessary for the concept to be recognized as its own word. Such a notion would surely apply to other cultures as well, as humans have lived alongside nature from long ago.

Varying ways of life and the variety of existing cultures are the result of differences in the natural environment. Whether the environment is warm or cool, or whether the environment is surrounded by the sea or by mountains—throughout history, such factors have had a direct bearing on the life and culture of certain regions. Thus, it is difficult to separate the concepts of nature and technology. Yet, while digital technology brings ease and convenience to the dental fabrication process, I can't help but feel that so much is lost when dental prostheses are fabricated solely through such means. It is as if pursuing convenience results in the loss of the ability to sense what is good and what brings happiness.

All aspects of dental treatment rest in the hands of people. In order to fabricate high-quality dental prostheses, the skills, knowledge, and experience of those involved in the process are essential. "Experience" is a term that encompasses many things, but one crucial aspect of experience is failure. Digital technology may allow us to create dental prostheses with greater convenience and precision, but going through the process of trial and error and overcoming mistakes gives the work of a technician a human touch that simply cannot be replicated by digital technology. A technician who has thoroughly experienced failure is able to fabricate a dental prosthesis that is richer and more organic due to such experiences.

At a glance, attaining simplicity may seem easy. Yet, it is in fact quite the opposite, for it requires the elimination of excess. What is truly important is to work with clear standards in mind. We have now reached 2020, and as technology continues to advance, I believe that modern dentistry must find a way for the "human touch" and "digital technology" to achieve harmony with one another. Rather than leaning toward one method or the other, we must bring the best of both worlds together, bringing dentistry into harmony with nature. In so doing, we will be able to reach greater heights in dental prosthetic treatment, leading to greater patient satisfaction and happiness.

—Naoki Hayashi

The Pillars of Full-Mouth Rehabilitation: A Minimally Invasive, Low-Cost Approach to Prosthetic Treatment

Mario Alessio Allegri, DDS[1]
Cristian Marchini, DT[2]
Allegra Comba, DDS, PhD[3]

For full-mouth rehabilitation, traditional fixed prosthodontics is considered a reliable and long-lasting treatment option.[1] Nevertheless, some concerns remain regarding tissue invasiveness, time required for treatment, and overall costs for patients. Scientific and technological advancements in adhesive dentistry have allowed clinicians to preserve larger quantities of sound tooth structure.[2,3] Although they are biologically more conservative, indirect adhesive full-mouth ceramic rehabilitations are still expensive treatments for most patients. Moreover, total chair time is considerable and may be the main obstacle for many patients to accept such treatment plans.

In this context, resin-based materials have gained popularity due to their mechanical and esthetic properties, which are associated with reduced economic impact to the patient. These materials can be used for both indirect and direct protocols. Direct full-mouth rehabilitation has been proposed for the treatment of worn dentition by several authors, with satisfactory outcomes in terms of esthetics and biomimetic integration.[4,5] However, the long-term occlusal stability of composite resin has been questioned in full-mouth rehabilitation.[6] Providing patients with stable and functional occlusion is essential in restorative disciplines, along with maintaining periodontal health, esthetic outcome, improvement of facial harmony and proportions, care for temporomandibular joints (TMJs), and overall patient satisfaction (which often is related to the quest for rapid dentistry and simplified procedures). While the dental provider must fulfill the patient's expectations, no compromises should be made regarding biologic constraints and treatment outcome quality. New strategies are therefore needed to achieve the treatment objectives of occlusal dentistry and to provide flexible and modular planning of appointments that best accommodate patients' busy lives while reducing overall treatment costs.

A combination of restorative strategies and different materials, along with a treatment concept based on the identification of the teeth mainly involved in oral functions associated with static and dynamic loads, could meet the above requirements. In this context, the canine, first premolar, and first molar are regarded as the most important teeth for laterotrusive guidance, retrusive control, and occlusal and articular stabilization, respectively.[7] These teeth should be considered the pillars of full-mouth rehabilitation,

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1a

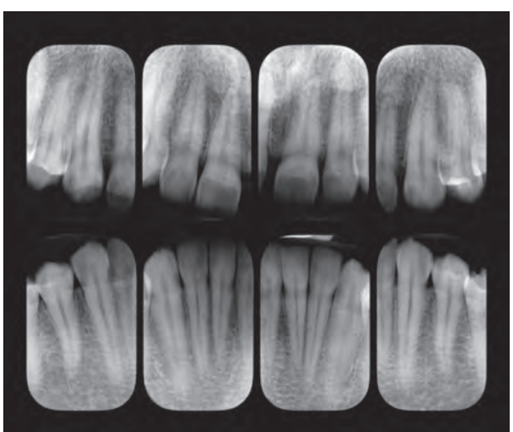
1b

1c

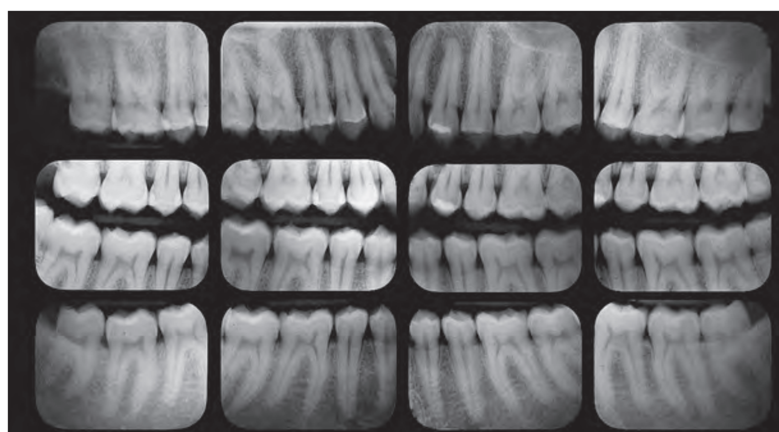
1d

1e

Figs 1a to 1e Initial situation of the patient complaining of general teeth sensitivity, craniomandibular system muscle pain, and wear of the palatal surfaces of the anterior teeth. Areas of deep dentin exposure are visible also on posterior teeth.



2a



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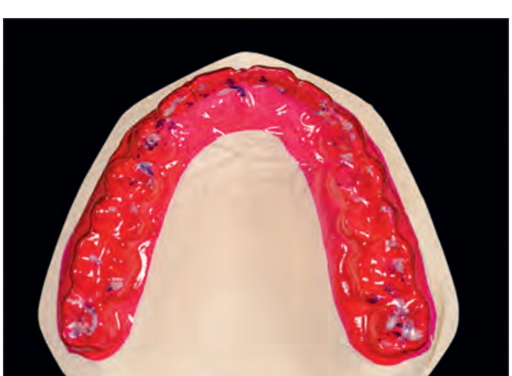
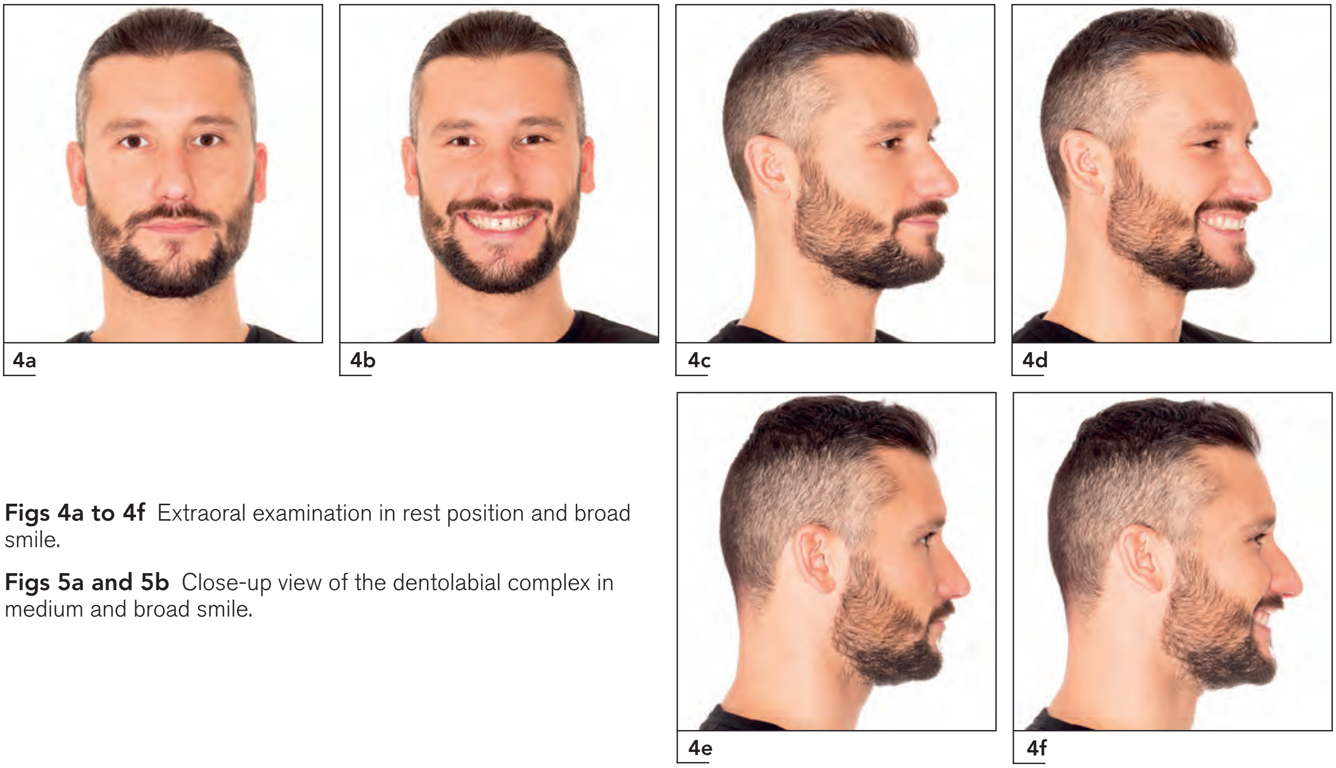


3

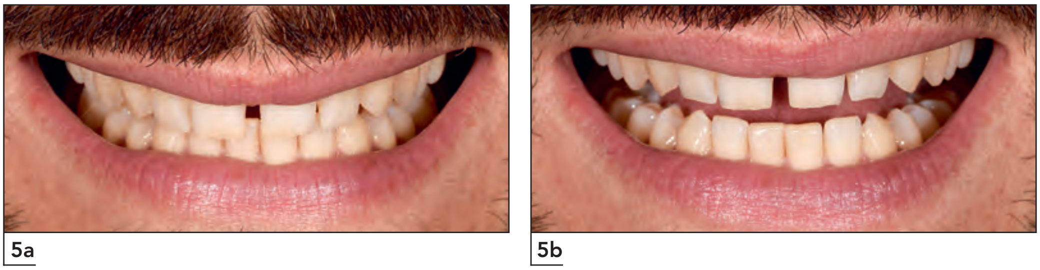
Figs 2a and 2b Preoperative full-mouth radiographic examination.

Fig 3 Brux Checker shows lack of static load support and severe interferences during eccentric movements involving both the anterior and the posterior teeth.



Figs 4a to 4f Extraoral examination in rest position and broad smile.

Figs 5a and 5b Close-up view of the dentolabial complex in medium and broad smile.

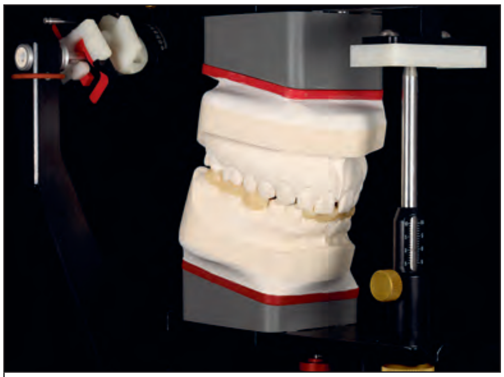


as they represent the resistance units to static and dynamic loads associated with masticatory functions. Consequently, different restorative approaches may be necessary for their treatment. In the following case, high-strength, long-lasting indirect restorations were used on the abovementioned pillars, whereas less expensive low-strength direct composite restorations were used to restore the remaining teeth.

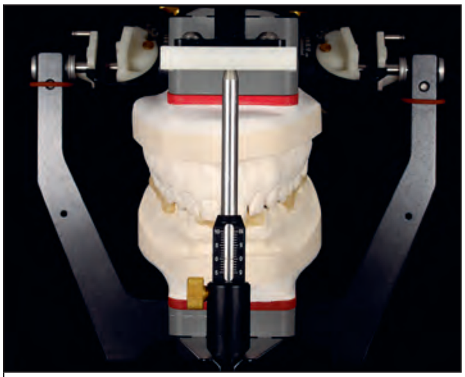
CASE PRESENTATION

During a follow-up visit, a 35-year-old patient complained of general oral sensitivity, craniomandibular system (CMS) muscle pain, and wear of the palatal surfaces of the anterior teeth. Medical anamnesis results were negative. Clinical examination revealed medium to severe wear[8,9] of the occlusal surfaces of the posterior teeth, as well as the palatal surfaces of the canines and the central and lateral incisors, along with areas of deep dentin exposure (Figs 1a to 1e). Radiographic examination revealed interproximal caries and two preexisting fillings that needed to be replaced (Figs 2a and 2b). Analysis of dental surfaces, Brux Checker (Scheu Dental) evaluation,[10] and anamnestic evaluation of extrinsic and intrinsic factors contributing to the tooth wear (eg, acidic diet and gastroesophageal reflux) led to the diagnosis of tooth wear associated with sleep bruxism in combination with chemical erosion (Fig 3). Full-mouth radiographs, periodontal charting, study casts, and complete photographic documentation were carried out (Figs 4 and 5).

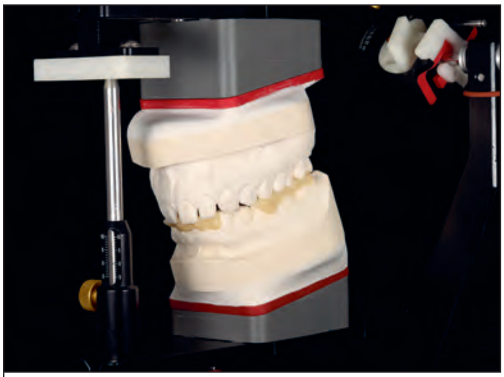
6



7a



7b



7c

Fig 6 Rest position recorded with self-curing composite resin indices. VDO increase was set with 1.5-mm Flex Tabs.

Figs 7a to 7c Plaster casts mounted in the articulator by means of a facebow and intermaxillary resin keys registered in neuromuscular position.

TREATMENT GOALS

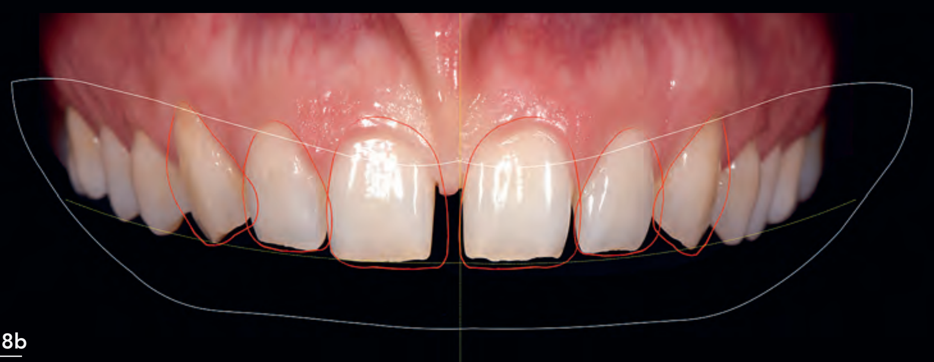
The following treatment goals were established with the patient's consent: caries treatment and replacement of old inadequate fillings; full-mouth rehabilitation to minimize the detrimental effect of bruxism on teeth, muscles, and joint structures; as well as replacement of lost dental substrate, minimal removal of sound tissue, and cost limitation.

CLINICAL PHASES

Phase 1: Establishing Therapeutic Position—Sagittal and Vertical Intermaxillary Relationships

The position of the mandible at rest without muscular tension (ie, neuromuscular relaxation) was recorded. To compensate for the loss of dental tissue, increased vertical dimension of occlusion (VDO)[11,12] was tested with multiple sets of calibrated interocclusal tabs and then validated by palpation of muscular and articular structures. Flexible clearance tabs with a thickness of 1.5 mm (Flex Tabs, Kerr) were selected (Fig 6). Three hard-setting self-curing resin indices, two on the posterior and one on the anterior area, were created to collect all information (ie, sagittal and vertical plane intermaxillary relationships) necessary to mount the casts in the articulator (Figs 7a to 7c).

8a



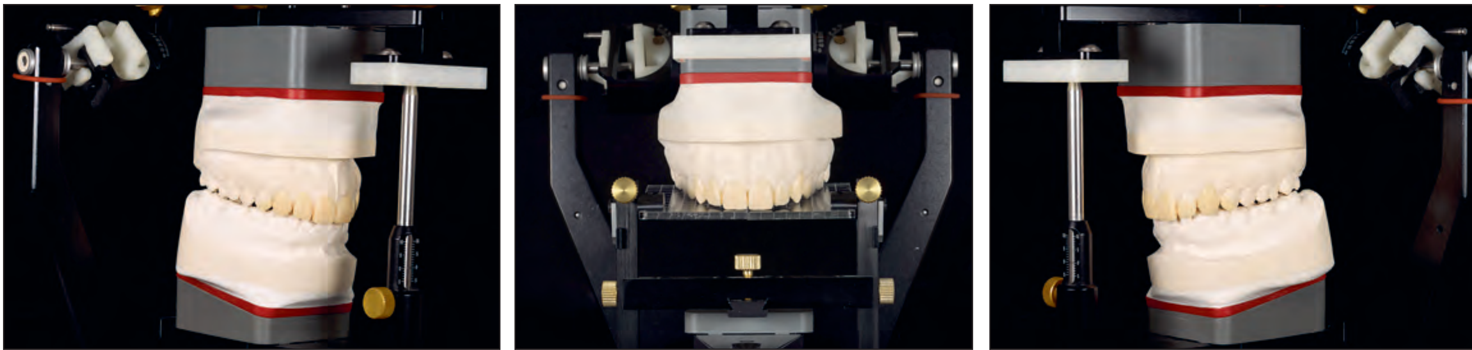
8b

8c

Figs 8a to 8c Digital smile previsualization of the esthetic outcome. Two solutions were presented to the patient: *(a)* The first proposed complete closure of the diastema between the maxillary central incisors; *(b)* the second proposed partial closure of that space. *(c)* The right central incisor was planned to be moved in an ideal position, using a combined intrusive and medial force.

Phase 2: Digital Smile Planning

Digital smile system software was used to previsualize the esthetic outcome. Two options were presented to the patient: complete closure of the diastema between the maxillary central incisors or only partial closure of that space. Digital planning revealed that minimal orthodontic pretreatment was needed to minimize the biologic cost of sound tissue. The right central incisor was planned to be moved to an ideal position, using a combined intrusive and medial force with respect to both esthetic and functional restorative solutions (Figs 8a to 8c).



9a 9b 9c

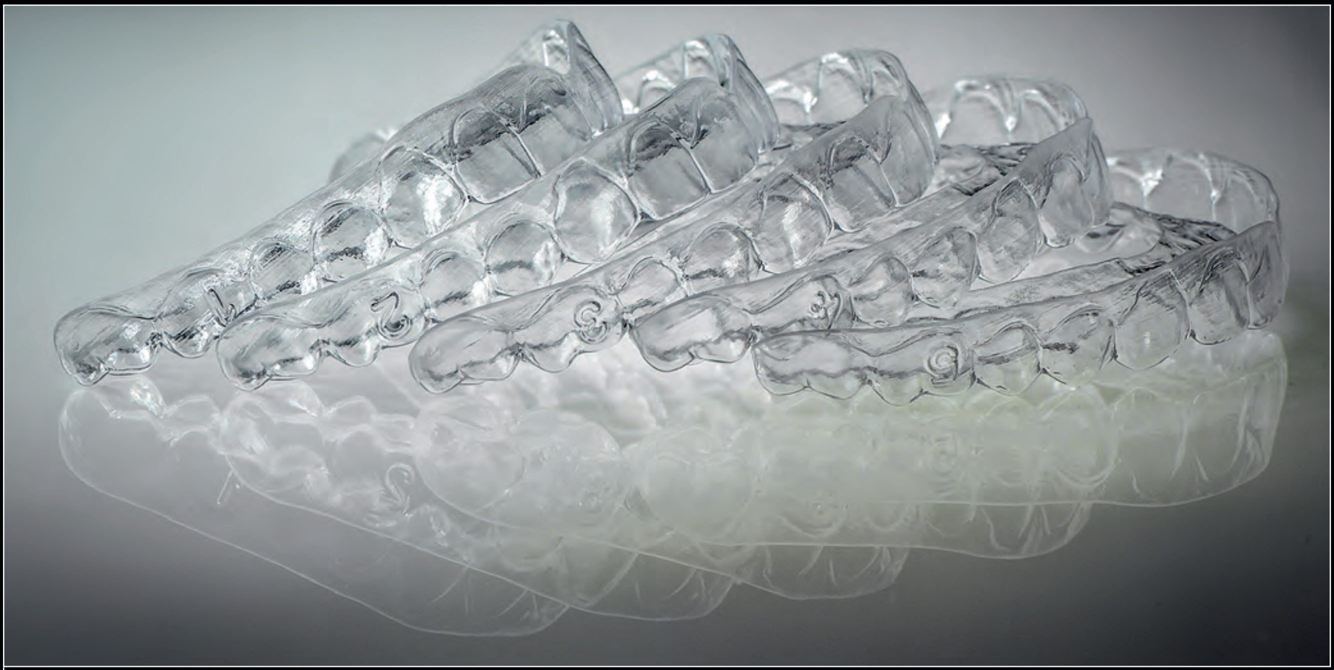
10a 10b 10c 10d 10e

Figs 9a to 9c Analogic wax-up according to the virtual smile design.

Figs 10a to 10e Composite resin mock-up validating the esthetic outcome planned with the wax-up. The patient asked for a small diastema to be maintained between the maxillary central incisors.

Phase 3: Esthetic Outcome Validation

Esthetic validation of the wax-up obtained from the digital smile system software was performed using a mock-up (Figs 9a to 9c). A silicone index with high Shore Hardness and a self-curing composite resin were used for this purpose. To meet the patient's expectations, some modifications were made to the shapes and proportions of the teeth. The opening of a small diastema between the central incisors, in particular, was necessary. A full set of photographic images and phonetic tests completed the clinical evaluation (Figs 10a to 10e).



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12a

12b

12c

Fig 11 The aligners obtained digitally to move the maxillary right central incisor mesially and apically, in order to fit the esthetic planning (See also Fig 8c).

Figs 12a to 12c Initial situation of the maxillary anterior dentition, with the first of five aligners positioned in the mouth and the final outcome with the maxillary right central incisor moved according to the esthetic wax-up.

Phase 4: Minor Orthodontics of the Maxillary Right Central Incisor

The orthodontic movement of the maxillary right central incisor was digitally planned and achieved using five consecutive aligners over 5 weeks (Figs 11 and 12).


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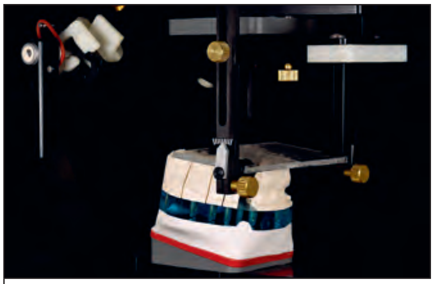
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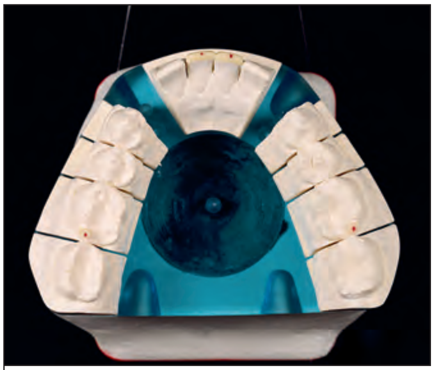
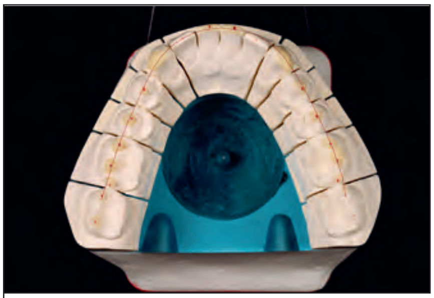
16a


16b


17a


17b


18

Fig 13 Esthetic wax-up is modified according to the patient's requirements.

Fig 14 Axis of the mandibular incisors is checked with the Stuart plane.

Fig 15 Occlusal plane setting by means of a dedicated device. The occlusal plane inclination (OPI) was set to 5 degrees with respect to the axio-orbital plane.

Figs 16a and 16b Close-up view of the mandibular occlusal plane according to Slavicek[7]: The landmarks for its definition are the incisal margin of the central incisors and the distal cusps of the first molars.

Figs 17a and 17b Passive centric arch of the maxilla created in harmony with the active centric arch of the mandible.

Fig 18 Static relationships of the mandibular supporting cusps with the maxilla.

Phase 5: Complete Wax-up

The buccal aspect of the wax-up was then implemented with the function-driven restoration of the palatal surfaces of the maxillary anterior teeth and the occlusal surfaces of premolars and molars (Figs 13 to 30). The casts were mounted on a fully adjustable articulator, which was configured in accordance with the indications provided by condylography (Fig 20). Protrusion and retrusion curves were selected, and sagittal condylar inclination (SCI) values of 41 degrees and 39 degrees were set for the right and left sides, respectively.

The plan for restoring functional occlusion was developed using a Slavicek Class I wax-up.[7] The gnathologic occlusal plane (the incisal edge of the mandibular central incisor to the tip of the distal cusp of the mandibular first

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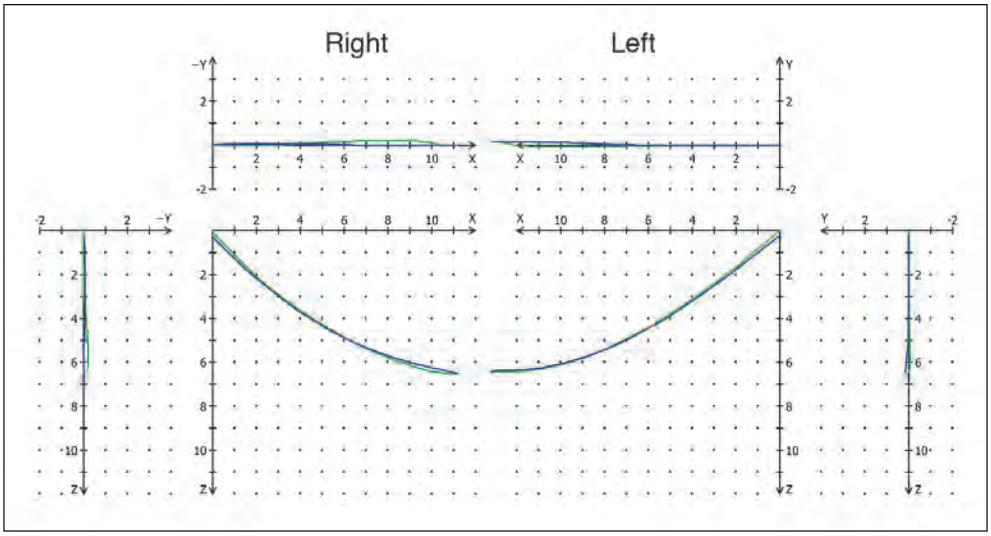


Fig 20

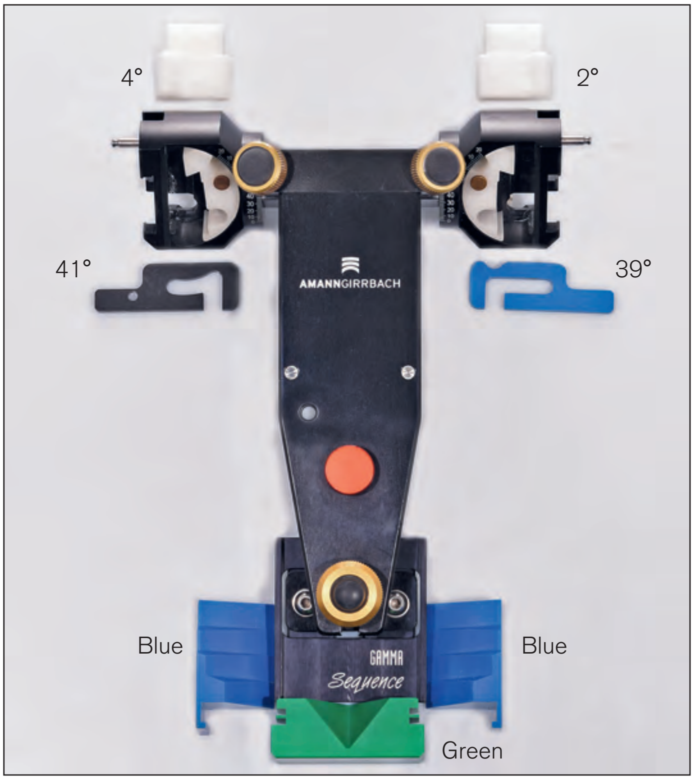


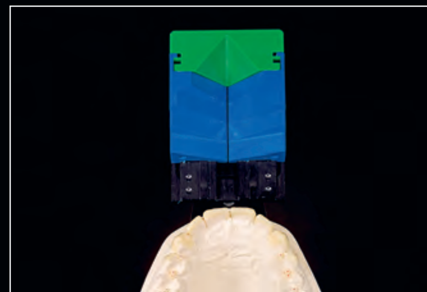
Fig 19 Protrusion and retrusion curves and sagittal condylar inclination (SCI) values of 41 degrees and 39 degrees for the right and left sides of the jaw, respectively.

Fig 20 Articulator setting according to condylography.

molar) was established, beginning from the evaluation of the position of the mandibular incisal margin relative to the dynamics of the lower lip. Incisal margin exposure at rest and at broad smile, together with analysis of the ideal inclination of the mandibular central incisor (obtained by comparison with the Stuart plane) were correct (Fig 14). Thus, to maintain the mandibular incisal margin unaltered as previously projected, the interocclusal anterior space caused by the increased VDO was closed with an additive wax-up of the palatal side of the maxillary anterior teeth.

An occlusal plane inclination (OPI) of 5 degrees relative to the axio-orbital plane was calculated based on the following rule (Fig 15): OPI = SCI – disclusion angle (DOA) – cusp inclination (CI). The DOA represents the patient's freedom of sagittal movement, with higher values indicative of lower risk of occlusal interference. DOAs are typically 8 to 12 degrees. However, patients with bruxism require larger DOAs, so an angle of 10 to 12 degrees was chosen. The CI is closely related to chewing efficiency, where a higher value is indicative of greater masticatory


21a


21b


21c

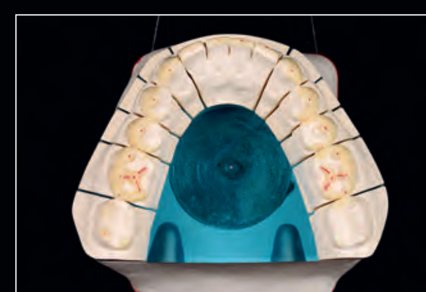

22a


22b


22c


23


24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26a


26b


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Figs 21a to 21c Right chest, incisal table, and left chest settings.

Figs 22a to 22c Sequential guidance system developed starting from the functional guiding path of the maxillary first molar.

Fig 23 Occlusal view of the guidance system of the maxillary first molar.

Fig 24 Wax-up of the functional guiding path of the maxillary first molar and of the first and second premolars. The guidance system was set to allow the anterior tooth to disclose the immediate distal one.

Fig 25 Occlusal view of the mandible. Support cusps of the posterior and lateroposterior teeth are completed.

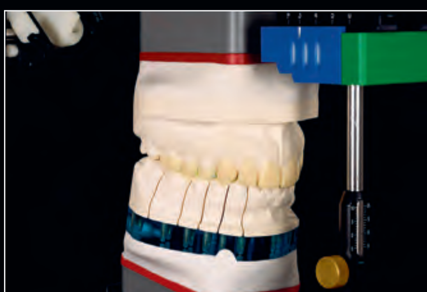
Figs 26a and 26b Sequential guidance creating a minimal, but effective, disclusion between the arches during laterotrusive movements on the articulator.

Fig 27 Protrusive guidance system waxed on the maxillary canine and central incisors according to articulator settings.


28a


28b


28c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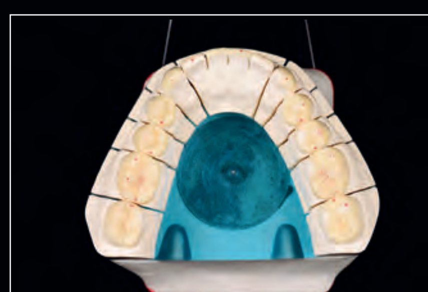
29b


29c


29d


29e


29f


29g

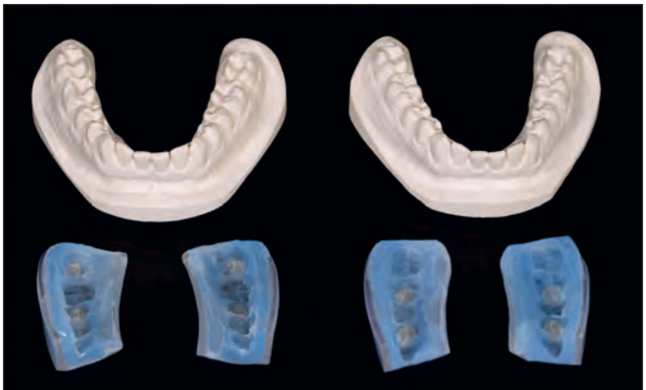

30

Figs 28a to 28c Right laterotrusion, protrusion, and left laterotrusion after the completion of the canine wax-up.

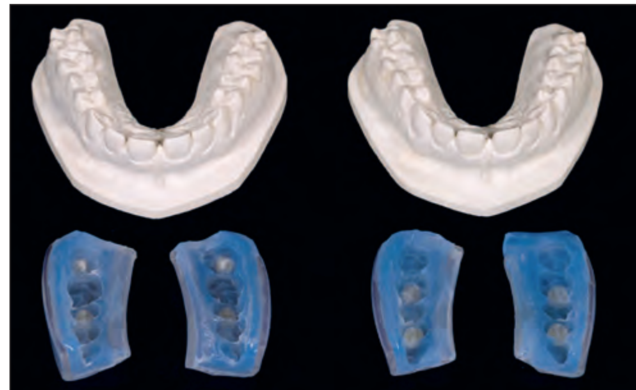
Figs 29a to 29g Final result of the wax-up. Progressive inclination of the functional slopes of the maxillary arch from the molars to the canine is evident, as well as compensation curves (Spee and Wilson).

Fig 30 No-prep composite resin veneers according the wax-up on the palatal surface of the maxillary anterior teeth.

efficiency. In the present case, a CI of 30 degrees was planned to provide favorable chewing function; the disto-buccal cusp and individual curve of Spee were established accordingly. The wax-up performed by the dental technician created a sequential guidance system with canine dominance that was developed in harmony with the SCI to avoid interference during functional movement and ensure minimal, but efficient, disclusion. The guidance system was studied to ensure progressive enrollment of the posterior elements if canine wear occurred.



31a



31b

32a

32b

32c

33

Figs 31a and 31b Rigid customized matrices obtained from modified transparent trays relined with clear silicone. Two sets of indices were created for each quadrant: the first one replicating the wax-up of the first premolar and first molar with resin occlusal stops on the second premolar and second molar, the second one replicating the latter with resin occlusal stops on the former.

Figs 32a to 32c Customized trays modified to avoid the clamps from interfering with the rubber dam positioning.

Fig 33 Light curing of the preheated composite during this modified index technique. Note: Teflon was employed to protect the teeth when functioning as occlusal stops.

Phase 6: Clinical Evaluation of Function—Copy and Paste Approach

The occlusion obtained with the wax-up was replicated in the mouth of the patient with direct composite restorations in the posterior teeth and no-prep palatal veneers in the maxillary anterior teeth.[13–15] A modified index technique was used in the posterior area.[4] Rigid customized matrices were obtained from modified transparent trays that were relined with clear silicone. Two sets of indices were created for each quadrant (Figs 31a and 31b). Initially, the wax-up of the first molars and first premolars was replicated on both maxillary and mandibular plaster models, with intact second premolars and molars. These prepared solid casts were used to realize the first sets of indices in each quadrant. Two occlusal stops were realized with a light-curing resin on the unmodified occlusal surfaces of the second premolar and molar, in order to improve the precision and reproducibility of the molding technique.

The second set of indices was created from the full wax-up, with occlusal resin stops on the first premolars and molars. The resulting customized silicone relined resin trays were sequentially used to mold new occlusal surfaces with preheated medium-translucency composite resin in the posterior area (Figs 32 to 37). After completion of this treatment step, masticatory muscles and articular structures were evaluated, and a Brux Checker was used to test the clinical effectiveness of the newly provided occlusion from a dynamic perspective (Figs 38 and 39).


34a

34b

34c

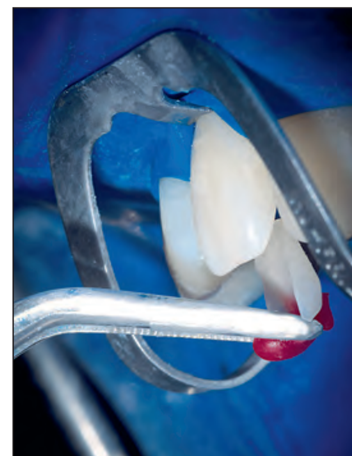
34d

35a

34e

34f

34g

34h

35b

Figs 34a to 34h The four quadrants before and after the composite molding procedure.

Figs 35a and 35b Luting procedure of the palatal no-prep veneer on the maxillary left central incisor. The surface was sandblasted and acid etched. The correct positioning when the palatal surface is not naturally retentive is warranted by a photocured resin hook that engages the incisal margin.

Fig 36 Maxillary arch after the preheated composite molding on the occlusal surfaces and luting of the palatal veneers.


36

38a

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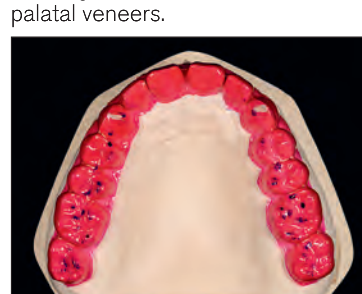
38b

39

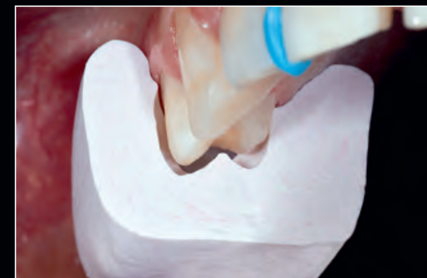
Fig 37 Mandibular arch after the preheated composite molding on the occlusal surfaces.

Figs 38a and 38b Static and dynamic occlusion with excursive movements verified with 21-micron disclosure papers.

Fig 39 Brux Checker showing correct support (blue marks recorded with the occlusal paper in maximum intercuspation) and efficient canine guidance.

40a

40b



41

42a

42b

43a

43b

43c

Figs 40a and 40b Calibrated 0.8-mm grooves prepared to allow thickness to be controlled and anatomical preparation of the maxillary right first premolar.

Fig 41 Silicone index from wax-up used to double-check the tooth reduction.

Figs 42a and 42b Calibrated 0.8-mm grooves prepared to allow thickness to be controlled and anatomical preparation of the maxillary right first molar.

Figs 43a to 43c Silicone index from the wax-up used to double-check the tooth reduction of the maxillary right first molar. The index for the first molar is specifically cut to give a precise reference for the cusp tips, mesial and distal fossae, and the crista obliqua, which is of paramount importance as a retrusive control. (Credits to Dr Riccardo Stefani.)

Phase 7: Ceramic Restoration of Maxillary First Premolars and First Molars

Tooth preparations were completed on the maxillary first premolars and molars. Calibrated burs were used to achieve predictable anatomical reduction of the teeth, controlled thickness of the indirect restorations, and minimal tissue invasiveness. Preparations were confirmed with appropriate silicone indices (Figs 40 to 44). Silicone impressions were made using a one-step double-mix technique (Fig 45). The casts were mounted in therapeutic position, and heat-pressed lithium disilicate occlusal and vestibular overlays replicating the wax-up were obtained. The restorations were checked to ensure marginal fit, appropriate occlusion, and color integration (Figs 46 to 48). Luting was performed under rubber dam isolation following a multistep protocol (Figs 49 and 50). Tooth surfaces were cleaned and gently sandblasted with aluminum oxide particles.

44

45

46a

46b

47a

47b

47c

Fig 44 Tooth preparation for lithium disilicate indirect occlusal onlays of the maxillary right and left first premolars and first molars.

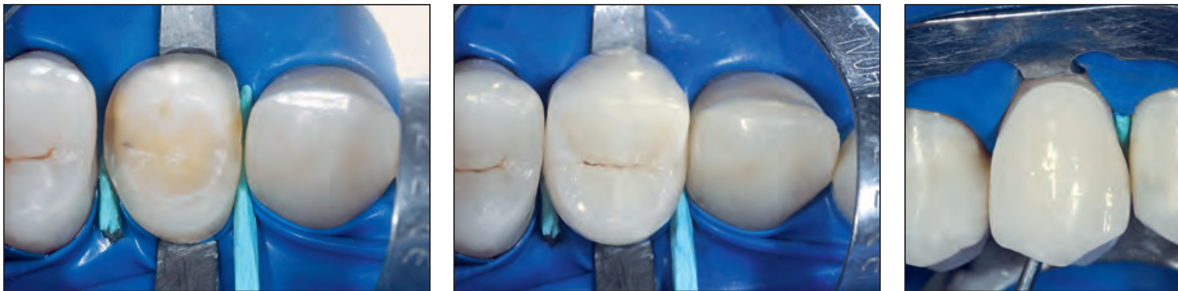
Fig 45 One-step double-mix silicone impression of the maxilla.

Figs 46a and 46b Master casts for the manufacturing of lithium disilicate monolithic occlusal and vestibular overlays. The restorations were waxed, heat pressed, and stained.

Figs 47a to 47c Lithium disilicate indirect restorations in the articulator to check static and dynamic occlusion.

Fig 48 Solid cast employed for evaluation of interproximal contacts and for delivery of the restorations.

48



49a 49b 49c

50a 50b 50c

Figs 49a to 49c Evaluation of the fit of the restoration on the maxillary right first premolar before luting procedures under rubber dam isolation.

Figs 50a to 50c Evaluation of the fit of the restoration on the maxillary right first molar before luting procedures under rubber dam isolation.

A three-step etch-and-rinse adhesive with 2% chlorhexidine digluconate as an additional primer was used on tooth surfaces. After appropriate application and air-thinning, the bonding was cured for 40 seconds with a second-generation LED unit. Inner ceramic surfaces of restorations were etched with 9.7% hydrofluoric acid for 10 seconds and treated with silane (heat treatment for 4 minutes at 80°C) and an uncured bonding agent. Preheated high-viscosity photocured composite resin was used to lute the overlays. After polymerization, finishing, and polishing procedures, careful occlusal control was performed; few adjustments were required.

Phase 8: Ceramic Restoration of Mandibular Canines, First Premolars, and First Molars

In the mandible, first premolars and molars were prepared for lithium disilicate occlusal overlays (Fig 51). Calibrated burs were used to achieve predictable anatomical reduction of the teeth, controlled thickness of the indirect restorations, and minimal tissue invasiveness. Again, preparations were verified with appropriate silicone indices. Silicone impressions were made using a one-step double-mix technique (Fig 52). The casts were mounted in therapeutic position, and heat-pressed lithium disilicate veneers with occlusal and vestibular overlays replicating the wax-up were obtained. Additional feldspathic veneers were created with the platinum foil technique on the canines to improve guide efficiency (Figs 53 and 54).

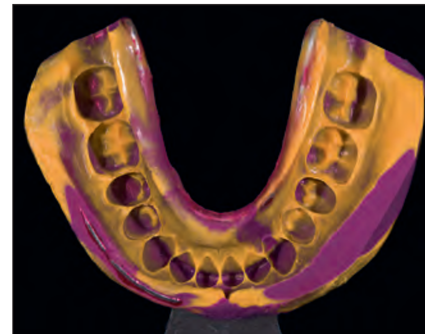
All restorations were checked to ensure marginal fit, appropriate occlusion (Figs 55 to 57), and color integration. Luting was performed under rubber dam isolation following the multistep protocol previously described. The feldspathic ceramic surfaces of the additive veneers for the canines were etched for a longer time (60 seconds with 9.7% hydrofluoric acid). Preheated high-viscosity photocured composite resin was used to lute the overlays, while a low-viscosity translucent resin cement was used for additional veneers. After finishing and polishing procedures, careful occlusal control was performed.

Fig 51 Tooth preparation of the mandibular left and right first premolars and first molars for lithium disilicate indirect occlusal and vestibular overlays.

Fig 52 One-step double-mix silicone impression of the mandibular arch.

Figs 53a and 53b Master cast for manufacturing of lithium disilicate monolithic occlusal overlays on the mandibular left and right first premolars and first molars. The restorations were waxed, heat pressed, and stained. Two feldspathic ceramic veneers were added on the canines to improve guidance.


51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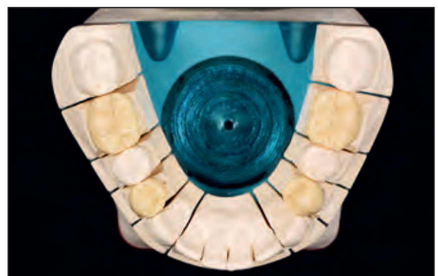

53a


53b


54a


54b


54c


54d


54e


54f

Figs 54a to 54f The additional veneers on the mandibular right and left canines created with the platinum foil technique.


55a


55b


55c

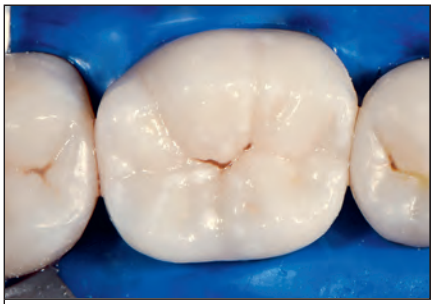
Figs 55a to 55c Lithium disilicate occlusal overlays and additional feldspathic porcelain veneers in the articulator to check static and dynamic occlusion.


56

Fig 56 Solid cast employed for evaluation of interproximal contacts and delivery of the restorations.


57a


57b


57c

Figs 57a to 57c Careful evaluation of the fitting of additional feldspathic ceramic veneers and of the lithium disilicate occlusal overlays before luting procedures.

Phase 9: Preparation for Veneers of Anterior Teeth

Mock-up–driven preparations for veneers were performed on the six maxillary anterior teeth (Fig 58). Calibrated burs were used to achieve the correct amount of space for indirect restorations with particular attention to minimal tissue invasiveness. Butt margins were prepared occlusally and interproximally, while the cervical finishing line was outlined with a fine-grit chamfer-shaped drill. Definitive preparations were evaluated with appropriate silicone indices, and silicone impressions were made using a one-step double-mix technique (Fig 59). Casts were mounted in the therapeutic position, and heat-pressed lithium disilicate veneers were prepared for the canines. Layered composite veneers were planned for lateral and central incisors (Fig 60).

All restorations were checked to ensure marginal fit, appropriate occlusion, and color integration (Figs 61 to 63). Luting was performed under rubber dam isolation, in accordance with the same multistep protocol described for lithium disilicate (Figs 64a and 64b). Composite veneers were sandblasted with alumina powder and etched with phosphoric acid for a deep cleaning of the inner surface before treatment with silane and application of an uncured bonding agent. Low-viscosity translucent luting cement was used for all six veneers. Careful occlusal control was performed when cementation procedures were completed.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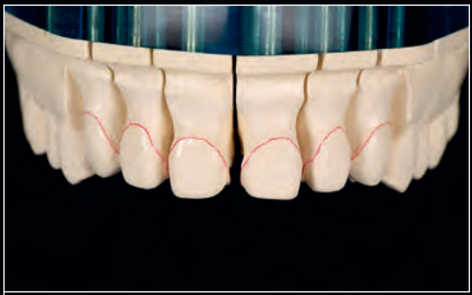
60


61a


61b


62a


62b


62c


62d


62e


62f


62g

Fig 58 Final preparation of the maxillary anterior teeth. A cervical light chamfer and interproximal and occlusal butt joints were designed.

Fig 59 One-step double-mix silicone impression of the maxillary arch.

Fig 60 Master cast for manufacturing of lithium disilicate monolithic veneers on the maxillary right and left canines. Less-prep minimally invasive composite resin veneers were planned for the central and lateral incisors.

Figs 61a and 61b Wax-up of the maxillary anterior indirect restorations duplicating the esthetic and functional plan. The occlusal view shows the overjet created between the planned restoration and the opposing arch.

Figs 62a to 62g Lithium disilicate (maxillary canines) and composite resin veneers (maxillary central and lateral incisors) in the articulator to check static and dynamic occlusion.


63a


63b


63c


64a


64b

Figs 63a to 63c Maxillary anterior indirect restorations on the master cast ready for luting procedures.

Figs 64a and 64b Evaluation of the fit of the restoration on the maxillary left central incisor before luting procedures under rubber dam isolation.

Phase 10: Occlusal Reevaluation and Follow-up

At the completion of treatment, full-mouth radiographs, periodontal charting, and complete photographic documentation were performed. Final casts were made, and the patient was evaluated using a Brux Checker, which confirmed excellent functional results. The patient confirmed satisfactory chewing efficiency, absence of CMS muscle pain, and a pleasant esthetic outcome (Figs 65 to 69).


65a


65b


65c


65d


65e


65f


65g


65h


66a


65i


66b


67

Figs 65a to 65i Intraoral photographs showing the final outcome of the rehabilitation.

Figs 66a and 66b Static and dynamic occlusion verified by means of excursive movements with 21-micron disclosure paper (blue marks for static contacts and red marks for eccentric movements).

Fig 67 Brux Checker showing correct support (blue marks recorded with occlusal paper in maximum intercuspation) and efficient canine guidance.

68a

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Figs 68a to 68h Extraoral photographs of the final outcome in rest position and medium and broad smile.

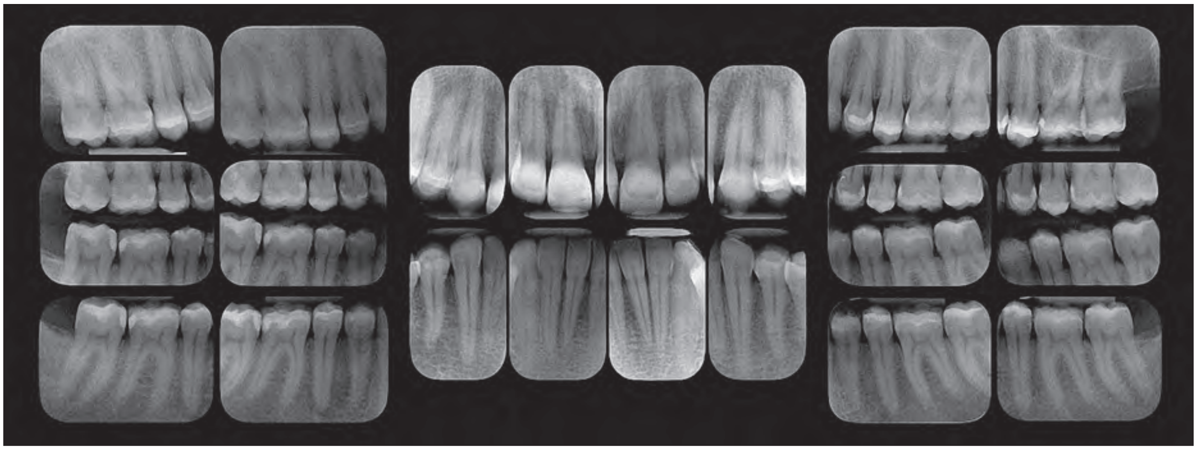

Fig 69 Postoperative full-mouth radiographs.

DISCUSSION

The occlusal branches of dentistry have many treatment objectives: achieve functional occlusion, respect and promote periodontal health, improve facial harmony and proportions, ensure temporomandibular joint health, guarantee long-term stability of esthetics and function, and respond to patients' needs and expectations.

Rationale for Pillar Selection

When a correct diagnosis and treatment plan is formulated, traditional prosthetic rehabilitation can satisfy all of the above requirements,[1] even if there are many concerns regarding costs, invasiveness, and total chair time. Thus, full-mouth restorations based on adhesive onlays, overlays, and veneers have grown in popularity because they preserve a greater extent of sound dental tissue.[2,3] However, high treatment costs to patients remain a limitation. Many conservative solutions have been suggested based on extensive usage of composite resins with both direct and indirect approaches.[4,5] Nevertheless, the long-term occlusal stability of composite resin has been questioned with regard to full-mouth rehabilitation.[6] Occlusal wear is primarily due to attrition and erosion. In most cases, these two aspects act synergistically.

Rapid and uneven wear is more closely related to lack of force control than to biocorrosion. Therefore, a carefully planned individual occlusal scheme might avoid detrimental effects of bruxism habits by altering force transmission interfaces (ie, OPI, guide inclination, CI, and DOAs); this should be regarded as more important than material selection.[16–18] Additionally, a differential restorative strategy on teeth mainly involved in static and dynamic loads, using high-strength long-lasting indirect restorations, could provide further long-term stability. This differential approach is based on the selection of strategic pillars, such as the canine, first premolar, and first molar. These teeth are critical because of their roles in occlusion.

From a functional perspective, we can distinguish three distinct areas in the mouth: anterior, lateroposterior, and posterior.[7] The anterior area is devoted to esthetics, phonetics, protrusive control, and laterotrusive guidance. Notably, there is a distinction between "control" and "guidance." All oral functions associated with protrusion are performed by highly coordinated neuromuscular schemes, based on avoidance patterns. Accordingly, there are no contacts between teeth, with the exceptions of sporadic and light contacts that can provide proprioceptive/fine-tuning feedback for the system. Consequently, the concept commonly described as "anterior guidance" should be more appropriately referred to as "anterior control." A correct incisor shape design is likely to be more important than the materials and techniques used for their restorations.

With regard to the canine, "guidance" is a more appropriate term. Upon its eruption in the maxillary arch, the canine presents a steeper functional surface relative to the teeth in the lateroposterior and posterior areas. The position of the canine within the arch, as well as its coronoradicular conformation and functional surface inclination, make this an ideal tooth for use as the laterotrusive guide (ie, for disclusion of all other teeth in eccentric movements). During bruxism, mandibular movements are associated with high dynamic contacts and loads that could be detrimental to natural dentition, as well as to restored teeth.[19] The canine has a fundamental role in the management of functional loads, regardless of occlusal concepts postulated by various gnathologic schools. This unique status of the canine in the anterior group, combined with its fundamental functional role from a mechanical perspective, requires reliable restorative strategies and high-strength material selection.

The lateroposterior area represents a transition zone between the frontal arch and the supporting teeth.[7] The premolars are designed to perform both laterotrusive control and support. In ontogeny, premolars are active in this dual function for a relatively long time during mixed dentition but also later in the mature bite. Even in normally developed occlusions, we often assist in the involvement of "intercuspating" teeth in laterotrusive control as a consequence of canine wear.

In this manner, the controversy between "canine guidance" and "group function" of different gnathologic schools appears resolved.[7,20]

The morphologies of human maxillary and mandibular first premolars require particular attention. The mandibular first premolar represents an exception to the dual role described above, as it does not exhibit a morphology suitable for intercuspation and should therefore be functionally included in the control group of the mandibular anterior area. From an anatomical perspective, it shows a strong buccal cusp and a more rudimentary lingual cusp. Its appearance is therefore similar to that of a canine. The buccal shoulder clearly recalls the vault and is therefore protruding. During protrusive movement, according to Slavicek,[7] the mandibular first premolar greatly contributes to the relief of the maxillary anterior arch. The occlusal surface has a distal fossa, while the mesial surface is rather flat and represents the anterior limit of the enamel ridge, extending in a buccolingual direction and connecting with the buccal and atrophic lingual cusp primary crests, without interruption. The tooth normally exhibits only one root.

The maxillary first premolar has two cusps of similar sizes—buccal and palatal. The palatal cusp is slightly larger but less pronounced in its height and inclination. The tooth typically exhibits two roots, located buccally and palatally; these are radial to the dental arch. The coronal aspect of the root before its division at the furcation level is similar to that of a kidney with mesial concavity. The occlusal relationship between the maxillary and mandibular first premolars does not allow intercuspation; however, the reciprocal positions of the mesial portion of the maxillary palatal cusp and the buccolingual enamel ridge of the mandibular premolar create the most important retrusive control of the mature dentition. From a therapeutic perspective, this offers a guide for mandibular repositioning when necessary.

The occlusal relationship between second premolars is simpler. The maxillary palatal cusp engages the mandibular distal fossa, since these teeth are intercuspating and primarily designed for support. In the lateroposterior area, the first premolars are the most important teeth because of their complex relationships and contributions to laterotrusive guidance and retrusive control. This consideration includes the attribution of occlusal support to molars. In their ideal occlusal relationship, maxillary and mandibular canines and first premolars represent a unique functional unit for guidance, control, and proprioception. Therefore, first premolars, more than second premolars, should be treated with load-bearing and wear-resistant restorations to maintain stable and enduring relationship and function.

The posterior area is represented by the first, second, and third molars, which form the so-called "support zone." These teeth are most suitable for the management of axial loads.[7] Given the extreme variability of the third molar eruption path, support functions are mainly exerted by the maxillary first and second molars via their cusp-to-fossa relationships with opposing teeth. The anatomical features of maxillary and mandibular first molars should be considered to understand their importance from a functional perspective. Despite some variations, the mandibular first molar generally has two buccal cusps, two lingual cusps, and a fifth cusp that is distally oriented and is smaller than the others. The distobuccal cusp is more markedly formed and is regarded as the central cusp of the tooth. Both lingual cusps are scissor-shaped with long and pronounced inclines. These three cusps together converge to create a marked "central" fossa. The tooth exhibits two well-represented roots, mesially and distally located, which are expressly designed for load-bearing function. The maxillary first molar exhibits four cusps, two each on the buccal and palatal sides. The mesiopalatine cusp is clearly visible and often constitutes the largest cusp of the dental arches; it is also regarded as the central cusp of the maxillary first molar. This tooth typically has three roots, the most developed of which is palatally located. The two buccal roots lie mesially and distally; their inclination is oriented toward the zygomatic crest through the alveolar bone. In ontogeny, during the early stage of mixed dentition, the first molar participates in eccentric laterotrusive guidance and retrusive control. This role in laterotrusive guidance can remain in certain physiologic conditions, even in mature dentition.

When there is an adequate dental relationship between the mandibular and maxillary molars, the morphology of the teeth is fully adapted to perform four main functions: laterotrusive guidance, retrusive control, food bolus and food preparation, and defense of delicate structures (eg, cheeks and tongue). Therefore, when long-term stability is needed, these teeth should receive the most reliable restorative treatments, together with high-strength material selection. The identification of strategic abutments corresponds to aspects relative to the case finalization, thus ensuring long-term stability of treatment outcomes and limiting overall costs for the patient.

Rationale for In Vivo Validation of Functional Treatment

In the case presented, particular attention was focused on the provisional phase. To replicate the project obtained with the wax-up in the patient's mouth, a composite resin for direct posterior restorations was selected. The use of composite resins was associated with a modified index technique (molding technique) for provisionalization. Although there is no clear agreement regarding the use of direct composite as a definitive solution in full-mouth rehabilitations, many case reports and case series have validated this type of approach with good medium- to long-term results.[5,21] Long-term provisionalization with composite resins enables evaluation of both static and dynamic aspects (wax-up in vivo validation) with a minimally invasive approach. Correct management of the VDO,[7,11,12,22] together with a no-preparation technique,[9] enabled preservation of considerable healthy tooth substance and aided in treatment reversibility.

The modified index technique presented in this case allowed fine reproduction of anatomical details and natural tooth contour. Importantly, this enabled the clinician to easily perform anatomical functionally guided tooth preparations for planned indirect restorations.[23] As reported by many authors, this approach can guarantee precise tooth reduction and shortening of chair time, together with thickness control that affects both the luting curing technique and mechanical resistance of indirect restorations. Additionally, teeth that receive only direct composite restorations benefit from the technical/procedural perspective of a favorable c-factor during curing, a higher degree of conversion due to preheating, and a functional morphology suitable for occlusal stabilization and support. Thus, the resulting stable and efficient composite restorations allow treatment phases to be adapted to each particular patient's expectations and needs.

Another important point is that preheated, molded, direct restorations do not require special care during maintenance, compared with other temporization strategies, and are not prone to secondary caries or periodontal adverse reactions.[24,25] Classic acrylic provisionals for full-crown preparations require periodic revision and renewal of temporary luting cement; in some cases, they may require short-term marginal relining or repair. Mock-up provisionals are also an alternative, but they have a shorter lifespan due to fracture or adverse responses from periodontal tissue. Thus, preheated, molded, direct restorations can allow the treatment plan to be delayed to meet the patient's economic needs and personal agenda, as well as to enable the clinician to ensure stable healing after endodontics or surgical procedures, prior to treatment finalization. Each step after full-arch, direct composite provisionalization is intended to constitute a continuous, progressive upgrade for the patient.

Long-Term Follow-up and Maintenance

Occlusal and functional surface wear is controlled by the occlusal scheme, which is the primary interface of load transmission. An acceptable working occlusal scheme should prevent excessive wear and stress concentration, which could be dangerous for natural and restored teeth, as well as for other structures of the CMS.[7,22] Based on the different mechanical and chemical properties of ceramic and composite resins, less favorable aging of composite restorations might be expected. However, with respect to wear, there are some important considerations.

First, bruxism is the only function that leads to attrition and occlusal wear, regardless of its clinical manifestation.[7] Therefore, the types of materials used are secondary to the efficiency of the guidance system. Second, attrition on the second premolar and second molar become clinically relevant only after flattening of the guidance system. This is not expected to occur rapidly, if the canines and first premolars are restored with ceramics and involved in a sequential guidance system with a canine dominance. If this situation should occur, the second premolar and the first molar are designed to participate as a group in laterotrusive movements based on the SCI, registered via condylography. Third, if there are any adverse effects on the occlusal surfaces of composite restorations, they can easily be refurbished or restored with a ceramic indirect restoration.

With regard to the maxillary and mandibular incisors, their functions, when correctly planned, should be limited to proprioceptive control without heavy contact.[7] Esthetic reasons could cause reintervention in the frontal area. In the present case, indirect composite veneers were delivered to the patient, but the same result could be obtained with direct veneering resin restorations. The aging of composite in the anterior dentition could require management of these restorations.[6] This minimally invasive approach could enable the clinician to choose different strategies, from refurbishment to ceramic veneers, based on the patient's needs and expectations.

CONCLUSION

Tooth wear, extensive failing pre-existing restorations, and occlusal treatment require the dentist to manage complex rehabilitations. In addition to technical details, which represent a unique challenge, patient care currently includes management of cost limitations and maintenance of a flexible schedule that meets the needs of each patient. After appropriate data collection and diagnosis formulation, a stable therapeutic position must be obtained with respect to VDO and 3D intermaxillary relationships to satisfy both functional and esthetic requirements; this can be achieved with extensive use of composite resins, using an index-assisted direct technique or an indirect technique. This approach enables assessment of the functional aspects of the rehabilitation by means of a Brux Checker device, periodic patient interviews, and muscle and articular palpation.

Many authors support the definitive use of composite in full-mouth rehabilitation, but this remains controversial in the literature, particularly for patients with a bruxing habit. With regard to a full-mouth ceramic rehabilitation, the pillar selection approach could help to avoid expensive treatments and allow a more flexible schedule of chair appointments, while ensuring long-term occlusal and periodontal stability, temporomandibular joint care, and esthetic outcome. Abutment selection for indirect high-strength restorations, which is necessary to overcome criticisms in the literature regarding composite full-mouth rehabilitations, should be guided by hierarchical function-related evaluations of the roles of specific teeth in the mouth, as well as considerations of static and dynamic loads acting on those teeth. As explained above, the selection of canines, first premolars, and first molars seems to be the most appropriate.

Full-mouth restoration based on these pillars, as well as differential treatments with respect to technique and material selection, could represent a viable solution that meets all requirements of traditional prosthetic rehabilitation, provides lower treatment costs, facilitates a versatile appointment schedule, and enables long-term upgrades based on the patient's needs.

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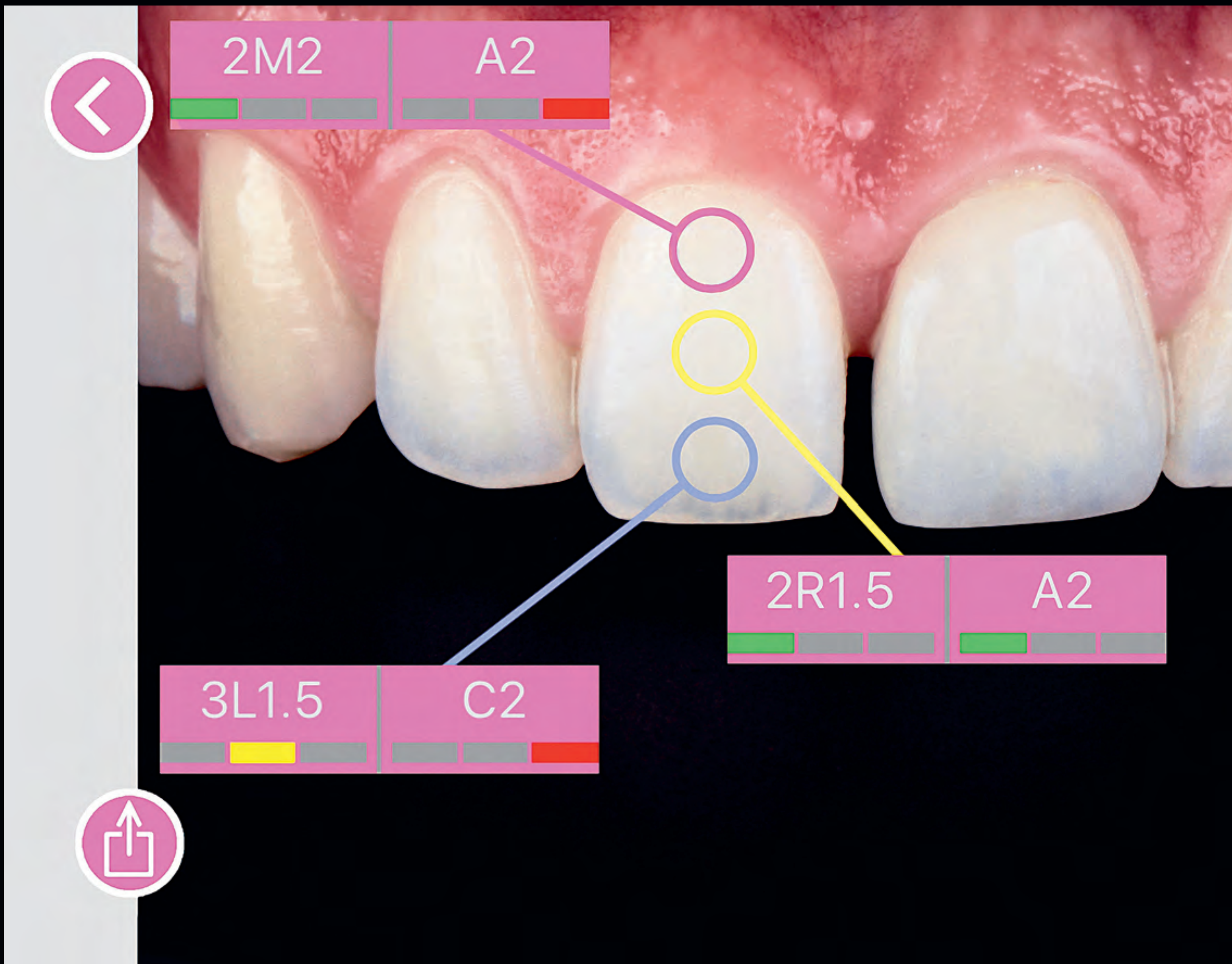

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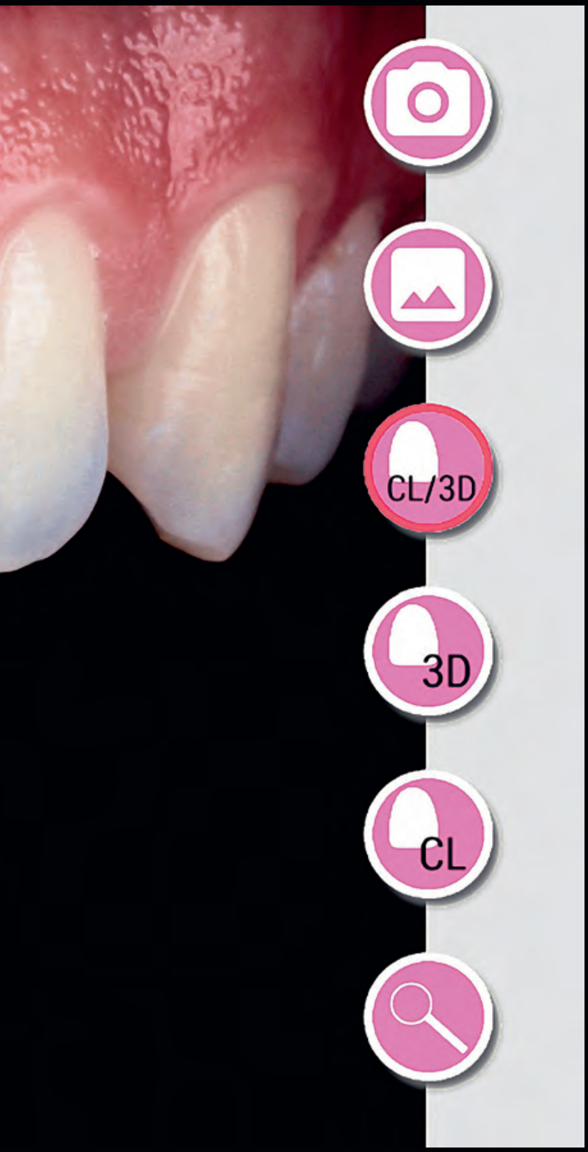

Veneer and Crown Shade Matching: A Digital Approach

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Shade matching indirect restorations of central incisors with different types of ceramic has always been a challenge for clinicians and dental technicians.[1] A digital approach implementing the latest dental applications (apps) for mobile devices can simplify the treatment planning, accurate shade selection, and patient communication involved in this treatment. The combination of new CAD/CAM software technology with improved design features allows clinicians and dental technicians to successfully address demanding clinical challenges such as matching the appearance and shades of maxillary central incisors that require different types of indirect restorations.[2]

This article presents key details of the clinical and laboratory steps for chairside CAD/CAM restorations and a case that illustrates a technique to predictably match color and translucency of a laminate veneer and a full-coverage crown. The presented approach involves multilayer monolithic restorations with symmetric support structures and ceramic laminate veneers to achieve a good match and natural appearance.

1

2

Fig 1 Dr Markus Blatz/Dr Julián Conejo Preparation System for CAD/CAM Restorations #K0394, Brasseler.

Fig 2 Intraoral view of the maxillary central incisor preparations.

MOBILE APPLICATIONS

Mobile applications, commonly referred to as apps, are application software that run on mobile devices such as smart phones and tablets. Apps have become part of our daily lives, providing valuable information and facilitating common tasks. Their implementation in clinical and laboratory protocols provides opportunities to streamline workflows and surpass common communication challenges between clinicians, dental technicians, and the patient.

The Digital Smile Design (DSD) App is an advanced tool for 2D and 3D treatment planning and patient education on a mobile device, based on preoperative STL files from intraoral scans, specific intra- and extraoral photos, face scans, and videos.[3] Shade selection and communication are other key components of the workflow when restoring maxillary central incisors with indirect ceramic restorations. A small dental spectrophotometer (Easy Shade V, VITA Zahnfabrik), controlled through the VITA mobileAssist App and supported by intraoral photos, simplifies the shade-taking process and facilitates shade communication. Accurate shade taking and effective communication reduce the number of clinical appointments and possible remakes.[4]

TOOTH PREPARATION

When treating both maxillary central incisors with the same type of indirect ceramic restorations, clinical outcomes can be greatly improved by preparing the abutment teeth symmetrically with the same amount of 3D tooth reduction and finish line position.[5]

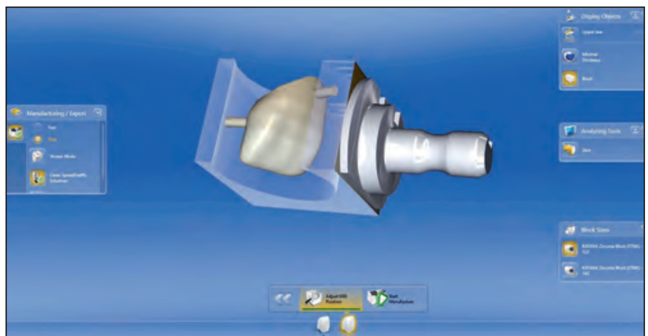
Preparation design features for full-coverage CAD/CAM restorations on maxillary central incisors include:

- Finish line with an internally rounded shoulder and symmetric zenith levels
- Smooth transitions from interproximal walls to the incisal edge while avoiding sharp angles, corners, and undercuts
- Same preparation design and amount of 3D tooth structure reduction for both abutment teeth

Fine diamond burs with specific dimensions and shapes (eg, Dr Markus Blatz/Dr Julián Conejo Preparation System for CAD/CAM Restorations #K0394, Brasseler; Fig 1) are necessary to carry out ideal tooth preparation designs (Fig 2) for chairside CAD/CAM restorations, which are typically fabricated without any models. An ideal tooth


3a


3b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5a


5b

Figs 3a and 3b Design of CAD/CAM restorations.

Fig 4 Dry-milling preview.

Figs 5a and 5b Fully sintered monolithic polychromatic preshaded zirconia crowns.

preparation also simplifies the digital restoration design process and provides better design proposals (Figs 3a and 3b), especially for endodontically treated teeth, which have less critical anatomical design considerations since they are not vital.[6]

When the abutment teeth reveal a noticeable color difference after tooth preparation, the design proposals for monolithic restorations should provide a minimum thickness of 1.0 mm on the labial surfaces to mask any discolorations and avoid discrepancies in the appearance of the final restorations.[7] A chairside digital workflow and high-translucent multilayer preshaded zirconia blocks (eg, Katana STML, Kuraray Noritake) provide viable options in such situations. The presintered zirconia blocks (Fig 4) are dry milled in a 4-axis milling machine (eg, MCXL, Dentsply Sirona) with carbide burs and are then fully sintered with a speed sintering cycle in a small-footprint furnace (eg, Speed Fire, Dentsply Sirona). In this manner, the entire fabrication process of a chairside full-contour monolithic zirconia crown takes only slightly more than half an hour (Figs 5a and 5b).[8] The restorations are tried in and delivered with the proper cementation materials and protocols (Figs 6a


6a


6b


7a


7b

Figs 6a and 6b Try-in and cementation of final restorations.

Figs 7a and 7b Postoperative extraoral views at rest and during a smile.

and 6b) with the goal to provide natural tooth morphologies and shapes (Figs 7a and 7b).

CASE PRESENTATION

A 23-year-old male patient presented with an overcontoured porcelain-fused-to-zirconia crown on the maxillary left central incisor and a diastema between the maxillary central incisors. Extraoral frontal, lateral, and anterior 12 o'clock views of the patient's smile as well as intraoral photographs were taken (Figs 8 and 9). These photographs and STL files of preoperative maxillary, mandibular, and buccal intraoral scans were uploaded to the DSD App on a tablet (iPad Pro, Apple).

The maxillary intraoral scan was calibrated and positioned to the extraoral images to calculate the smile frame. The width/length ratio of both maxillary central incisors was calculated for ideal restorative space distribution (Figs 10a to 10c). A 2D smile that included a proposal for the maxillary central incisors was designed and used to explain the treatment and possible esthetic outcomes to the patient for motivational purposes (Figs 11a and 11b). A spectrophotometer (Vita Easyshade V) and App (Vita mobileAssist) were used for shade communication with the patient and the laboratory technician (Fig 12).

After approval of the 2D design, a digital 3D wax-up and set-up were created with natural tooth shapes from the tooth and smile libraries in the DSD App. A resin model was 3D-printed based on the digital wax-up, and a silicone index was made to serve as a guide for the tooth preparations.

The maxillary right central incisor was prepared for a ceramic laminate veneer following common preparation guidelines. The endodontically treated maxillary left central incisor was prepared for a full-coverage crown (Fig 13). Digital and conventional impressions were made.

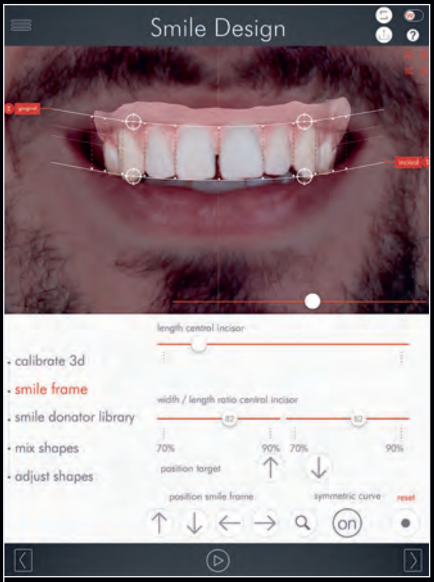

8a


8b

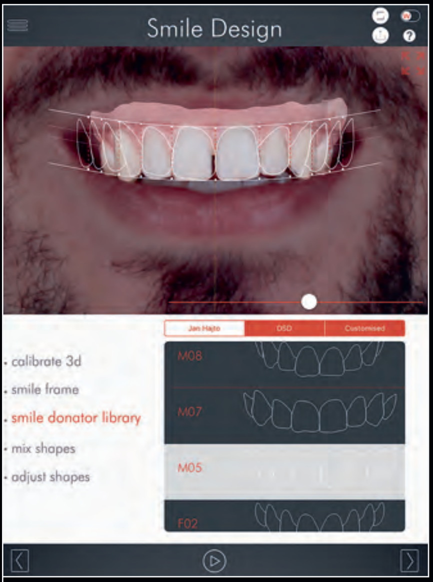

8c


9

10a



10b



10c

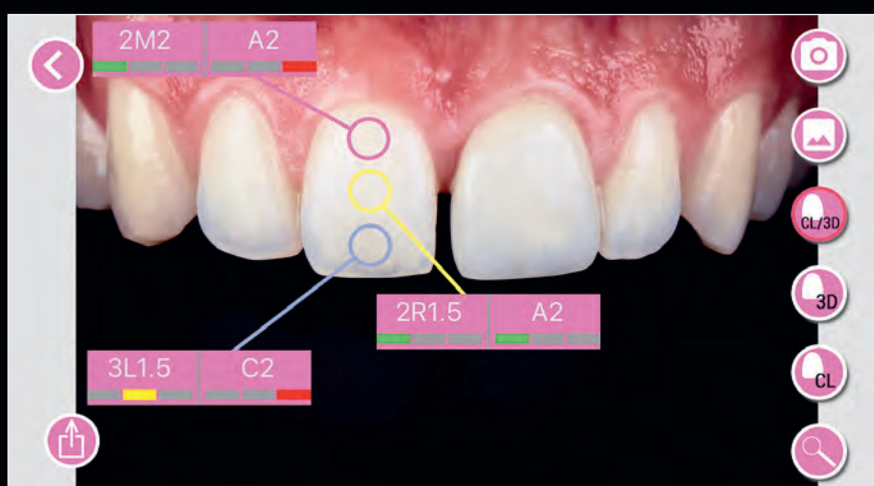
Figs 8a to 8c Preoperative extraoral views.

Fig 9 Preoperative intraoral view.

Figs 10a to 10c Smile-frame calculation and width/length ratio of maxillary central incisors with the DSD App.

11a

11b



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13

Figs 11a and 11b Visualization of the anticipated 2D smile design.

Fig 12 Shade values from the spectrophotometer are uploaded to the mobileAssist App through Bluetooth connectivity.

Fig 13 Tooth preparations for a veneer on the maxillary right central incisor and a crown on the maxillary left central incisor.


14


15


16a


16b


17a


17b


17c

Fig 14 Digital restoration design in full contour.

Fig 15 Design of two symmetric laminate veneers after split-file of the maxillary left central incisor.

Figs 16a and 16b Crown coping design on the maxillary left central incisor.

Figs 17a to 17c The crown coping was fabricated from a preshaded multilayer zirconia block, and laminate veneers were milled from a polychromatic feldspathic ceramic.

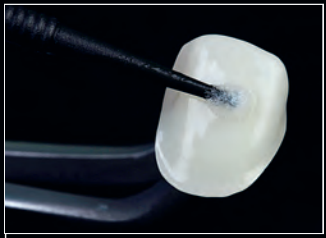
Two symmetric monolithic restorations were designed (Fig 14) and a split-file was created on the maxillary left central incisor to obtain symmetrically shaped veneers for both central incisors (Fig 15). In addition, a full-coverage coping was designed for the crown preparation (Figs 16a and 16b) in a shape that imitated a veneer preparation symmetrically to the prepared maxillary right central incisor.[9] The two veneers were milled from polychromatic feldspathic ceramic blocks (Vita TriLuxe forte, VITA Zahnfabrik), shade A2, while the zirconia coping was milled from a multilayer preshaded zirconia block (Katana ML, Kuraray Noritake; Figs 17a to 17c).[10] The block was selected to mimic the shade of the contralateral prepared central incisor with the intent to achieve the best possible color match between the two most visible teeth.


18a


18b


18c


19a


19b


20a


20b

Figs 18a to 18c Intraoral views during try-in of the restorations.

Figs 19a and 19b A ceramic primer that contains both a silane and the zirconia-binding MDP monomer was applied to the bonding surfaces of the veneers and the zirconia coping after air-particle abrasion and to the feldspathic ceramic after hydrofluoric acid etching.

Figs 20a and 20b Extraoral cementation of the veneer to the coping ensures a simplified bonding procedure, excess cement removal, and polishing process. The same clear composite resin cement was used for the veneer.

After try-in and esthetic evaluation (Figs 18a to 18c), the feldspathic ceramic veneers were etched with 5% hydrofluoric acid for 60 seconds, followed by ultrasonic cleaning. Following the APC technique,[11–13] the zirconia coping was air-particle abraded with 50-micron aluminum oxide particles for 10 seconds. A ceramic primer that contains both a silane and the zirconia-binding MDP monomer (Clearfil Ceramic Primer Plus, Kuraray Noritake) was applied to the bonding surfaces of the veneers and the zirconia coping (Figs 19a and 19b).[11] The zirconia coping and ceramic veneer were cemented extraorally with an adhesive resin system (Panavia V5 Clear, Kuraray Noritake; Figs 20a and 20b). Extraoral cementation of the veneer to the coping ensures a simplified bonding procedure, easy excess cement removal, and ideal polishing process.[12] The ceramic laminate veneer for the maxillary right central incisor and the bilayered crown on the maxillary left central incisor were inserted with the same resin cement (Figs 21 and 22) after proper pretreatment of the restoration and tooth bonding surfaces.[13]

CONCLUSION

Matching a veneer and a crown in the esthetic zone is one of the great clinical challenges, especially when the abutment teeth present variations in stump shades. The reported approach was applied in an attempt to match the restorations of the two central incisor teeth in a most ideal manner despite the variations. Matching the crown coping to the tooth prepared for a veneer in terms of both shade and 3D design allows for the fabrication of two symmetrically designed ceramic laminate veneers that offer the exact same material, shade, shape, thickness, and translucency.

A fully digital approach that includes all treatment steps from design to completion and even allows for chairside restoration fabrication is highly supportive of achieving the esthetic and functional goals in a variety of challenging clinical situations. Novel tools such as mobile smile design applications further simplify these processes and improve communication with the patient and between clinical and laboratory teams.

21

22

Fig 21 Postoperative intraoral situation 4 weeks after insertion.

Fig 22 Postoperative extraoral view.

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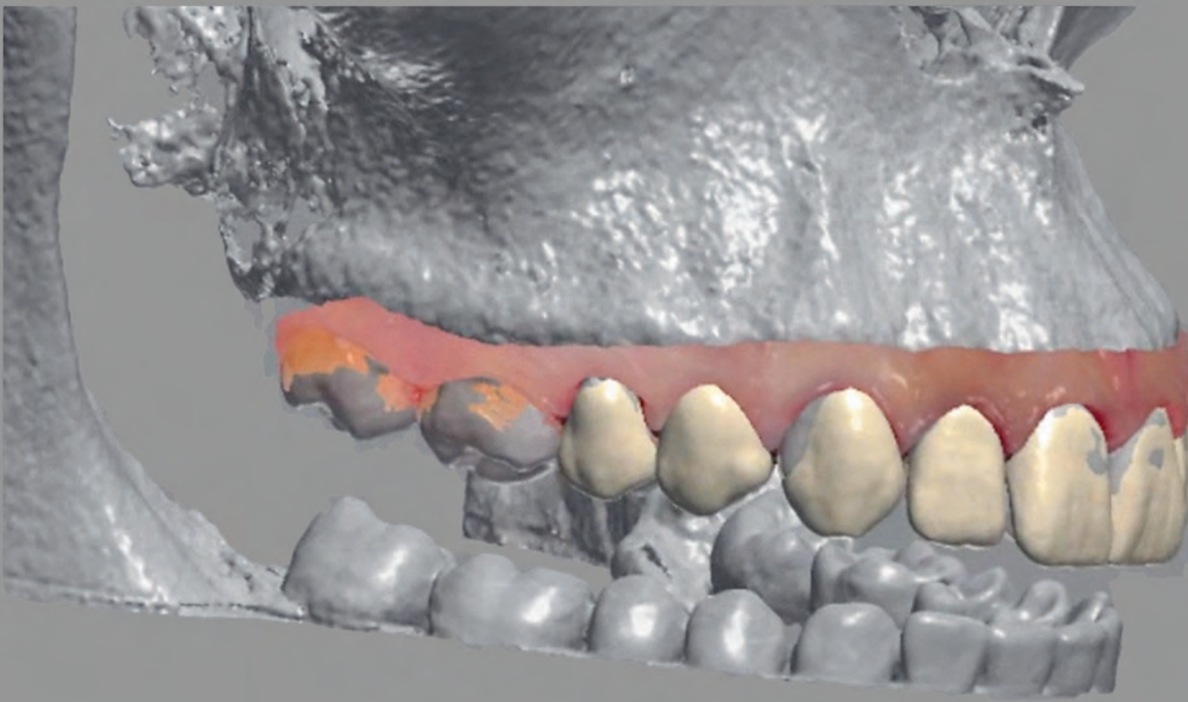

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In 1953, Chernyshevsky stated that "the first purpose of art is to reproduce nature and life, and this applies to all works of art without exception."[1] Reproducing nature is a daunting task that can be deceptive and requires years of training, hard work, study, and dedication. The same author also noted that it is impossible to achieve complete success when imitating nature due to its intricacies, complexity, and, of course, one's own bias. The interpretation of reality can lead to intentional or unintentional flaws in design and execution—just compare the differences in the interpretations of nature by famous artists such as Pablo Picasso, Salvador Dali, Leonardo da Vinci, and Michelangelo.

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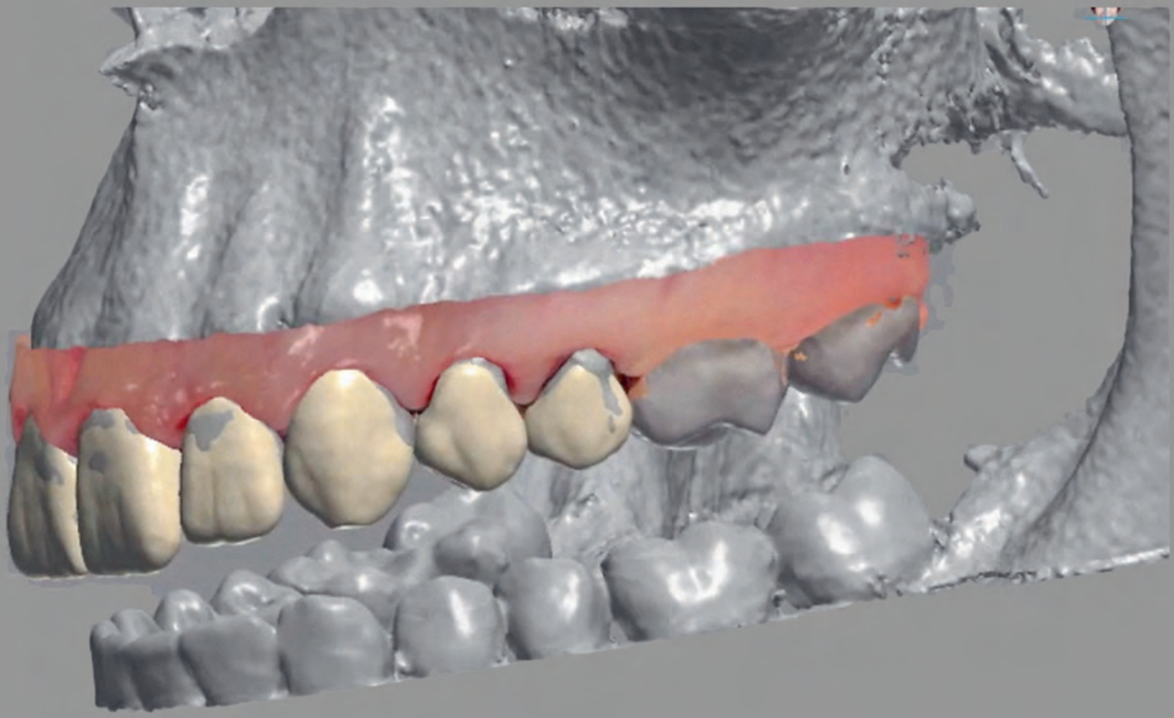
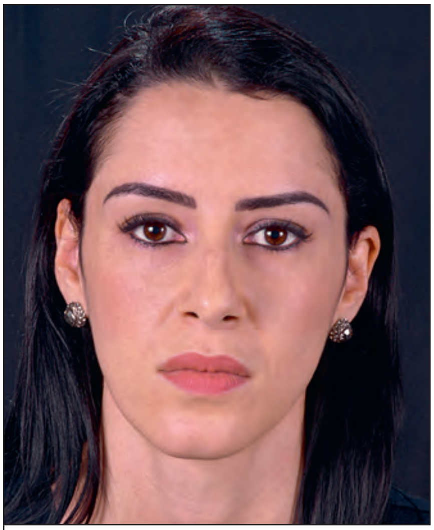


The Cllones Library: Three-Dimensional Replication of Natural Dentition with CAD/CAM Restorations

In dentistry, the reproduction of dental morphology down to its fine details is essential for producing appropriate form, function, and esthetics. However, reproduction of dental morphology is always subject to practitioners' and dental technicians' own interpretations and understandings of reality. Fortunately, dental morphology can be artistically reproduced to create pleasant oral reconstructions; however, its precise reproduction is limited to highly skilled individuals who have devoted their lives to achieving excellence in dental restoration.

Several techniques that use computer-aided design/computer-assisted manufacturing (CAD/CAM) technologies have been introduced with the aim of replicating the details observed in existing dental structures.[2–5] These techniques were developed to overcome the deficiencies in tooth anatomy experienced with CAD/CAM.[2,3] However, at least one analog step was still required that was subject to one's skill or traditional dental models.

Luckily, biotechnology has advanced so much in the last few years that it now allows us to produce digital mimicry of dental morphology through a cloning process using CAD/CAM technologies. The term "clone" is derived from ancient Greek, referring to the process whereby a new plant can be created from a twig. The production of multiple copies using digital technology can be referred to as digital cloning. Digital cloning is an emerging technology that uses deep-learning algorithms to allow the creation of hyper-realistic objects that are challenging for the human eye to distinguish from the real thing.



1a

1b

1c

Figs 1a to 1c Initial extraoral photographs of the patient *(a)* at rest, *(b)* during smiling, and *(c)* during exaggerated smiling.

2

Fig 2 Preoperative intraoral photograph.

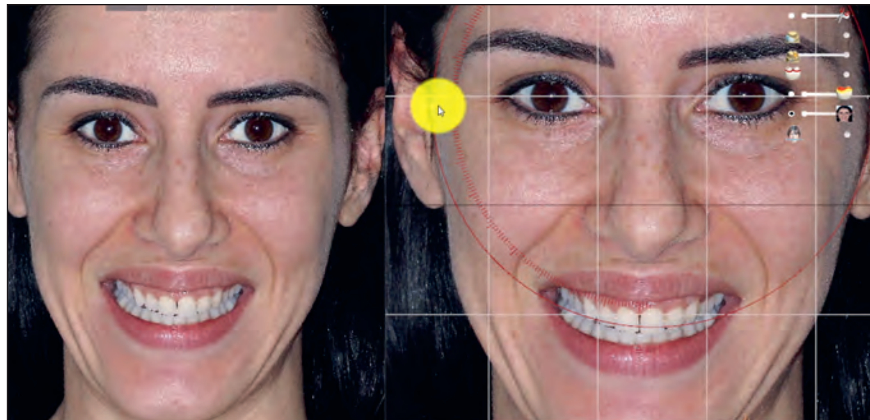
DIGITAL CLONING

The first step to creating digital clones of natural dentition was the acquisition of a highly accurate three-dimensional (3D) scan of natural dentitions. A 3D mesh of every tooth was carefully evaluated under high magnification to ensure that all dental micromorphology was precisely attained. To accurately render a tooth, it was necessary to take into account the two key elements of light interaction with dental enamel: subsurface scattering and light reflection at the surface of the tooth. Thus, light interaction with the dental surface under different light conditions was also studied by the authors. Numerous tests were performed to ensure that not only were the morphology and light scattering correct, but also that the surface texture resembled that of the natural dentition. Next, special algorithms were developed to allow re-dimensioning of the digital dental clone during the design phase. These newly developed algorithms prevent morphologic distortions during design that would otherwise preclude the rendering of an accurate dental morphology; thus, after the digital design was deemed completed, the restorations could be fabricated with minimal to no additional adjustments necessary. For example, polishing could be achieved using only diamond pastes to preserve the original micromorphology as observed in a real tooth, simultaneously saving time and effort for the restorative team. The authors named this digital library "Cllones."

The following case describes the sequence of patient treatment using digital technology as a guide to obtain reliable and predictable outcomes through the use of the Cllones library.

Digital Treatment Planning with Layers

To prepare for a digital treatment plan, initial extraoral photographs of the patient were taken at rest, during smiling,



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4

Fig 3 Alignment of intraoral photograph (exaggerated smile) uploaded into the design software.

Fig 4 The outline of the lips was carefully selected to isolate the teeth displayed in the patient's smile.

and during exaggerated smiling (Figs 1a to 1c). Intraoral photographs were also taken (Fig 2). Intraoral scanning (Trios, 3Shape) was performed for the maxillary and mandibular arches and with the patient in maximum intercuspation. The patient was then subjected to facial scanning and cone beam computed tomography (CBCT).

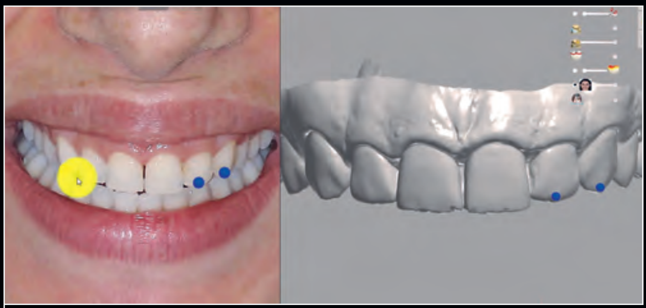
The following digital files were then generated: JPEG (photography), STL (intraoral scan), and DICOM (tomography). All files were then imported into the dental design software (Dental System, 3Shape) to produce different layers of information.

Alignment of Facial Photography and Intraoral Scan

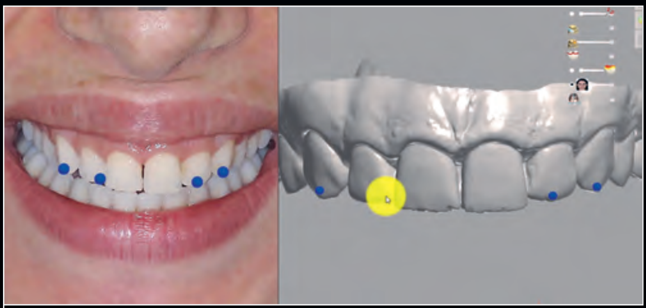
At first, the two-dimensional (2D) file of the patient image during exaggerated smiling (JPEG) and the 3D maxillary intraoral scan (STL file) were imported into the design software (Dental System, 3Shape).

The JPEG file was duplicated. This duplicated image was rotated and aligned so that the midline coincided with the sagittal plane and the occlusal plane with the transversal plane (Fig 3). For correct alignment of the extraoral image, one must take into consideration known landmarks such as the midline, bipupillary line, and incisal edge curvature of the anterior teeth. The outline of the lips was carefully selected to isolate the teeth displayed in the patient's smile (Fig 4).

Next, to integrate the 2D and 3D images, four reference points were created in both the JPEG and STL files using the incisal edges of the maxillary canines and lateral incisors as reference (Figs 5a to 5c). The opacity of the patient's extraoral photograph was decreased to assist in the visualization. The intraoral scan was then overlayed onto the patient's smile (Fig 6). New reference points were added at the cervical aspects of the maxillary central incisors, the first premolars, and the first molar, as distal as shown in the patient's smile (Figs 7a and 7b). The intraoral scan and the patient's smile image were then digitally aligned (Figs 8a and 8b).

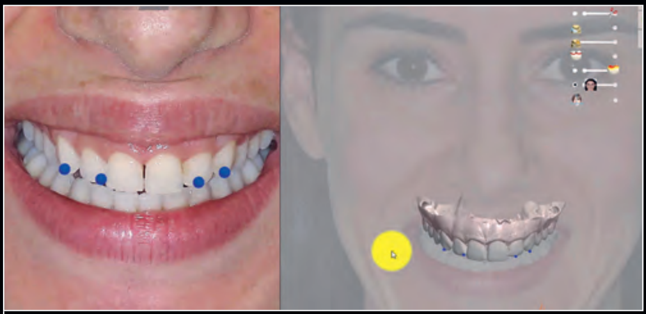


5a



5b

5c



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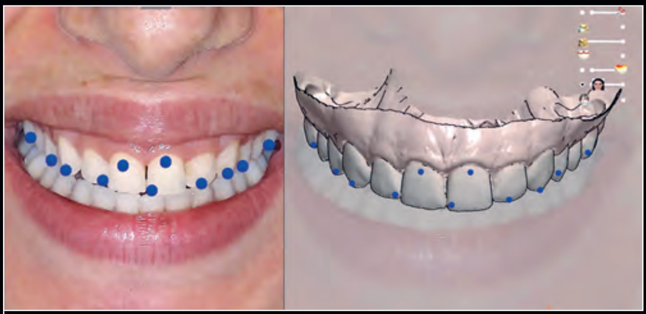
7a



7b

8a

8b

Figs 5a to 5c Integration of two- and three-dimensional images. Four reference points were created in both the patient's smile photograph (JPEG) and the intraoral maxillary teeth scan (STL) using the incisal edges of the maxillary canines and lateral incisors as reference. *(a)* Reference points being added to the maxillary left lateral incisor and canine in the 2D and 3D images. *(b and c)* Reference points added to the incisal edges of both maxillary canines and lateral incisors.

Fig 6 Intraoral scan superimposed onto the patient's smile image, achieved thanks to the reference points.

Figs 7a and 7b New reference points being added at the cervical aspects of the maxillary central incisors, first premolars, and first molar, as distal as shown in the patient's smile.

Figs 8a and 8b Digital alignment of intraoral scan and patient's smile image. *(a)* Superimposed 3D image with reduced opacity for verification. *(b)* Superimposed files.

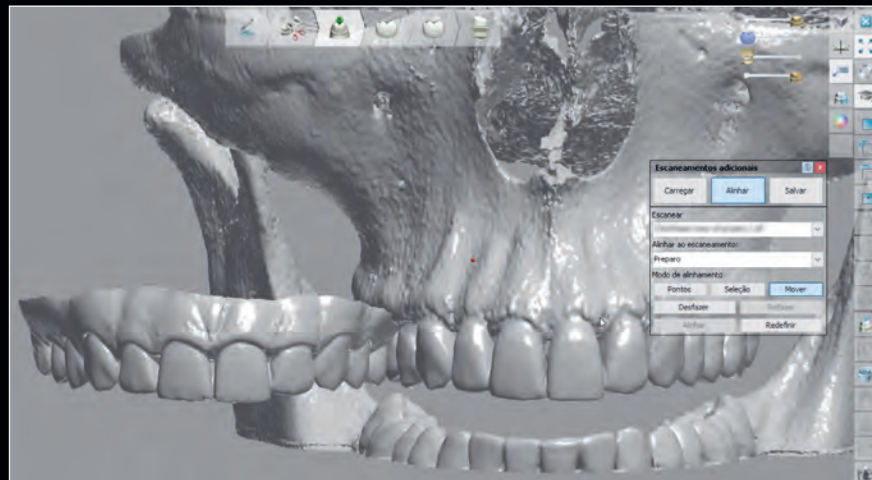


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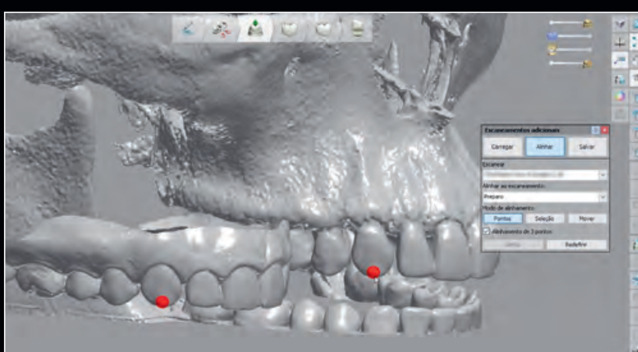
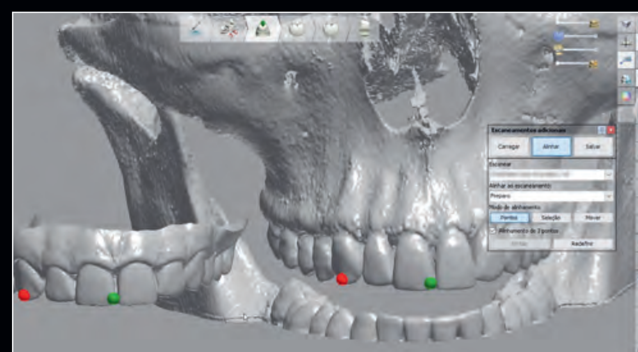
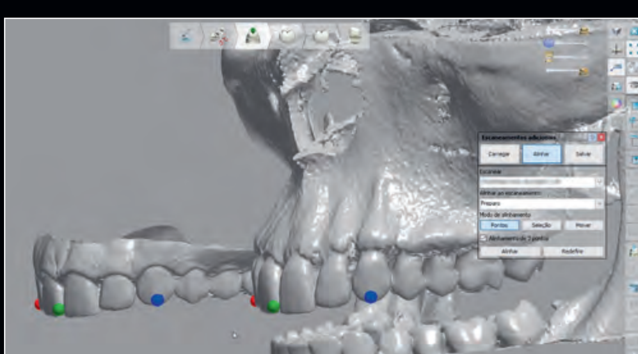
Fig 9 The tomography file was imported into the design software to start the process of integration of the DICOM and STL files.



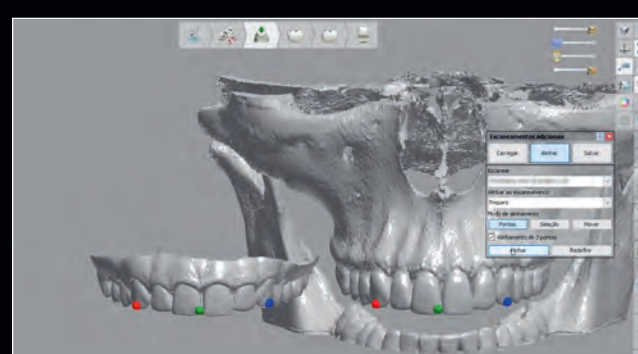
10a



10b



10c



10d

Figs 10a to 10d To ensure adequate alignment, reference points were precisely added in both files to *(a)* the incisal edge of the maxillary right canine, *(b)* the mesial incisal point angle of the maxillary right central incisor, and *(c)* the incisal edge of the maxillary left canine. *(d)* Alignment according to reference points.

Alignment of DICOM and STL Files

The DICOM file (tomography) was converted to STL using a conversion software (InVesalius). Then, the STL files of the maxillary intraoral scan and the converted tomography were imported into the design software (Dental System, 3Shape) (Fig 9).

Reference points were precisely added to both files to ensure adequate alignment of the files. For this particular case, reference points were added to the incisal edges of the maxillary right canine (Fig 10a), the mesial incisal point angle of the maxillary right central incisor (Fig 10b), and the incisal edge of the maxillary left canine in both files (Fig 10c). The points must be positioned as precisely as possible to ensure appropriate alignment of the files (Fig 10d). With the reference points added to both files, the software was able to align the CBCT and intraoral scan into a single overlaid image (Fig 11). This image showed the patient's osseous structure with the gingival tissues presented. The authors suggest always adjusting the translucency of the tomography to ensure proper alignment of the files (Figs 12a to 12c).

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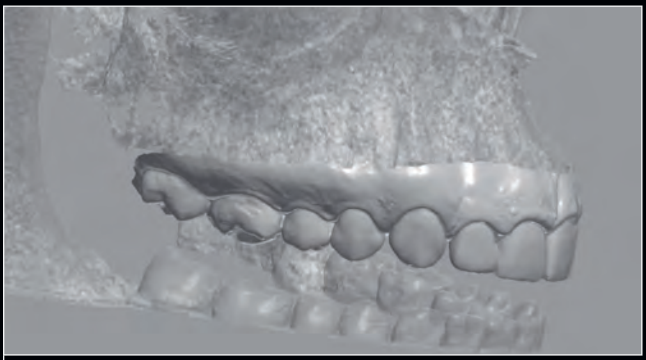
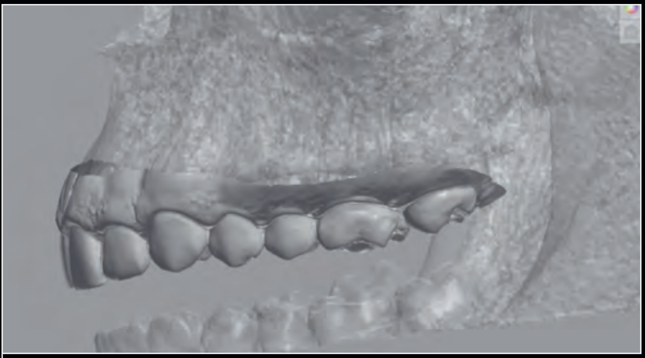


12a

12b



12c

Fig 11 Final integration of the tomography and intraoral scan files for digital esthetic planning.

Figs 12a to 12c Different aspects of integration of tomography and intraoral scan files, with reduced opacity of the tomography file.

Integration of Natural Morphology: The Cllones Library

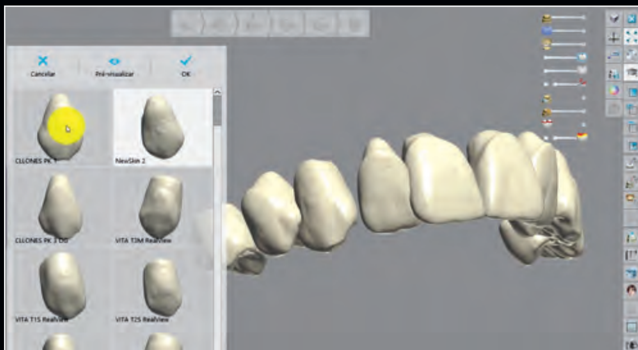
The Cllones tooth library was then selected and the virtual library applied over the overlaid image. The Cllones library is composed of 10 specially designed natural tooth models with ideal morphology (including tooth width/length ratio and surface texture) and occlusion to fit the needs of digital planning of the smile. The algorithms were developed to allow tooth re-dimensioning or alignment without incurring distortion; thus, the need for digital sculpting was eliminated through digital cloning, allowing the restorative team to realign or replicate features of natural dentition for ultimate esthetic outcomes. This feature represents a paradigm change in the field of digital rehabilitation.

The appropriate tooth morphology was selected (Fig 13a), placed over each single tooth on one side of the patient's arch, and carefully positioned. Mesial-distal width and gingival-incisal length, rotation, and facial-lingual inclination were adjusted for the maxillary right segment (central incisor to second premolar). Once the tooth shape, morphology, and arrangement were deemed acceptable, the design was mirrored and replicated to the other arch (Fig 13b). Mirroring is one of the most important tools for digital design, since the restoration design can be copied and reproduced on both sides of the patient's arch. Then, occlusion was digitally verified.

The patient's facial photography was retrieved, and the design of the restoration morphology was minorly adjusted to fit the patient's smile and face (Figs 14a and 14b). The patient's midline was then reevaluated (Fig 14c), and a golden proportion grid was added to the design.

The digital design of the restorations was then observed over the tomography, which were all layered onto the patient's smile photograph. Adding the tomography allows the visualization of the relationship between the digital design and the osseous structure (Figs 15a and 15b), thus allowing the clinician to verify the possible limitations of periodontal surgery, including osteotomy and gingivectomy, in case surgery must be performed.

The final arrangement and design were revisited one last time to ensure an appropriate esthetic outcome of the final restorations (Fig 15c).


13a


13b


14a

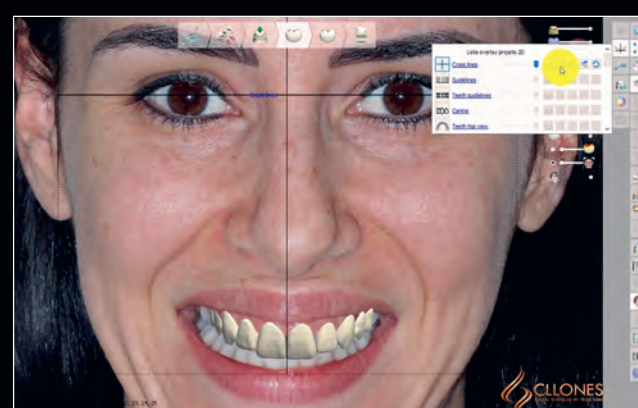

14b

Figs 13a and 13b Selection of appropriate tooth morphology from Cllones library and digital design and mirroring of the digital dental clones.

Figs 14a to 14c Design of restoration morphology, adjusted to fit the patient's smile and face, and evaluation of patient's midline with golden proportion grid.

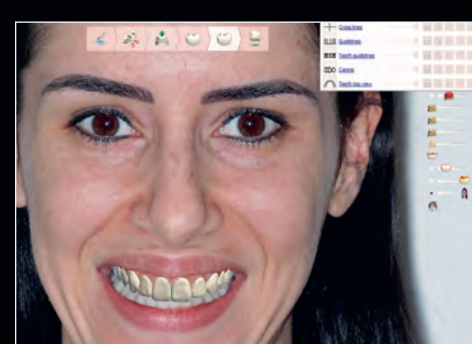
Figs 15a and 15b Integrated intraoral scan and tomography files, displaying the digital esthetic design of the restorations.

Fig 15c Final arrangement and design revisited one last time to ensure an appropriate esthetic outcome of the final restorations.


14c


15a


15b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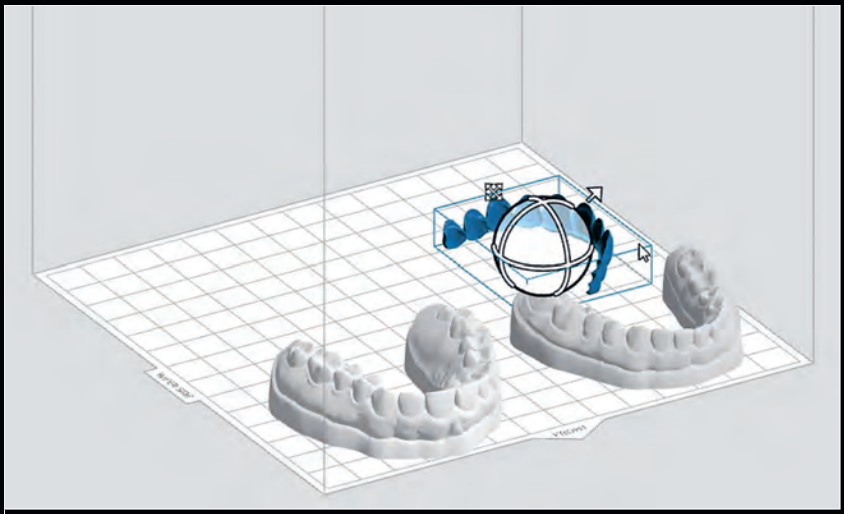

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Fig 16 Files transferred to the model builder for prototype printing.

Fig 17 3D-printed prototypes.

Fig 18 Patient's smile with 3D-printed prototypes in place.

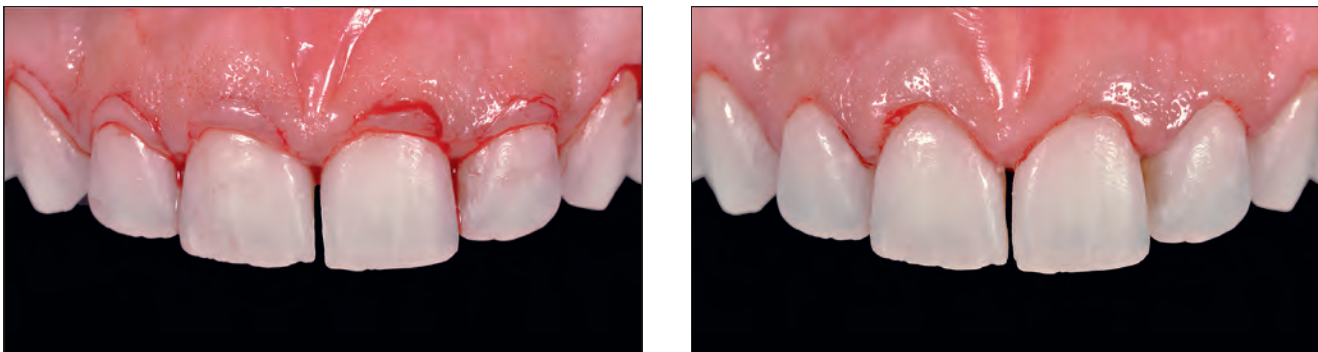
17

18

3D Prototype and Esthetic Analysis

After digital planning of the smile was concluded, the final design was transferred to the model builder (Fig 16) to create 3D-printed casts of the maxillary and mandibular arches (Formlabs 2). In addition, a 3D prototype shell was created to be tested on the patient's own teeth for esthetic evaluation and also as a surgical guide for the periodontal surgery (Fig 17). The 3D prototype was placed in the patient's mouth over the existing teeth, revealing the need for gingival modifications. The patient was able to visualize the intended final outcome (Fig 18), and, upon her approval, esthetic crown lengthening was immediately performed.

19a 19b 19c



20a 20b

Figs 19a to 19c Sequence showing gingivectomy performed at the facial aspect of the involved teeth, following the contour of the 3D prototype to determine the new gingival zenith and gingival outline.

Figs 20a and 20b Intraoral views of the incisions and completed gingivectomy.

Flapless Esthetic Crown Lengthening Using Piezoelectric Surgery

Digitally designed 3D surgical guides were essential to define the desired and planned final gingival contour for this case. The patient received local anesthesia with an electronic device (The Wand, Milestone Scientific). The gingival sulcus depth and depth to bone, as well as the cementoenamel junction (CEJ), were evaluated.

The 3D surgical guide was then internally relined with a thin layer of flowable composite resin and photopolymerized. This step is important to ensure that the surgical guide is stable during the initial incision of the surgery.

A gingivectomy was accomplished with an internal beveled incision (no. 12D scalpel) performed at the facial aspect of the involved teeth and following the outlined contour of the 3D prototype to determine the new gingival zenith and gingival outline (Figs 19a to 19c). The 3D-printed prototype was then removed, and a sulcular incision was completed to allow removal of gingival tissue and creation of a new gingival margin (Figs 20a and 20b). The sulcus depth, sounding depth, and CEJ were reevaluated.

No gingival flap was performed for the crown-lengthening procedure. Osteotomy and osteoplasty were then performed to create the new biologic width. Osteotomy was performed with a piezoelectric device (CVDentus, CVD Vale) using specially designed ultrasonic piezo inserts (TR1-PK, VR1-LPK, and VR1-RPK, CVD Vale) (Figs 21a to 21c). The special piezo inserts were made of ultra-fine, rounded diamond-like carbon created through chemical vapor deposition, resulting in a homogenous surface and distribution and producing a smoother bone surface. The piezoelectric tips were carefully used under continuous mesiodistal movement following the new gingival contour to remove and recontour the alveolar bone through incisions, without flap elevation and without touching the CEJ, all under copious saline solution irrigation.

The distance of 3.0 mm between the bone crest and the CEJ was obtained and verified by inserting a periodontal probe into the incision, and sutures were not performed. The root surfaces were carefully planned via incisions. The outline of the new gingival design was carefully refined using a diode high-power infrared laser (Thera Lase Surgery, DMC). It is the authors' experience that flapless crown

21a

21b

21c

Figs 21a to 21c Osteotomy performed with piezoelectric device using specially designed ultrasonic piezo inserts.

lengthening produces very favorable postoperative conditions with faster healing time and virtually no pain. The literature has also found flapless crown lengthening to be an appropriate option over traditional open-flap surgical procedures.[6–8]

Immediately after esthetic flapless crown lengthening, intraoral scanning procedures were performed in order to design and print the enamel reduction preparation guide for the veneers.

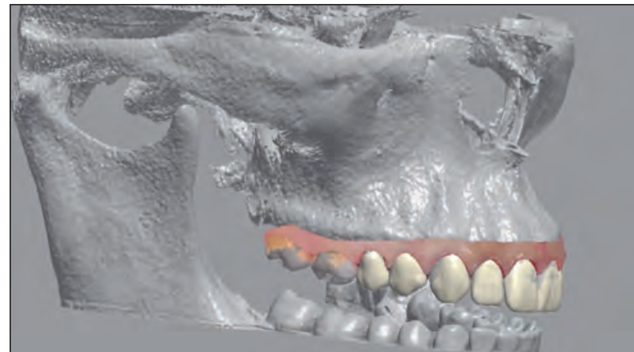
Chlorhexidine gluconate mouthwash (0.12%) was prescribed for 2 weeks, and oral hygiene at the area of the surgery was accomplished with cotton swabs dampened with 0.12% chlorhexidine gluconate.

FINAL PREPARATIONS

One day after esthetic flapless crown lengthening was done, minimally invasive ceramic veneer preparations were performed from the maxillary right second premolar to the maxillary left second premolar. An intraoral scanner was used to capture the preparations digitally and to produce an STL file (Fig 22).

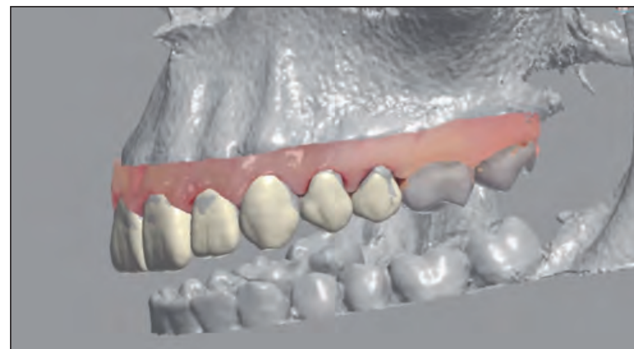
The STL file was imported into the design software (Dental Systems, 3Shape) and aligned with the existing files. The digital planning of the restorations using the Cllones library was transferred to the new STL of the prepared teeth (Figs 23a to 23c) and realigned. The final restorations were once again carefully evaluated (Figs 24 and 25) and sent to the milling unit.

22



23a

23b



23c

24

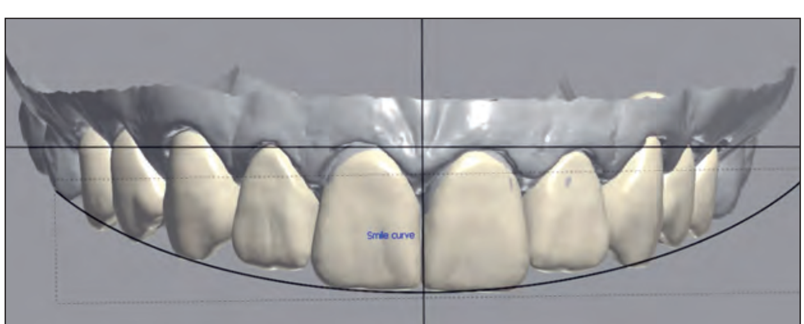


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Fig 22 Intraoral scan of minimally invasive ceramic veneer preparations performed 1 day after the flapless crown-lengthening procedure.

Figs 23a to 23c Digital esthetic design of the restorations using the Cllones library and transferred to the new STL file of the prepared teeth.

Fig 24 Digital design of the final restorations.

Fig 25 Evaluation of the final restorations before milling.

26a

26b

Figs 26a and 26b Printed cast showing lithium disilicate restorations milled, stained, glazed, and polished, and the final restorations designed with the Cllones library.

Highly translucent monolithic lithium disilicate glass-ceramic restorations (CAD HT, IPS e.max, Ivoclar Vivadent), shade A1, were milled. The sprue was carefully removed, and the restorations were polished with rubber wheels in the blue stage. Three distinct firing cycles were used to stain the restorations: *(1)* incisal translucency using basic blue at the incisal third; *(2)* basic red applied to the gingival third, while mamelons and incisal halo were created at the incisal third; and *(3)* a final diluted white stain applied to the entire facial surface of the veneers. All firing was produced at 800°C. After the third firing cycle, all restorations were carefully polished using a goat hair brush and diamond pastes (Figs 26a and 26b).

Bonding

Three days after the surgery, the monolithic lithium disilicate glass-ceramic restorations were tried in the patient's mouth, and the patient had the opportunity to review the restorations before bonding. The patient accepted the final restorations, and the adhesive procedures were initiated.

The intaglio surfaces of the restorations were acid etched with 5.5% hydrofluoric acid for 20 seconds and rinsed with water. This was followed by the use of 35% phosphoric acid to remove any debris and then silanization (Monobond Plus, Ivoclar Vivadent).[9] The teeth were acid etched with 35% phosphoric acid for 30 seconds, followed by the application of a universal adhesive system (Adhese Universal, Ivoclar Vivadent) and bonding with a light-cured resin cement (Variolink Esthetic LC, Ivoclar Vivadent).

Occlusion was checked, and the patient was satisfied with the final outcome (Figs 27 and 28) and with the experience of treatment with digital technologies.

27a

27b

Fig 27a Final outcome, intraoral view.

Fig 27b Final patient smile.

CONCLUSIONS

The dental professional's interpretation of dental morphology can lead to esthetic mismatches that negatively affect an esthetic rehabilitation. Thus, elimination of interpretation of dental morphology by the restorative team is essential to produce reliable clinical outcomes. This can only be achievable through digital cloning of teeth using CAD/CAM technologies. The opportunity to use different digital files applied in layers within the design software allows an improved understanding of the clinical case through a tridimensional study. This tridimensional study represents a new benchmark of treatment planning and treatment execution aiming to produce esthetic rehabilitations that are more predictable, precise, and reliable for clinicians, dental technicians, and patients.

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Fig 28 Final outcome of minimally invasive CAD/CAM restorations using integration of different digital files and digital design.

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Shogo Yamamoto, RDT[3]

Digital Minimally Invasive Esthetic Treatment

Modern prosthetic treatment, along with the continuous development of digital technology and maturation of adhesive dentistry, is focused on four main themes:

1. Minimally invasive (MI) esthetics (bioesthetics)
2. Digital dentistry
3. Microscope use
4. Facially generated treatment planning (smile design)

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Adhesive restorative treatment with a minimum amount of tooth reduction has become popular in bioesthetics, a concept proposed by Dr Didier Dietschi,[1–3] which promotes restorative treatment with better biocompatibility and minimal invasion. "Bio-Emulation," which is the name of the study group led by Mr Sascha Hein, a dental technician in Freiburg, Germany, is becoming recognized worldwide and is considered a similar concept.

Digital dentistry and facially generated treatment planning (smile design) are closely related. Natural reconstructions with application of digital facial scanning and analysis as well as other digital technologies vital to all phases of clinical dentistry are required in current esthetic restorative treatment. Dr Christian Coachman, developer of Digital Smile Design (DSD),[4,5] has become a favorite of the times with his concept. The facially generated treatment planning concept,[6] which was developed by Dr Frank Spear, is considered the basis for DSD. And finally, precise and minimally invasive tooth preparation under microscopic view is necessary to establish supragingival margins, preserving a maximum amount of enamel.

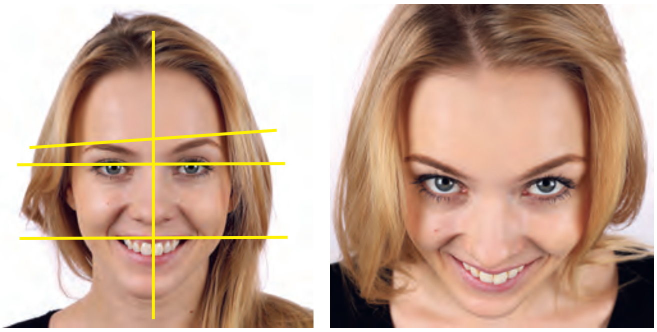
The most current esthetic restorative treatments including these four elements are described in the following case, which was treated utilizing a semi-digital approach. A discussion on adhesion, which directly impacts the long-term prognosis, is also presented.

1a

1b

2a

2b



3a

3b

3c

3d

3e

Figs 1a and 1b Intraoral photographs at patient's first visit. *(a)* Maximum intercuspation. *(b)* Edge-to-edge position.

Figs 2a and 2b Relationship between maxillary anterior teeth and lips. *(a)* At rest. *(b)* In smile.

Figs 3a to 3e Relationship between the face and the dentition at the first visit.

Fig 4 Preliminary smile design at the first visit.

4

DESCRIPTION OF THE CASE

The patient is a 26-year-old woman who works as a model and wished to have general esthetic treatment. She first presented with several problems in terms of esthetics, including maxillary midline deviation to the right, crowding of the mandibular anterior teeth with deviation to the left, labial displacement and rotation of the maxillary left central incisor, and predominance of the central incisors with excessive width and uneven gingival line despite prior orthodontic treatment in her home country (Figs 1 to 3). The preliminary smile design by the designated software (3Shape Smile Design, 3Shape) is shown in Fig 4.

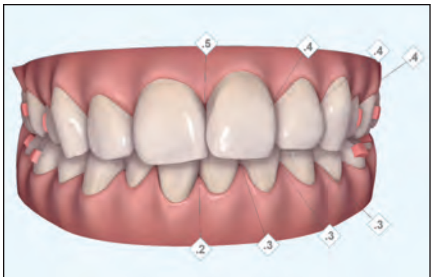
DIAGNOSIS AND TREATMENT PLAN

Initially the patient did not agree to preprosthetic orthodontic treatment but later accepted the option of Invisalign treatment (Invisalign, Align Technology). The orthodontic treatment with Invisalign is shown in Figs 5 to 8. The seven-step method, which offers the shortest treatment time of Invisalign protocols, was selected, with the plan that restorative treatment would compensate for any spaces that remained.

In succession, the incisal plane, which is parallel to the interpupillary line of the patient, facial midline, and Camper's plane were recorded on the model using the Ditramax system[7] (Ditramax) (Figs 9 and 10). Ditramax is designed to transfer the facial information of the patient from chairside to the laboratory, which is different from a simple facebow. The basic technique is to mark the obtained facial information on the model using the attached pencil lead (Fig 10) and the technician then uses these lines as reference for fabrication of the prosthesis. However, in this case, the lines were engraved on the model so that the information could be scanned as digital information (Figs 11a to 11c). Ditramax can be utilized not only in analog but also in a digital environment with this process. Mistakes that still can occur in a digital environment, such as deviated midline, can thus be prevented.

The definitive smile design for the restorative treatment was then planned (Figs 12 to 15). There are two ways to design the crown shape to match the patient esthetically and functionally using digital technology: *(1)* design all digitally or *(2)* design by combining wax-up on the stone model with the digital data (W scanning method). The W scanning method was employed for this case. The reason for this will be explained later.

Combining analog and digital methods is an important step. A diagnostic wax-up was performed after simulation using smile design software once the preprosthetic orthodontic treatment was completed. The wax-up was scanned and then esthetic harmony with the face was confirmed and reevaluated using the smile design function of CAD software (CEREC Software, Dentsply Sirona). Figure 15 shows the scanned data of the diagnostic wax-up superimposed on the photograph of the patient's face. Laminate veneers of the four maxillary anterior teeth and veneer overlays of the maxillary right and left second premolars were planned using these data.



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8a

8b

8c

8d

9a

9b

9c

10

Fig 5 Orthodontic simulation using ClinCheck Software (Align Technology).

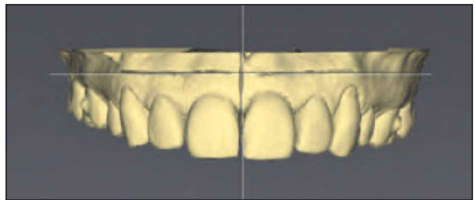
Fig 6 Interproximal reduction with dental abrasive strips (0.12 mm, ContacEZ) according to the Invisalign protocol.

Fig 7 Inserted aligners (Invisalign).

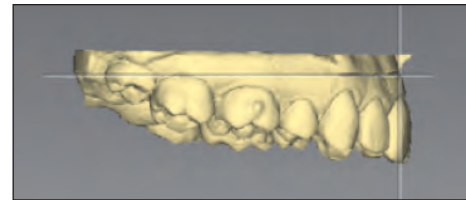
Figs 8a to 8d Completion of orthodontic treatment with Invisalign.

Figs 9a to 9c Recording incisal plane parallel to *(a)* interpupillary line, *(b)* facial midline, and *(c)* Camper's plane using Ditramax.

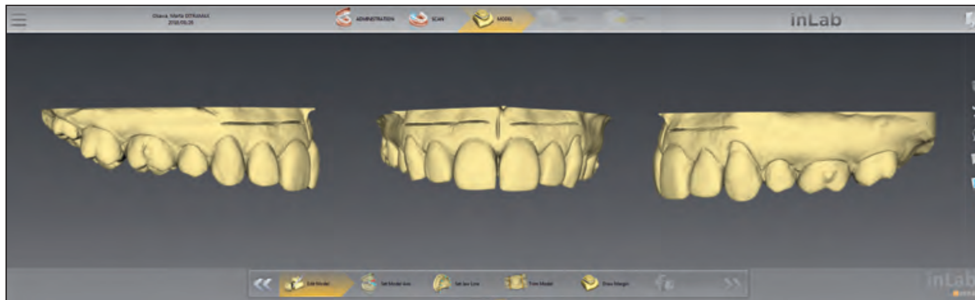
Fig 10 Imprinting standard lines on the model using Ditramax.



11a



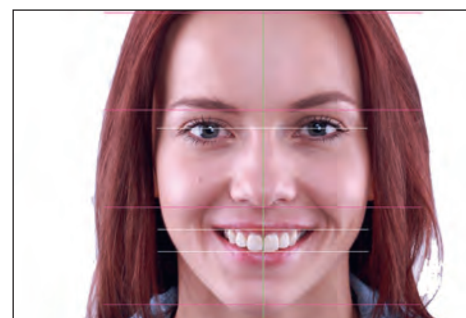
11b



11c

Figs 11a to 11c Depression was left on the model by imprinting strongly using Ditramax. Ditramax can be used on digital data by doing so.

12a



12b

Figs 12a and 12b Smile design for the restorative treatment after orthodontic treatment.

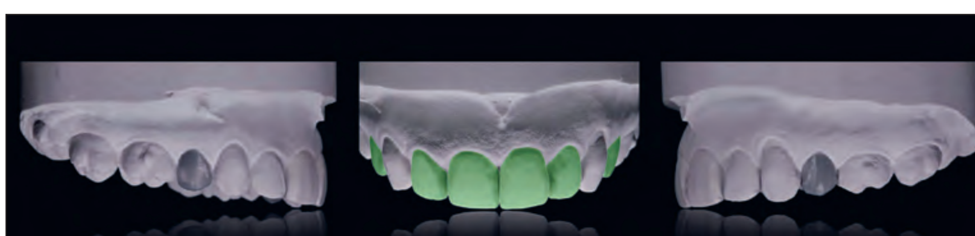


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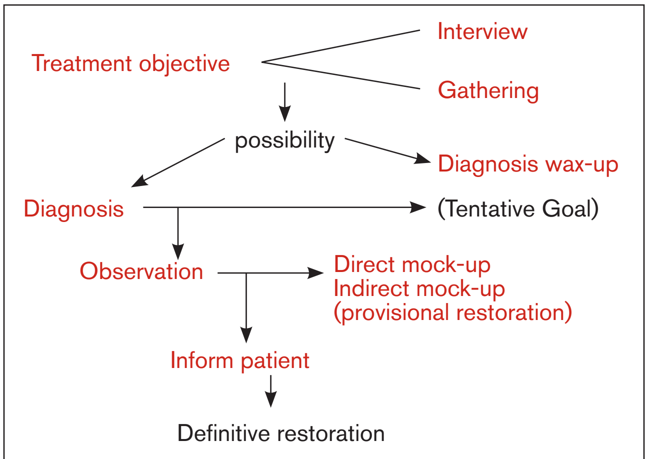
Fig 13 Diagnostic wax-up on the stone model.

Fig 14 Digital data was obtained by scanning the diagnostic wax-up.

Fig 15 Scanned data of the diagnostic wax-up superimposed on the patient's facial photograph to confirm the harmony.



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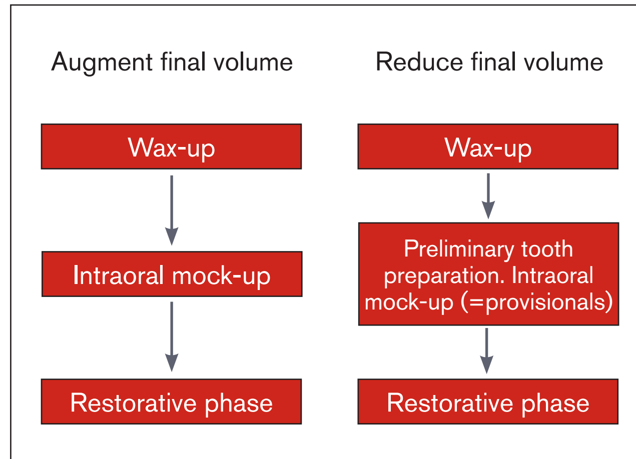

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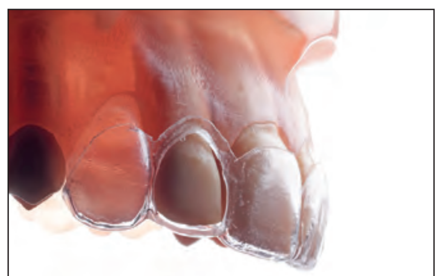
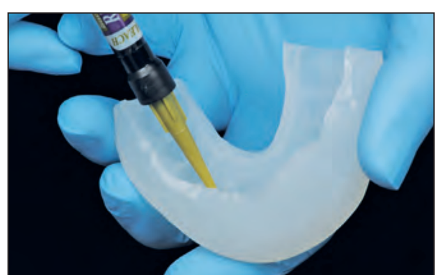
18a



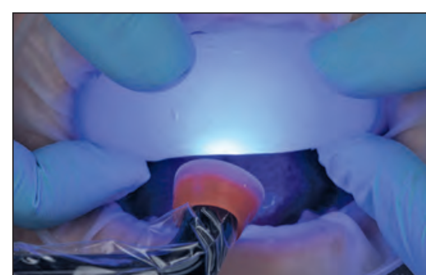
18b

18c

19a



19b



19c

Fig 16 Treatment planning process for laminate veneer restorations.

Fig 17 Treatment sequences with mock-up of two clinical conditions.

Figs 18a to 18c Reduction index for preliminary tooth reduction of *(a)* central incisor and *(b)* lateral incisor. *(c)* Preliminary reduction was performed.

Figs 19a to 19c Impression of the wax-up was taken to fabricate the clear matrix (Reveal Clear Matrix. BISCO). *(a)* Teeth were conditioned with spot etching and bonding agent. *(b and c)* Direct mock-up was fabricated by pressing the clear matrix, which was filled with temporary light-cure flowable composite resin (Reveal, BISCO).

TREATMENT PROCESS

Mock-up Prototype

The treatment planning process of laminate veneer restorations and mock-up of two different clinical conditions (*augment final volume*, where only augmentation of volume is needed, and *reduce final volume*, where preliminary reduction of volume is required) are shown in Figs 16 and 17.[8] Preliminary tooth reduction was performed with the guidance of a tooth-reduction index in this case according to the planned crown design (diagnostic wax-up) (Figs 18a to 18c). Direct mock-up was performed by injection and pressing of esthetic interim light-cure flowable composite resin (Reveal, BISCO) using a clear matrix, which was fabricated from the impression (polyvinyl siloxane duplicate impression material from Reveal Clear Matrix, BISCO) of the wax-up, after spot etching and bonding application (Figs 19a to 19c). This technique is a modification of the Bonded Functional Esthetic Prototype[9] (BEEP) proposed


20a


20b


20c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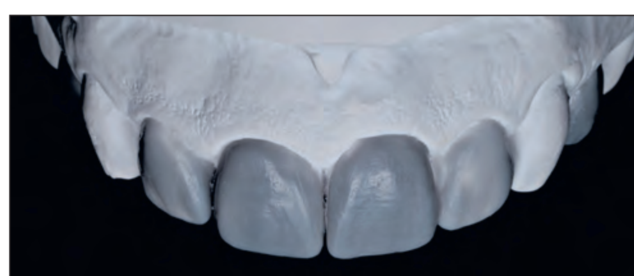
Figs 20a to 20c Intraoral photographs with mock-up.

Fig 21 Facial photographs with mock-up.

Fig 22 Intraoral scanning of mock-up.

Fig 23 Wax-up was modified according to the scanned data and was used as a guide for the laminate veneers.

Fig 24 Scanned images of modified wax-up.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by Dr Edward McLaren. Intraoral and facial photographs after the direct mock-up are shown in Figs 20 and 21.

An intraoral scanner (CEREC AC Omnicam, Dentsply Sirona) was used to scan the dentition once the patient agreed to the shape of the direct mock-up and minor esthetic-functional adjustments (Fig 22). The scanned data was compared to the smile design at the wax-up stage. The original wax-up was readjusted and finalized for fabrication of the laminate veneers (Fig 23). The final wax-up was scanned (Fig 24), and the model was fabricated by the 3D printer to produce the index for tooth preparation.

Fig 25 Before adjustment of tooth reduction.

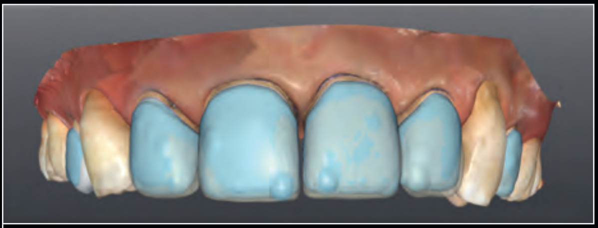
Tooth Preparation

At the tooth preparation stage, the distance between adjacent teeth becomes problematic when an intraoral scanner is used for the final impression. The first author usually designs the finish line of the interproximal contact areas of veneer cases rather labially, even when using the traditional approach, depending on the case. It is difficult to scan unprepared tight interproximal contact areas accurately using an intraoral scanner. It is also not clear how much reduction is required for an accurate digital impression. The first author has proposed the following guidelines for tooth preparation design of interproximal areas adapted to digital dentistry. The preparation design guidelines described in points 1 and 2 are employed for tight interproximal contact areas:

1. The finish line is not extended to the interproximal contact area and designed labially so that the area can be accurately scanned by the intraoral scanner. This design requires fabrication of a model with sectioned dies from the 3D-printed model that must be matched with data of the dentition. Esthetics of the area needs to be carefully considered.
2. No definitive finish line is placed at the proximal area other than removing undercut area of the tooth structure. The die model is fabricated from the 3D-printed model, and the dental technician designs the restorative margin of the proximal area arbitrarily. The data of the model needs to be matched to the data of the dentition, as in point 1.
3. Interproximal space of 0.3 to 0.4 mm is necessary if space remains after orthodontic treatment, as in this case, or the space is due to conditions such as diastema. Appropriate proximal space allows easy scanning of the proximal area by the intraoral scanner and fabrication of the 3D model or 3D model with removable dies. This method was used in this case for anterior tooth preparation.

Preparations of the anterior and premolar teeth (before adjustment) are shown in Fig 25. This particular case required only removal of the existing occlusal composite resin restoration and preparation of the internal slope of the buccal cusp of the right and left second premolars without providing a definitive finish line at the proximal and cervical areas, so the margin of the restoration was designed arbitrarily, since it required only additive volume. However, the buccal surface was roughened with a diamond bur, since there is evidence that prismatic enamel without exposure of enamel rods does not provide adequate bonding even after etching.[10–12]

A digital impression was obtained by the intraoral scanner after initial tooth preparation. The result of the scan was not problematic; however, it became clear that more tooth reduction than was planned for the fabrication of the laminate veneer restorations was necessary due to a restriction of the CEREC system (Figs 26a and 26b). Another modification of the preparation was required, including eliminating undercut (Fig 27). Thereafter, a full-arch digital impression was taken (Fig 28), and shade was taken with the spectrophotometer (VITA Easyshade, VITA Zahnfabrik) as well. Superimposed data of the modified wax-up and teeth are shown in Fig 29. The milling pass showed that enough reduction was obtained (Fig 30).



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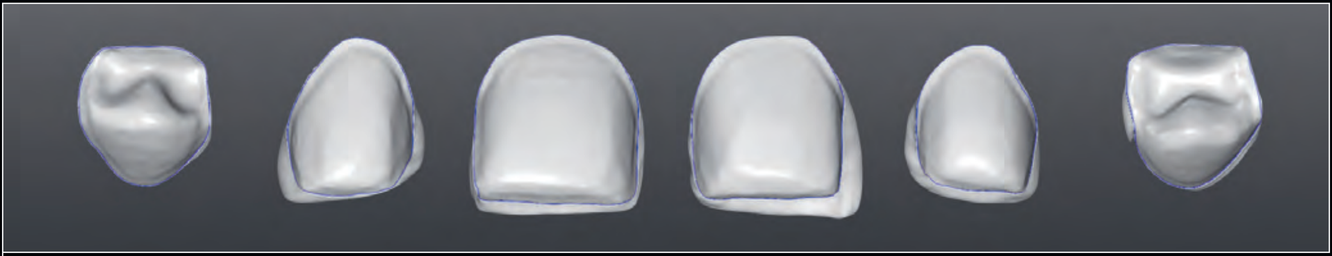

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Figs 26a and 26b Additional tooth reduction was necessary due to limitations of the milling machine (spherical areas at incisal edges).

Fig 27 Tooth reduction after modifications.

Fig 28 Digital scanning of modified tooth preparations.

Fig 29 There were no warning signs regarding material space after modifications were made.

Fig 30 Tool pass for milling was confirmed. Problems were solved.

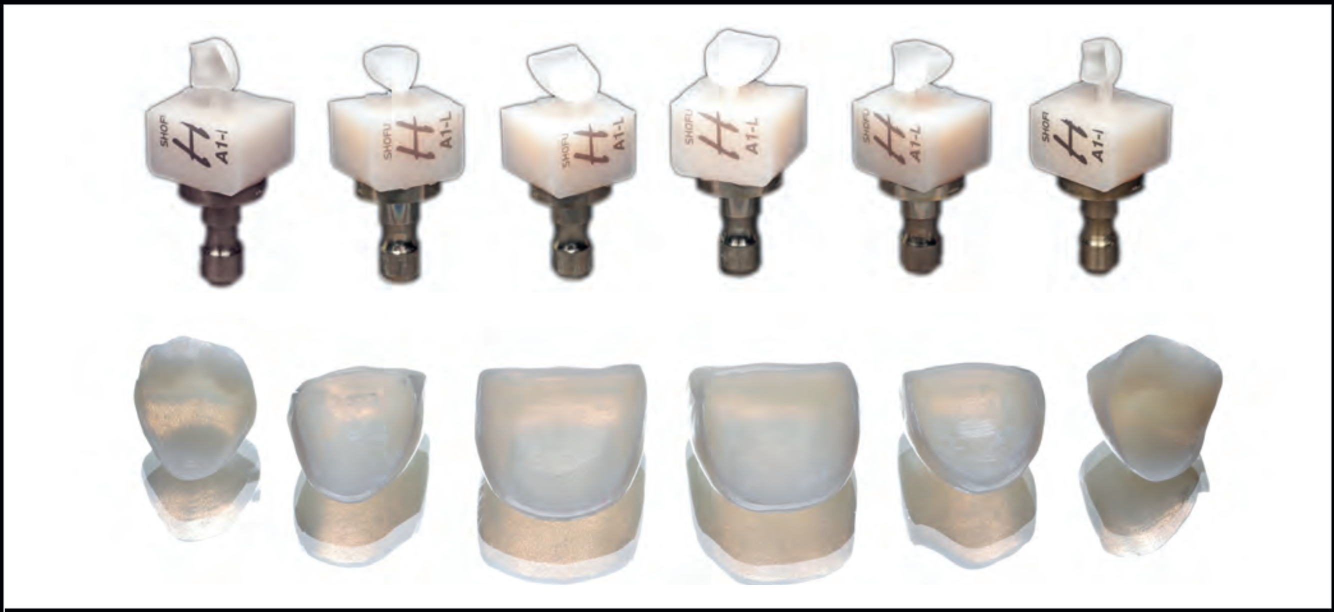

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Fig 31 Provisional restorations were fabricated from A1-LT/M Shofu HC block.

Fig 32 After insertion of provisional restorations. Appropriate fit and workability were confirmed.

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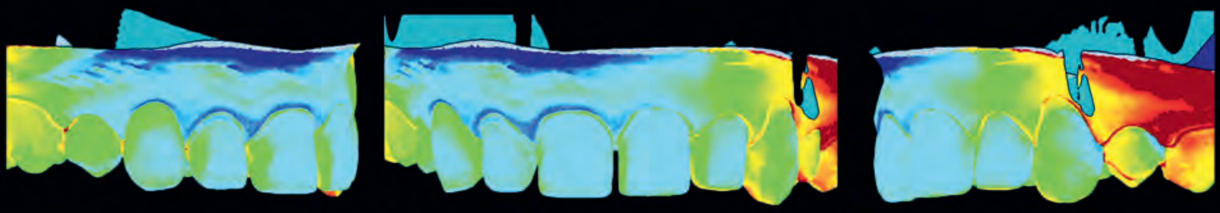

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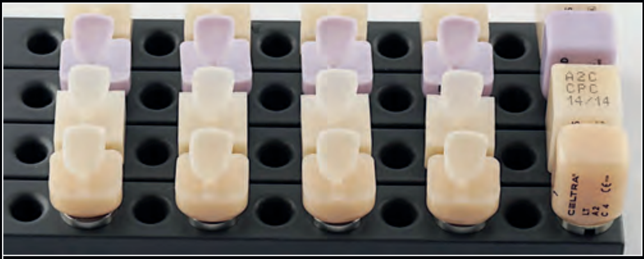

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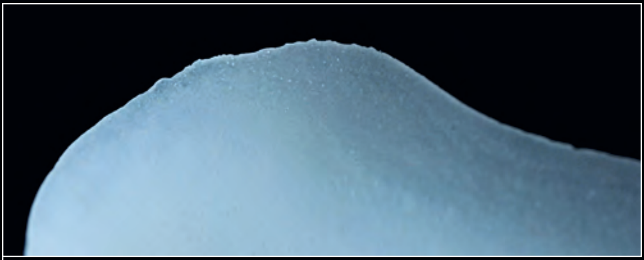

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Fig 33 Completed 3D-printed models.

Fig 34 Accuracy of scanned data and 3D-printed model is checked by superimposing both digital data at a maximum scale of 150 µm. High accuracy was confirmed, although some distortion was found in the molar region in the 3D-printed model.

Fig 35 Different ceramic blocks were milled under the same design data for comparison.

Fig 36 Magnified view of milled veneer, which was prepared by CEREC MCXL in feldspathic ceramic (TriLuxe forte). The margin tip area is well milled. The milling condition is satisfactory without chipping.

Then followed fabrication of the provisional restoration. Composite resin block (Shofu HC block, Shofu) A1-LT/M was used. Composite resin block has better workability than glass-ceramic material and can be milled rather thinly and sharply. The fit was excellent as well (Figs 31 and 32). The primer (Shofu HC primer, Shofu) was applied to the intaglio surface, and temporary resin cement (tempolink clear, Detax) was used to cement the provisional restoration. The 3D-printed model was fabricated as well (Figs 33 and 34).

Design of the Prosthesis

Various ceramic blocks were milled using the same data and considered for the final prosthesis (Figs 35 and 36). Feldspathic ceramic block (TriLuxe forte, VITA Zahnfabrik) with provided gradation was chosen. Of the various ceramic blocks, feldspathic ceramic block has superior workability. The microlayering method, which includes firing of a thin layer of surface porcelain, was employed. Milling data is programmed so that the thin margin area of the restoration does not become too thin when glass-ceramic block is used. Milling speed is set low to prevent chipping. The margin area is adjusted to make it thinner and sharper as designed on the 3D-printed model after the milling process.

The final adjustment of the margin area was made on the 3D-printed model. No definitive finish line was provided at the proximal margin area at the palatal aspect to avoid producing an undercut. Spacer was applied on each tooth on the software, and the margin was designed arbitrarily. The fabrication steps are described below.

Selection of Fabrication Method: All digital or combination with analog

In this case, the information of the facial midline and Camper's plane, which were recorded using the Ditramax system, was scanned and transferred to the CEREC system. Determination of the midline and some other factors used are not so precise with CAD software; however, precise long axis and right-left position of the tooth can be determined with the Ditramax system. Moreover, the process of designing the final prosthesis to fabrication becomes more effortless by being able to use esthetic proportions.

Data could be too extensive, depending on the specifications of the computer, if multiple data are synthesized, and it can be difficult to synthesize data that are not associated each other. Software companies have been developing and providing the technology to synthesize these data more easily. Synthesizing the analog and digital phases is an important step in difficult esthetic cases, such as this case. As mentioned previously, there are two methods to design the crown shape to match a particular patient's face—the all-digital technique and synthesizing digital data with analog wax-up (W scanning technique). The W scanning technique was employed in this case, in which the patient desired "smaller teeth and beautiful alignment." It is important to consider whether completed data is processed at CAM side precisely, since minimally invasive restorative treatment as much as possible was planned. The thickness of the wax-up was intentionally increased to a level at which it can be milled precisely and digital data of it obtained. Analog data was incorporated with digital data so that the milled prosthesis can be adjusted properly, maintaining high milling precision.

It is clear that precise and detailed treatment planning remains essential for current dental treatment, and it is still difficult to make the workflow completely digital. Digital technology is not almighty and it is important that analog technology is combined effectively.

Application of digital technology

Chairside and laboratory communication is required if the prosthesis is to be fabricated solely digitally. The steps of impression and model fabrication for esthetic prosthetic treatment with laminate veneers are quite different between the conventional and digital workflows (Fig 37). In this case, digital data from design to fabrication and the 3D-printed model were transferred through Sirona Connect. A free data transfer service (WeTransfer) was used to transfer detailed communication, such as photographs.

The elimination of possible distortion of the elastomeric impression material due to factors such as temperature and other stresses, as well as time savings, are benefits of transferring digital impression data. However, even more time would be required if digital communication between the dentist and technician were not done properly, requiring the prosthesis to be refabricated. The 3D-printed model will become more popular as intraoral scanners become more widely used.

A 3D-printed model can be fabricated in the dental laboratory or outsourced. Outsourcing is usually considered best at this point due to the high cost of a quality 3D printer and its maintenance. There also are uncertain factors, such as storage of the material and temperature and moisture control during the fabrication process, which could affect the accuracy of the model. Compatibility among different systems has been improving continuously since the intraoral scanner started to be applied. However, there is a cost involved in the license to use the data as well as royalty, and it is difficult to know how each company will handle these issues in the future.

Material selection

Material selection should depend on the case.[13–17] It is true that pressed restorations are more favorable for cases with thin laminate veneers. However, more materials are available for the milling method compared to the pressing method. The selected material should meet many requirements, including workability, color, polishability, compatibility with porcelain, stability of properties and color during adjustment, longevity, and bonding procedure. It is highly desirable that the CAD block consists of at least two color gradations of dentin and enamel (Figs 38 and 39). Needless to say, milling of multicolor blocks is more technique sensitive than that of monocolor blocks.

There was no pressed restoration option with feldspathic porcelain, which was one of the reasons the CAD/CAM method was selected, but the first author's 29 years of

Traditional Workflow

1. Impression taking.
2. Fabrication of stone model.
3. Facebow transfer and mounting models on articulator (functional and esthetic mounting; use of Ditramax).
4. Diagnostic wax-up (analog).
5. Preparation for mock-up (mock-up guide, fabrication from diagnostic wax-up).
6. Preparation for mock-up (preliminary reduction guide, fabrication on the stone model) depending on the case.
7. Mock-up (direct, indirect).
8. Impression after functional-esthetic adjustment of mock-up.
9. Wax-up for final prosthesis after facebow transfer and mounting on the articulator.
10. Abutment preparation (prepare directly through the mock-up; silicone indexes for preparation guide and for provisional restoration are fabricated from wax-up model).
11. Shade taking.
12. Fabrication of provisional restoration (acrylic resin is poured in the silicone index and then pressed on the abutment intraorally at chairside).
13. Final impression.
14. Fabrication of master stone model, fabrication of refractory model accordingly.
15. Facebow transfer and mounting on the articulator (fabrication of custom incisal guide table from provisional model after cross mounting).
16. Fabrication of the prosthesis (refractory cast or press method; staining or layering is employed accordingly in press method).
17. Try-in and adjustment.
18. Bonding of the final prosthesis.

Semi-Digital Workflow (double-scan method, used this case)

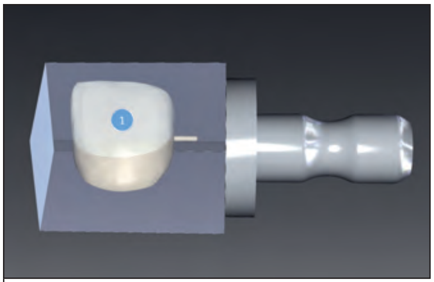
1. Impression taking.
2. Fabrication of stone model.
3. Imprinting of esthetic reference lines and Camper's plane on the stone model using Ditramax.
4. Scanning of the stone model (lab scanner).
5. Data of the stone model is set in the digital software, applying the reference lines by Ditramax.
6. Digital smile design.
7. Diagnostic wax-up (analog).
8. Scanning of diagnostic wax-up (lab scanner).
9. Confirmation of the harmony between wax-up design and face with smile design software.
10. Preparation for mock-up (mock-up guide, fabricated from the wax-up model).
11. Preparation for mock-up (preliminary reduction guide, fabricated by press method from the 3D-printed model made at the first visit in the present case), depending on the case.
12. Mock-up (direct).
13. Digital impression taken by intraoral scanner after functional-esthetic adjustment of the mock-up.
14. Comparison of wax-up data and mock-up data using smile design software.
15. Wax-up data of the final prosthesis is scanned in (lab scanner) to the software after modification of the analog wax-up.
16. Abutment preparation (preparation directly through the mock-up, the silicone index to check the reduction amount of incisal and labial surface is prepared from the 3D-printed model made out of the data.
17. The color of the block is selected by shade taking using digital spectrophotometer (the digital camera is used as well).
18. Digital impression of abutments by intraoral scanner.
19. Fabrication of 3D-printed model (sectioned die type, solid type).
20. Production of milling data by W scan technique.
21. Fabrication of CAD/CAM provisional restoration using PMMA.
22. Milling of glass-ceramic block to produce final prosthesis, which will be microlayered.
23. Try-in and adjustment.
24. Bonding of the final prosthesis.

Fully Digital Workflow

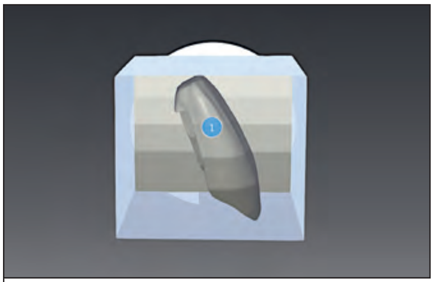
1. Digital impression by intraoral scanner.
2. Facial scanning.
3. Digital facebow transfer (natural head position).
4. Digital wax-up design.
5. Preparation of mock-up (fabrication of mock-up guide and preliminary reduction guide by 3D-printed model and milling model).
6. Mock-up (direct).
7. Digital impression taken by intraoral scanner after functional-esthetic adjustment of the mock-up.
8. Production of final prosthesis design according to the mock-up data.
9. Teeth preparation (preparation directly through the mock-up; silicone index to check reduction amount of incisal and labial aspects is fabricated out of 3D-printed model or milled model fabricated from the data in previous step).
10. Shade taking using digital spectrophotometer, colorimeter function of intraoral scanner, or digital camera.
11. Digital impression by intraoral scanner.
12. Fabrication of 3D-printed model or milled model.
13. Fabrication of milled polymethyl methacrylate provisional restoration according to the digital design data of the final prosthesis.
14. Fabrication of the final prosthesis with glass-ceramic block or polymer block according to the digital design data of the final prosthesis (staining or layering accordingly).
15. Try-in and adjustment.
16. Bonding of the final prosthesis.

Fig 37 Major differences in the impression-taking and model-fabrication steps are apparent when the traditional and fully digital workflows are compared to the semi-digital workflow used in this esthetic laminate veneer restoration case.

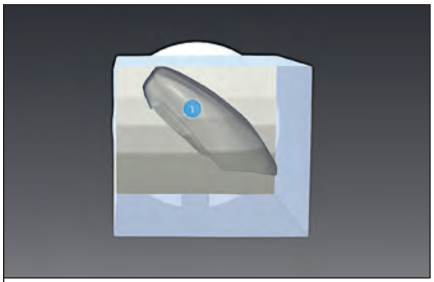
38a



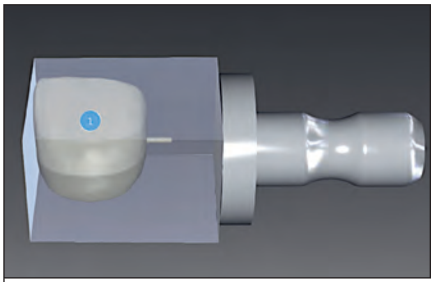
38b



39a



39b



39c

Figs 38a and 38b Image of the design with gradation of enamel and dentin for Shofu HC block to fabricate the provisional restoration. Color of the block is especially important for minimally invasive restorations. With its gradation of dentin, enamel, and translucency, the block is ideal, or at least two color gradations of dentin and enamel should be selected.

Figs 39a to 39c TriLuxe forte with four color gradations was selected for the final prosthesis. The veneer was positioned appropriately inside the block on the screen so that it would simulate the three-dimensional composition of enamel and dentin of the natural tooth (the design with consideration of dentin and enamel composition of natural tooth is preferred to horizontal plane gradation).

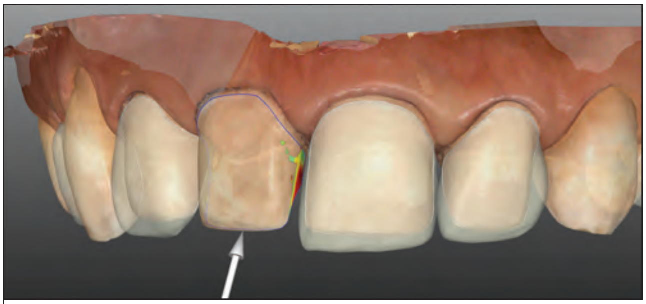
clinical experience with feldspathic porcelain as a CAD/CAM material was also a decisive factor. On the other hand, a different material would be more suitable if high translucency were required or only the labial surface were involved. The dentist and technician both need to understand the material well—its characteristics, compatibility with the system, bonding ability, etc—in order to select the appropriate material for each case.

Selection of the milling method for accurate milling

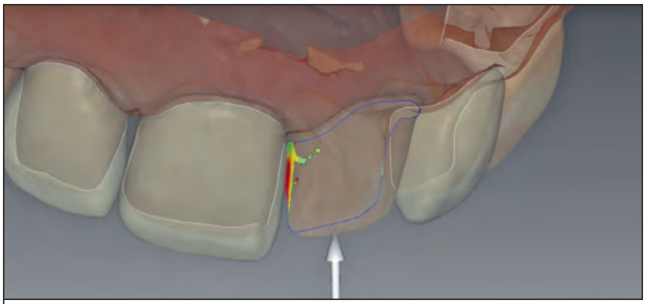
Managing the milling procedure to create high-quality laminate veneers with internal surface fit was the most difficult step of the laboratory procedure (Figs 40 to 45). Managing material space and cement space is an important aspect of the CAD/CAM process. It is necessary to determine the appropriate set-up of the system so that immediately after milling the fit is within the permissible range without requiring adjustment by the technician, since chipping or cracking tends to occur with thin laminate veneers. More important than material selection is whether to make the laminate veneer fit to the tooth by surface contact or line contact. It is also important to consider whether the design requires extensive adjustment after milling or only minor adjustment at the margin area.

Following are factors to be considered for managing CAD data for milling:

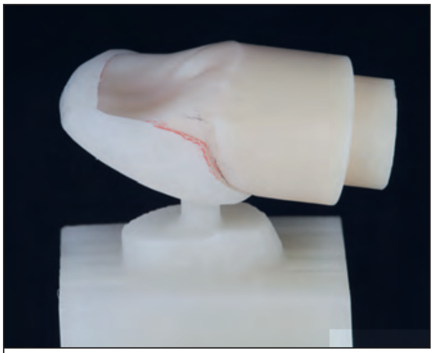
1. The unit is set up so that internal compensation is not required (sometimes extensive internal adjustment is required depending on the tooth preparation without internal compensation).
2. The insertion axis is set up (direction of the axis, which is controlled by the movement of milling bur) to mill the prosthesis when the data is set up (consider the direction to minimize the area of red and yellow colors, which indicates undercut).
3. The most difficult area is milled out after steps 1 and 2 are completed and checked on the model (on the 3D-printed model in this case), knowing it will be waste of the block.
4. The area of margin adjustment in the proximal region is marked on the 3D-printed model. The margin area is reset as much as possible comparing the tooth on the CAD screen.



40a

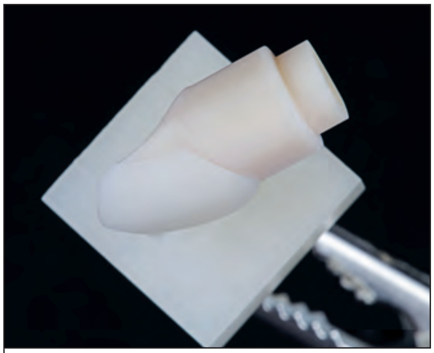


40b



41a

41b



41c

42a

42b

42c

Figs 40a and 40b Step 1 for precise milling. Undercut is eliminated as much as possible by adjusting the milling axis.

Figs 41a to 41c Step 2 for precise milling. Trial milling is carried out after eliminating undercut as much as possible. The margin area, where milling is difficult, is checked under the microscope.

Figs 42a to 42c Anterior and premolar overlay veneers are set on the solid 3D-printed model after sprues are cut off, and the margin area is adjusted using a hard carbide bur (EMESCO HP 1169). An acceptable fit was obtained overall.

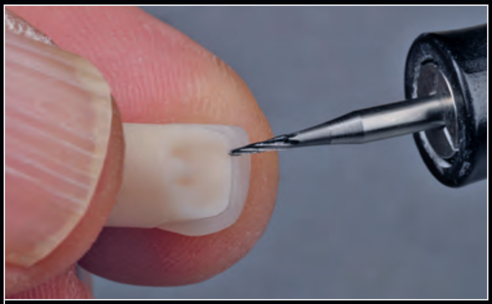
5. The margin area is compensated so as not to be too thin.
6. Milling speed is set to low to prevent chipping of the prosthesis.

Milling of difficult cases can be managed by following the above steps. Carbide burs (Komet 1170, 1169, Komet Dental) are better than diamond points for accurate adjustment of the margin area of milled laminate veneers. The remaining steps are shown in Figs 46 to 56.

Bonding Procedure

Bonding of laminate veneer

The indirect laminate veneer has two bonding interfaces: the ceramic surface of the prosthesis and the enamel surface of the tooth. High bond strength is obtained by appropriate conditioning of each bonding interface. The color, translucency, and fluorescence of the cement need to be considered as well as the color of the tooth, because they affect the color of the laminate veneer after insertion (Fig 57).



43a

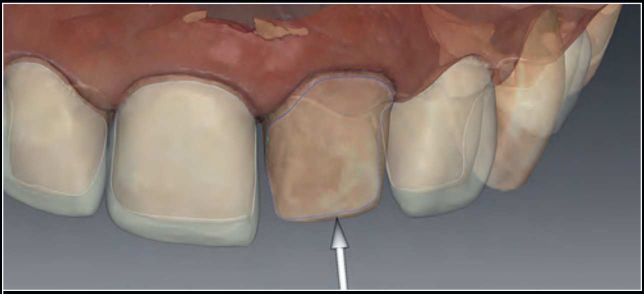
Figs 43a to 43d Final adjustment of margins on the 3D-printed model.

43b

43c

43d

44a



44b

Figs 44a and 44b Step 3 for precise milling. Milled veneers are set on the 3D-printed model to examine the area that is difficult to mill digitally. This step is necessary to obtain both acceptable margin fit and internal surface fit. This case was managed digitally because of the stability of the block material, which does not chip easily during adjustment. A hard carbide bur or sintered diamond bur is used for adjustment after milling (see Fig 41).

45a

45b

45c

46

47

48

Figs 45a to 45c The veneer is fitted on the abutment model. It is confirmed that the margin can be milled with CEREC inLab MCXL, but margins other than in the cervical area are adjusted in CAD.

Fig 46 The area of internal structure (mamelon) is cut away.

Fig 47 Staining with VITA AKZENT Plus provided proximal translucency and horizontal direction of internal dentin.

Fig 48 Mamelon is provided in two stages to avoid mixing of the detailed mamelon stains that can occur when done in one step.

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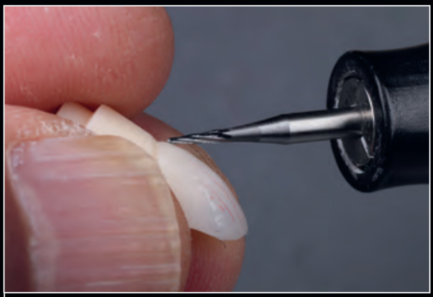


54

Fig 49 Shape of the lateral incisors is finalized by light layering of enamel.

Fig 50 Incisal edges and shape of the central incisors are finalized by light layering of enamel.

Fig 51 After firing.

Fig 52 Shape is adjusted considering gradation overall and harmony with adjacent teeth.

Fig 53 Ridges and grooves are added.

Fig 54 Detailed surface texture is provided with a hard carbide bur.

Fig 55 After glazing.

Fig 56 Completed laminate veneers: porcelain microlayered on TriLuxe forte feldspathic ceramic block with color gradation.

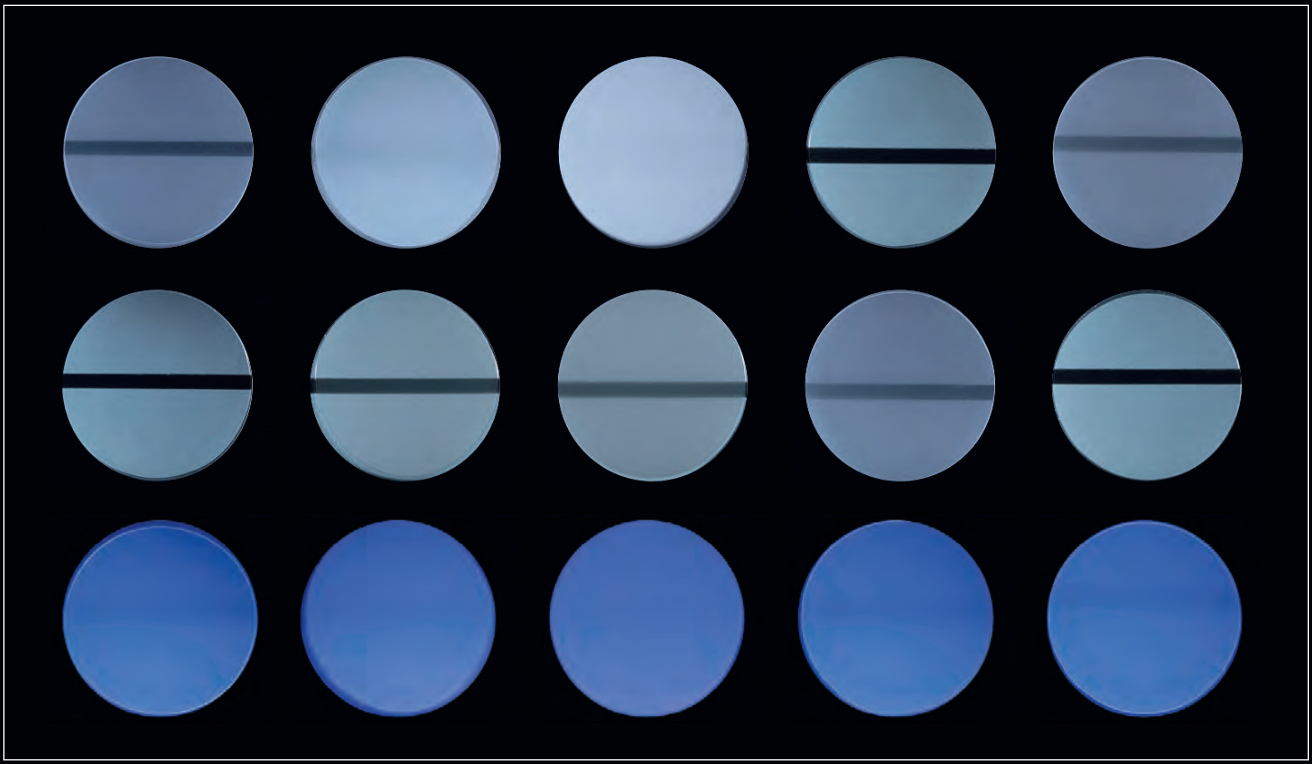
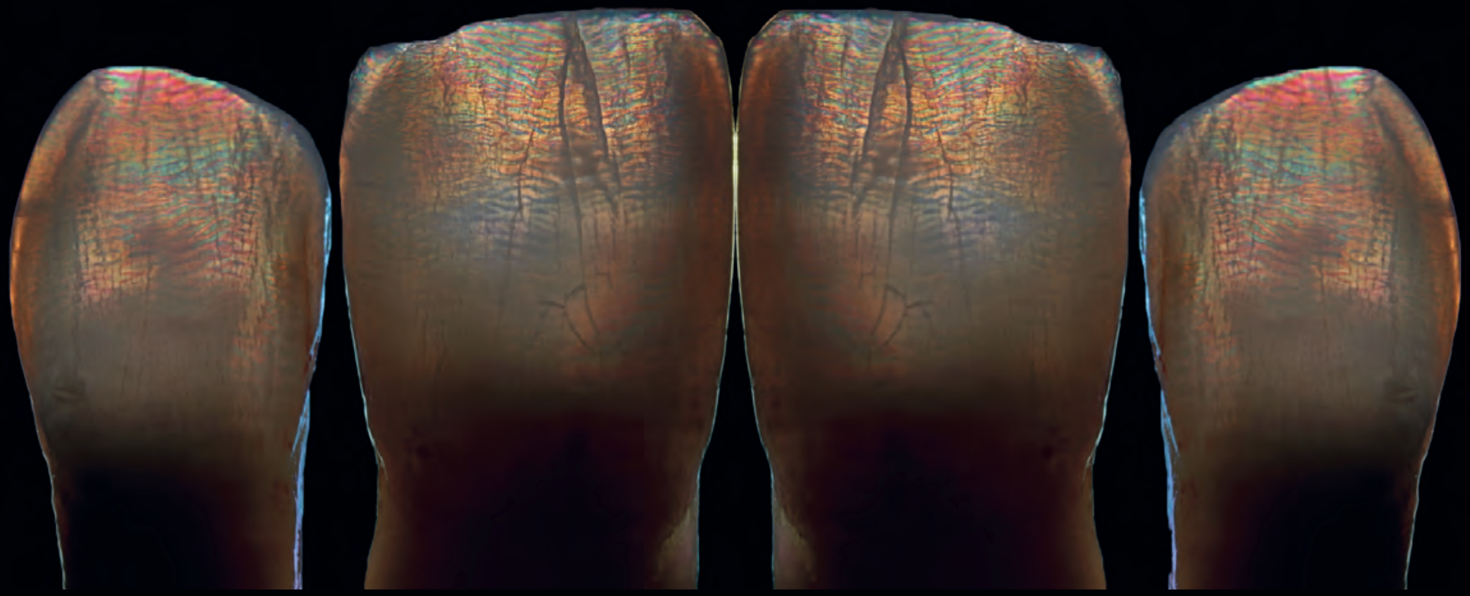
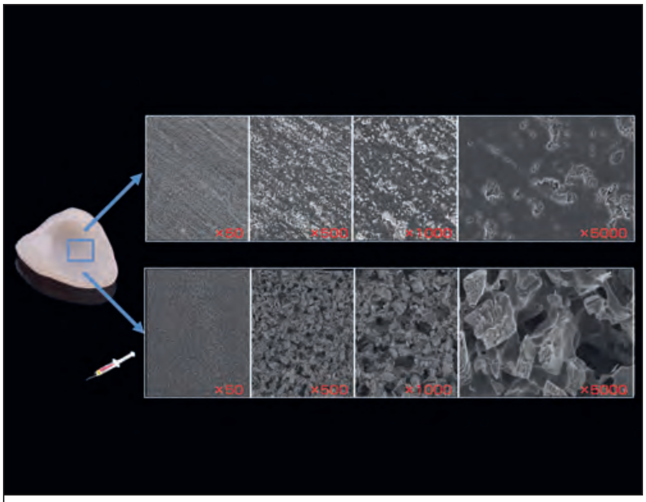


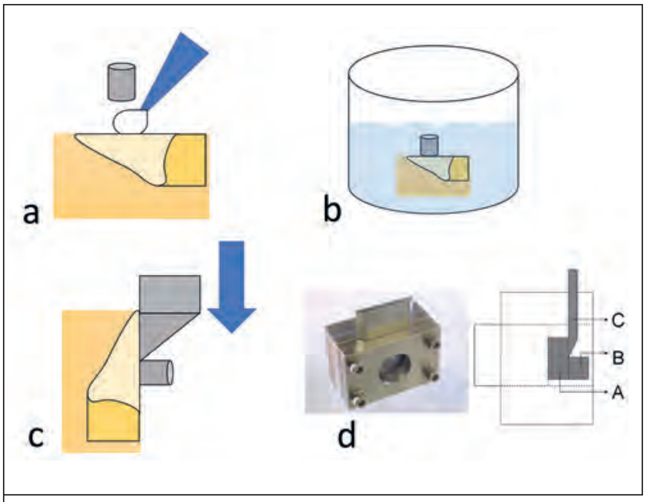
Fig 57 Reflective light, transmitted light, and fluorescence of BeautiCem Veneer from Shofu, the resin cement used for this case, were tested. Specimens from left to right: L- Value, M-Value, H-Value, Ivory-L, Ivory-D. In reflective light *(top row),* no translucency was found in H-Value and M-value. The rest showed some translucency. In transmitted light *(middle row),* L-Value and Ivory-D showed higher translucency than others. All specimens showed soft fluorescence *(bottom row),* which is similar to that of natural teeth.

Enamel exhibits different translucency with different wavelengths depending on the area.





58



59

Fig 58 Scanning electron microscope image of bonding surface conditioning of TriLuxe forte. *Top row:* Without hydrofluoric acid etching. *Bottom row:* After 90 seconds of hydrofluoric acid etching.

Fig 59 Steps of shear adhesion strength test: *(a)* Adherend is bonded on enamel surface of bovine tooth according to the manufacturer's directions. *(b)* The specimen is immersed in water for 24 hours. *(c)* Shear adhesion strength test is carried out after 24 hours at 37°C. *(d)* Test apparatus and experiment design.

Bonding to enamel

Bonding to enamel is the starting point for adhesive dentistry, and highly predicable procedures based on plentiful research have been established. The recommended standard conditioning procedure includes elimination of bonding inhibiting factors and smear layer, etching to obtain mechanical retention, and application of primer to improve chemical adhesion. Stable bonding strength is obtained on enamel, which consists mainly of inorganic components and is structurally stable, by establishing an acid-resistant hybrid layer mechanically fit in nano-macro scale between the cement and enamel after the conditioning procedures described above.[18,19]

Bonding to ceramic

Porcelain, which consists of mainly silica, dispersion-strengthened glass-ceramics such as e.max, and high-density polycrystalline ceramics such as zirconia are the ceramics used in current clinical dentistry. Different shades, various value/chroma, and high translucency are required for the laminate veneer material used in esthetic cases and are the reason silica-based ceramics became popular. Hydrofluoric acid etching (Fig 58) + silane surface treatment[20,21] is the most effective conditioning method for this material.

Timing of hydrofluoric acid etching

In Japan, hydrofluoric acid etching is carried out in the laboratory, preferably an in-house laboratory, since its chairside use is prohibited. However, the best timing for hydrofluoric acid etching is not quite clear. Therefore, the influence of the timing of hydrofluoric acid etching on bond strength was investigated. Details of the study are described in Figs 59 and 60. The shear strength test of TriLuxe forte (VITA), which is a feldspathic ceramic, on bovine tooth enamel was performed. The bonding procedure was carried out using adhesive resin cement (BeautiCem Veneer L-Value, Shofu) after phosphoric acid etching (Uni-Etch, BISCO) and conditioning (BeautiBond Universal, Shofu). Timing of the hydrofluoric acid etching (Porcelain Ethant, BISCO) was divided into four groups: immediately before insertion (HF), 24 hours before insertion (24HF), 72 hours before insertion, and no hydrofluoric acid etch as control (CON) (Fig 60). The phosphoric acid etching was performed right before insertion as decontamination after application of saliva for the CON, 24HF, and 72HF groups.[22–25]

As shown in Fig 61, the HF and 24HF groups had significantly higher bond strength compared to the CON group. No statistically significant difference was found between the HF and 24HF groups; however, a significant difference was found between these groups and the 72HF

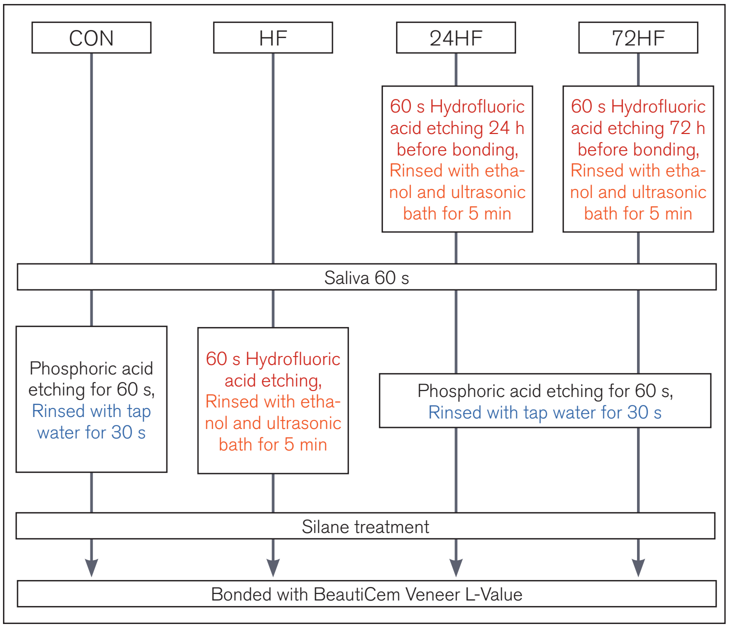


Fig 60 Test condition.

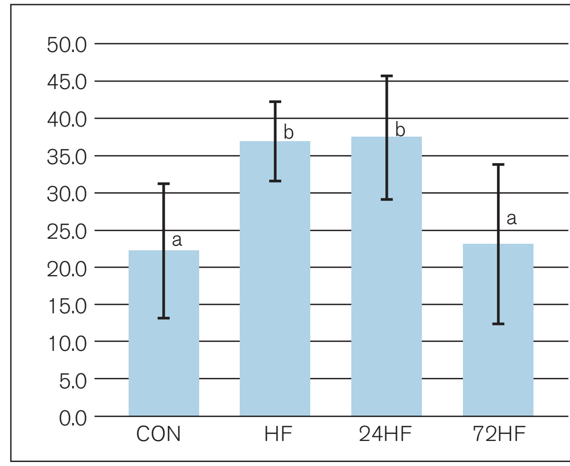


Fig 61 Test results (in MPa).

group. It was found that high bond strength was obtained by hydrofluoric acid etching, but in 72 hours the effect dropped as low as without etching. The phosphoric acid etching + wash with water groups (CON, 24HF, 72HF) showed a wide deviation in bond strength. It is considered that a small amount of remaining water on the bonding surface possibly affected the bond strength. On the other hand, it is considered that stable bonding strength was obtained in the HF group because it was washed with alcohol, leaving less residual substance on the bonding surface. It is concluded that hydrofluoric acid etching significantly improves the bonding strength of silica-based ceramics and its desirable timing is immediately before insertion (after try-in) or 24 hours before insertion.

Bonding procedure in this case

For this case it was decided to carry out hydrofluoric acid etching and ultrasonic washing with alcohol immediately before insertion based on the study results. Rubber dam was applied in the mouth to prevent contamination. First, the laminate veneers were tried in to check the fit; a microscope was used to confirm the fit. Next, try-in paste was used to select the shade of the cement. L-Value resin cement (BeautiCem Veneer, Shofu) was selected in this case since its plain shade showed better color reflection of the enamel color underneath. The bonding surfaces of the laminate veneers were roughened and cleaned: 90 seconds of hydrofluoric acid etching (Porcelain Etchant, BISCO) and ultrasonic cleaning with alcohol. The conditioning procedure was completed with the application of silane (Porcelain Primer, Shofu) and heating with a resin heater. The enamel was conditioned with phosphoric acid etchant (Uni-Etch, BISCO) and application of a priming/bonding agent (Beauti-Bond Universal, Shofu), then light-cured for 20 seconds (VALO curing light, Ultradent), after which the veneers were cemented. Small pieces of excess cement were removed under the microscope at the following appointment.

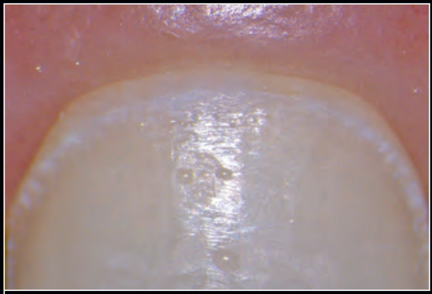
Treatment Result

The result immediately after insertion is shown in Fig 62a to 62c. A highly esthetic result was achieved with well-balanced color, shape, and texture. Excellent marginal adaptation even with the supragingival design was confirmed under microscope observation (Figs 63a to 63c). The patient was quite satisfied with the well-balanced result with her facial features (Fig 64). The result at 1 year after insertion (Fig 65) confirmed the stability of esthetics, function, and biocompatibility. The patient has been using a mouthpiece-type retainer on both arches to prevent orthodontic relapse.

62a

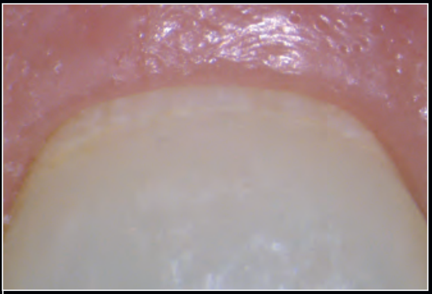
62b

62c



63a

63b



63c

Figs 62a to 62c After insertion of laminate veneers.

Figs 63a to 63c Margin integration and fit is natural and excellent, even with a supragingival margin. *(a)* Finish line. *(b)* Try-in. *(c)* After insertion.

64

65

Fig 64 Facial photographs after insertion of laminate veneers.

Fig 65 One year posttreatment (gingival view of the restorations).

CONCLUSION

Arriving at the best result for prosthetic cases requiring both high esthetics and function is no easy task. It requires careful selection and combination of the most appropriate equipment, techniques, and materials, in analog or digital format, out of the various options now available.

The goal of prosthetic treatment is harmony. This harmony refers not only to the treatment to provide optimal esthetics and function, but also the harmony among the treatment team—the restorative dentist, other dental specialists, dental technician, and staff members—which leads to the best treatment outcome. This interdisciplinary approach should be promoted by all professionals to make this harmony among them routine.

The treatment plan for this case was determined after thorough pretreatment evaluation using various analog/digital examination and diagnostic equipment. The prosthesis design, fabrication method, and material selection were discussed with other professionals. The most reliable bonding procedure was established based on the study presented. The final prosthesis required minimal adjustment and resulted in excellent overall harmony with the patient's smile and face.

DISCLOSURE

There is no conflict of interest to declare regarding this article.

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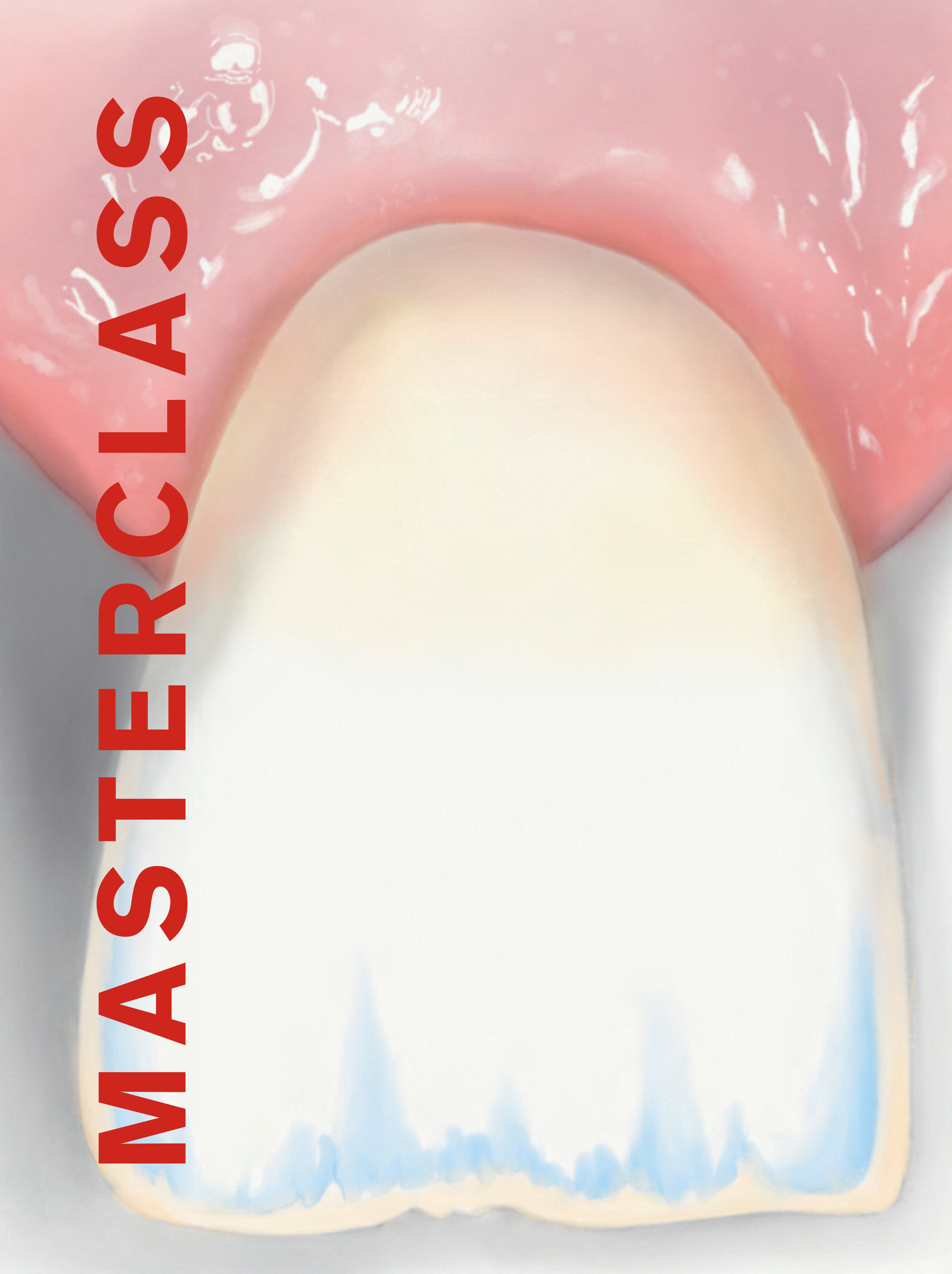
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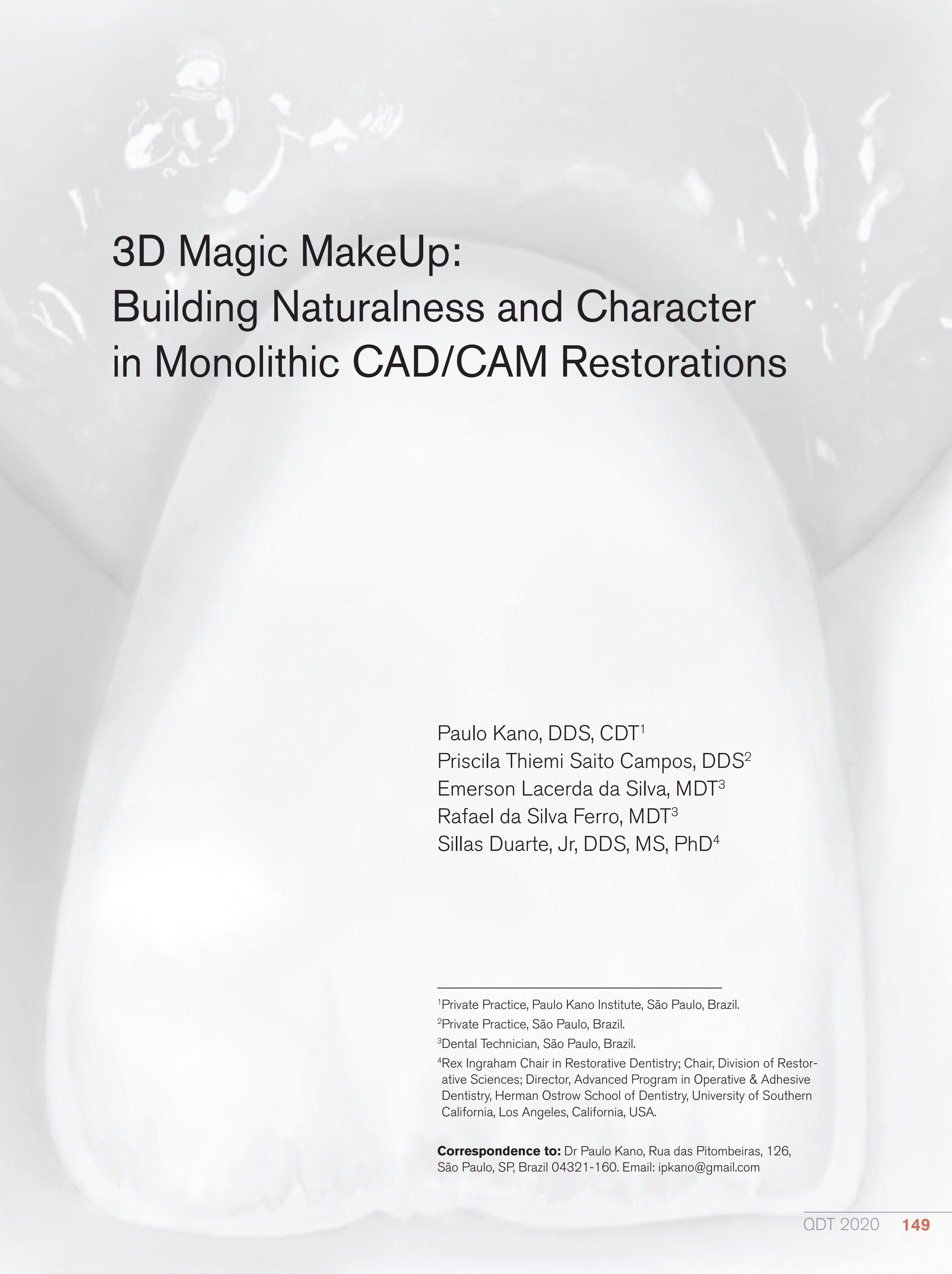

3D Magic MakeUp: Building Naturalness and Character in Monolithic CAD/CAM Restorations

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PREOPERATIVE

1

Fig 1 Preoperative condition of the patient.

Fig 2 Sequence of patient preoperative images in smile and exaggerated smiles.

Fig 3 Preoperative images of the patient aligned according to horizontal (bipupillary line) and vertical references (sagittal midline, tip of nose, tip of the chin).

2

3


4a


4b


5a

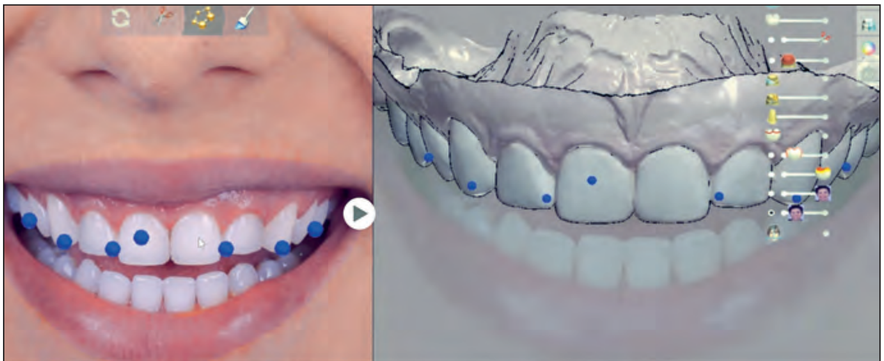

5b


5c

Figs 4a and 4b Close-up of the patient's smile and exaggerated smile.

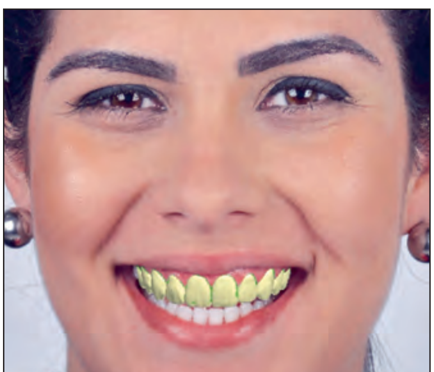
Figs 5a to 5c Preoperative frontal and lateral intraoral views of the patient's maxillary teeth.

DIGITAL DESIGN USING CLLONES LIBRARY



6a

6b



7a

7b

8a

8b

Fig 6a Integration process of 2D image of the patient's smile with the intraoral scanned 3D image (STL) through layers into the design software (3Shape) using reference points.

Fig 6b Intraoral scan and patient smile digitally aligned.

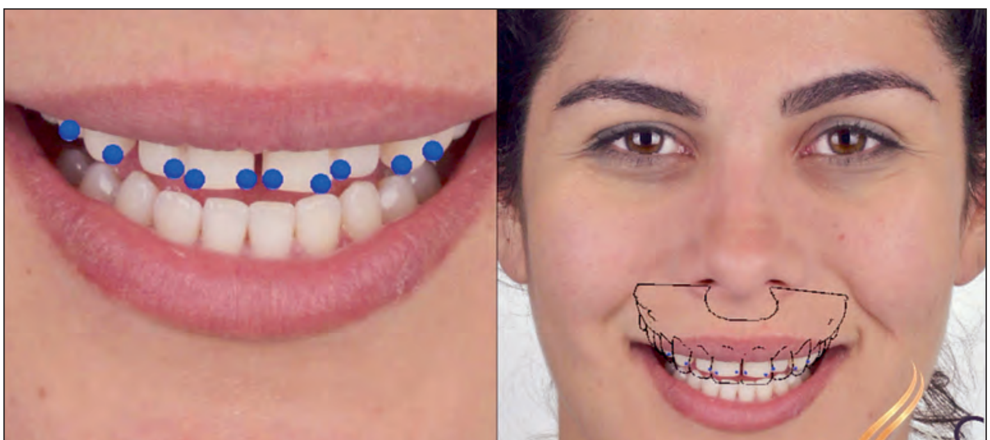
Fig 7a Digital design and mirroring of digital dental clones using Cllones library.

Fig 7b Close-up of the digital dental alignment using Cllones library reveals the need for gingival esthetic crown lengthening to improve the smile.

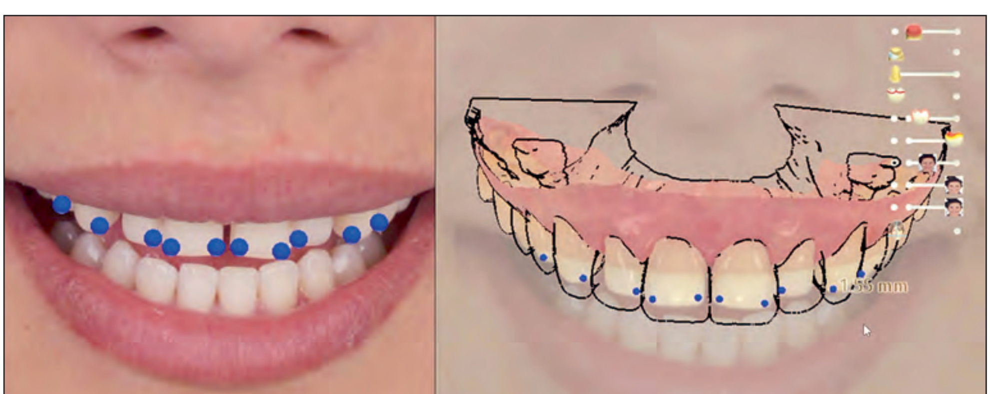
Figs 8a and 8b Gingivectomy was performed followed by a minimally invasive flapless crown-lengthening procedure with the help of a piezoelectric device (CVD, CVDentus) and specially designed ultrasonic piezo inserts (TR1-PK, VR1-LPK, and VR1-RPK, CVDentus). *(a)* Patient's smile and *(b)* exaggerated smile after flapless crown lengthening.

9a

9b



10a



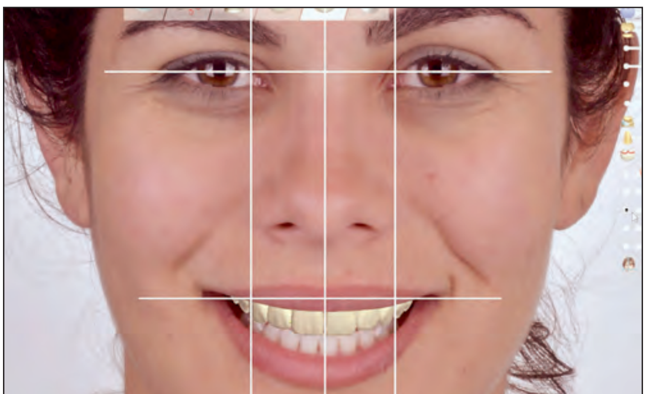
10b

Figs 9a and 9b Minimally invasive veneer preparations were performed for the maxillary anterior teeth and immediately scanned intraorally (Trios 3, 3Shape). STL file of *(a)* the patient's teeth preparations and *(b)* the teeth preparations in occlusion.

Figs 10a and 10b The 2D image of the patient's smile after esthetic surgery was uploaded to the software and aligned with the STL file of the preparations.


11a


11b


11c

Figs 11a to 11c Digital esthetic design of the restorations using the Cllones library transferred to the new STL of the prepared teeth and carefully analyzed with the patient's smile.

Fig 12a Frontal view of the finalized restorations using Cllones library.

Fig 12b Occlusal view of the digital design of the restorations.

Fig 13 Digital design of the restorations in occlusion.

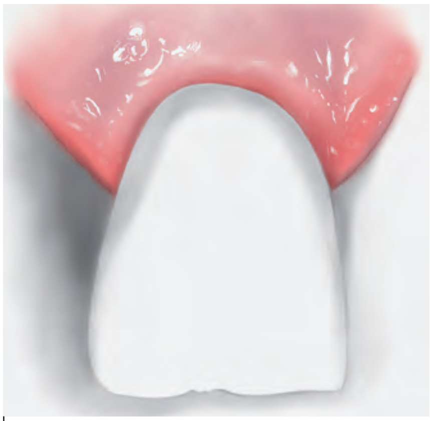
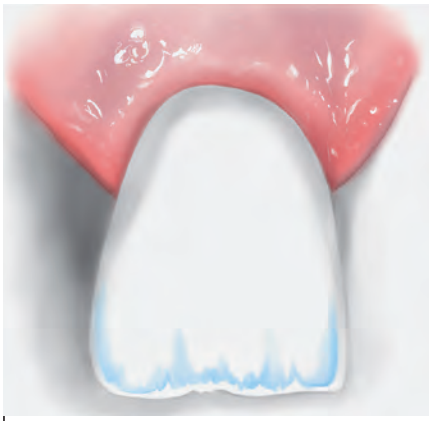

12a


12b


13

3D MAGIC MAKEUP

The restorations were milled using a leucite-reinforced glass-ceramic (Empress CAD Multi, Ivoclar Vivadent), shade A1. After milling, the sprue was carefully removed and the pre-staining polishing procedure was performed using a goat hair brush with a diamond paste (Diamond gloss, KG Sorensen) at low speed. No modification of the restoration's morphology was performed, since the Cllones library provides perfect replication of the dental anatomy and morphology, including surface microtexture, thus only polishing and staining are needed.


14a

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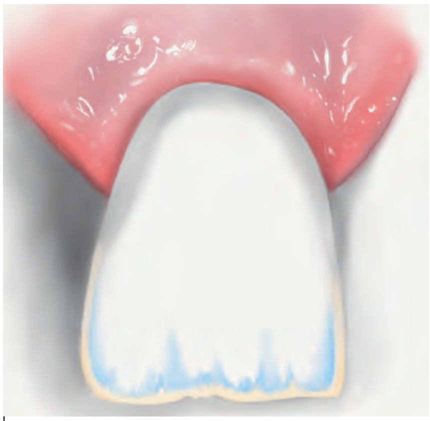
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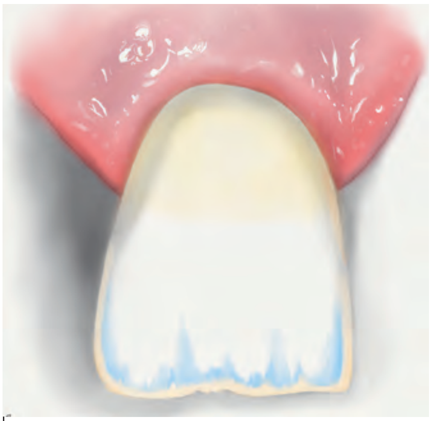
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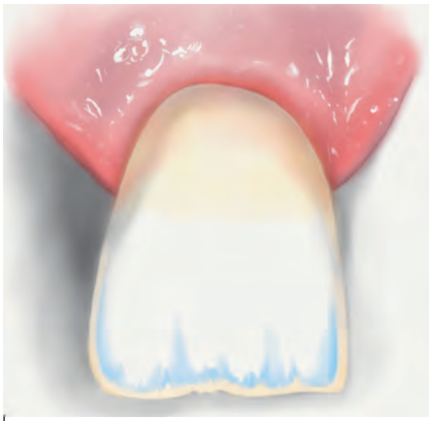

14e

Fig 14a Restoration before staining.

Fig 14b Fine and delicate layer of basic blue (E 23) applied to the incisal third to simulate the incisal opalescent layer and mamelon design (IPS Ivocolor, Ivoclar Vivadent).

Fig 14c Incisal halo created using a cream (E 02) (Ivocolor, Ivoclar Vivadent) carefully applied continuously at the incisal edge while following the contour of the opalescent layer.

Fig 14d Internal makeup performed at the intaglio surface of the veneers, more precisely at the gingival third, using sunset (E 04) or a combination of the colors orange and basic yellow (E 22) at 1:1 ratio.

Fig 14e Basic red (E 21) applied to the gingival outline on the facial aspect of the veneer to mimic the warm colors of the gingiva.

After the application of the stain layers described, the veneers were fired at 750°C (Programat P510, Ivoclar Vivadent), using the following settings:

Ti = 403°C
Tf = 750°C
V1 = 450°C
V2 = 749°C
V/°C = 60°C
HT = 1 min

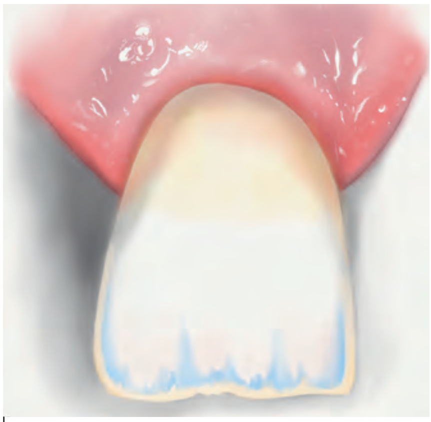
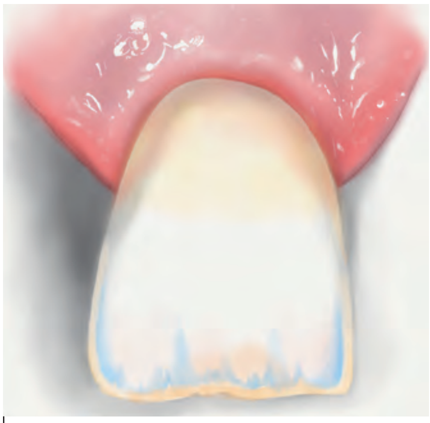

14f

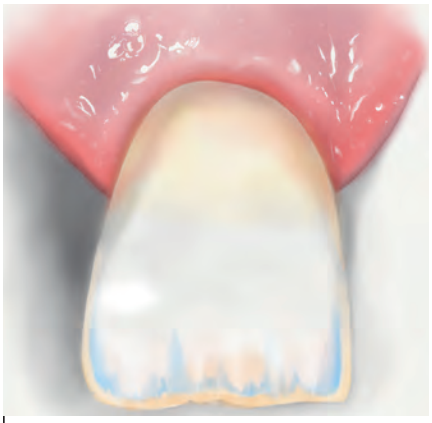
Fig 14f Upon completion of the firing cycle, one can see a slight salmon or orangish-pinkish cast with Empress CAD Multi A1, most likely due to the inherent opalescence properties of the CAD/CAM material.

The procedure described in Fig 15 allows an increase in value while producing a "pearl effect" to the monolithic CAD/CAM veneers.

Up to this stage, the layers of staining applied to the veneers were intentionally underfired at 750°C. The final layer must now be fired at 800°C for full sintering of all layers. This technique will increase the veneer translucency, improving the surface homogeneity and creating a lifelike effect to the ceramic. The firing setting used was:

Ti = 403°C
Tf = 800°C
V1 = 450°C
V2 = 799°C
V/°C = 60°C
HT = 1 min


15a


15b

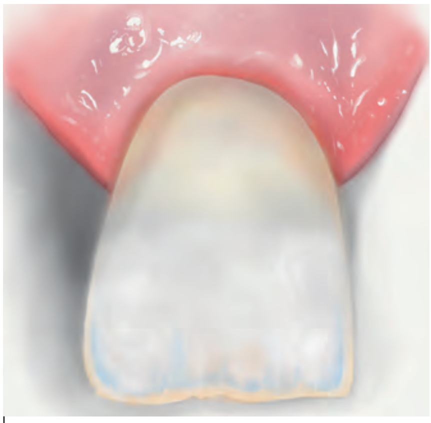

15c

Fig 15a Mixture of orange and sunset (1:3 ratio, respectively) was carefully applied at the center of the incisal edge (middle mamelon) and fired using the same settings as shown above.

Fig 15b At the incisal third, closer to the mamelons, a cream staining (E 02) was applied as inverted triangular shapes (tip toward the incisal edge). Then, a mixture of white (E 01) and shade dentin 0 (2:1 ratio, respectively) was applied, creating cloud-shaped stains throughout the facial surface of the veneer.

Fig 15c To reveal a tridimensional appearance, a white stain (E 01) was diluted in IPS Ivocolor Essence Fluid (Ivoclar Vivadent) and a thin yet homogenous layer applied throughout the facial surface of the veneer. One must be careful to avoid pooling during application. No accumulation or further staining should be seen at this stage.

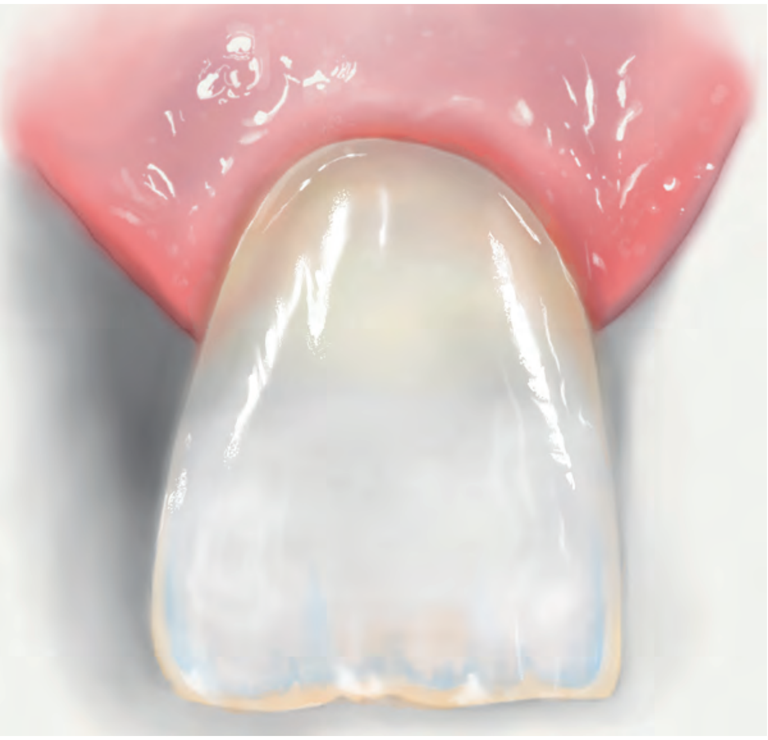


Fig 16 For the final glaze, a thin layer of Ivocolor Glaze (Ivoclar Vivadent) was applied.

After the final glaze, the veneers were fired using the settings below for three consecutive times (three layers of glaze):

Ti = 403°C
Tf = 730°C
V1 = 450°C
V2 = 729°C
V/°C = 60°C
HT = 1 min

After the veneers were stained using the 3D Magic MakeUp technique, the final polish was performed using a goat hair brush with diamond paste (Diamond gloss, KG Sorensen).

FINAL RESULT

17a

17b

17c

18

Figs 17a to 17c Veneers after bonding.

Fig 18 Close-up of the patient's smile depicting the natural-looking monolithic restorations created by the Cllones library and stained using the 3D Magic MakeUp technique.

Fig 19 Esthetic natural outcome.

Biologic Esthetics by Gingival Framework Design:

Part 4. Prosthetic Management of Marginal Gingiva Around Natural Teeth

Yuji Tsuzuki, RDT[1]

In the first three parts of this article, published previously in QDT,[1–3] evaluation standards for gingival esthetics and composition of the gingival framework[4] were presented. This article discusses the clinical application of these concepts with different treatments. Cases with natural abutments, where ideal esthetic results were achieved, are presented. The prosthetic management and results for each case are discussed. The role of the prosthesis to restore natural teeth is important. It has always been a challenge to minimize the risk of retreatment and achieve long-term maintainable and stable periodontal tissue.

Esthetic treatment includes not only the tooth crown but also gingival tissue, with consideration of the gingival level, line, color, and texture. A proper diagnosis, comprehensive treatment approach, and proper prosthetic management are required to achieve a highly esthetic result.

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Figs 1a to 1c Each clinical case presents different periodontal conditions, including gingival thickness, texture, and alveolar bone. Difficulties in prosthetic and tissue management differ case by case.

1a

1b

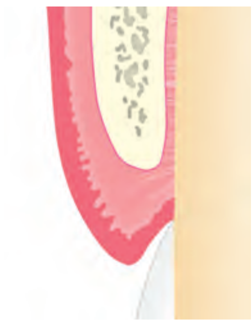
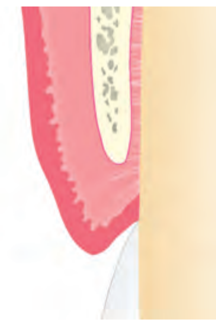
1c

MANAGEMENT OF PERIODONTAL TISSUE PLACEMENT

Placement of the finish line has a great impact on the esthetic and biologic results of prosthetic treatment. In general, the finish line is placed within the sulcus without violating the biologic width. Careful observation of the biotype and anatomical condition of the periodontal tissue of the patient is necessary to determine the ideal placement of the finish line according to specific treatment goals (Figs 1 to 3, Table 1).

TABLE 1 Relationship Between Tooth Morphology and Periodontal Tissue and Its Characteristics (Classification of Gingival Biotype[5] with Modifications from Ran,[6] Obama,[7,8] and the Present Author)

	Thick-flat type	Thin-scalloped type
Tooth morphology	Square	Triangular
Root morphology	Straight (following tooth width)	Tapered
Contour from CEJ to facial cervical area	There are roughly two groups: 1. Smooth transition from root surface 2. Large gap between root surface and facial cervical area (Ovoid, square, or triangular-shaped teeth with a prominent labial middle ridge tend to have a prominent cervical ridge and often fall into group 2)	
Distance between roots	Narrow	Wide
Morphology of gingival margin	Flat	Scalloped
Quality of gingiva	Dense and fibrous	Scarce and weak
Thickness of gingiva	Thick	Thin
Attached gingiva	Wide and strong	Narrow and weak
Shape of alveolar bone	Thick and flat	Thin and scalloped
Difference in height from CEJ to alveolar bone peak	Low	High
Height of interdental papillae	Low	High
Contact position	Low and long contact	Incisal 1/3
Risk factor	Gingiva in this group tends to react to inflammation or other periodontal invasion by gingival growth forming periodontal pocket	Shadow could be created depending on prosthetic material of choice; tends to result in attachment loss or gingival recession if margin placement is not appropriate
Example		

Type 1	Type 2	Type 3	Type 4
			
Thick alveolar bone and gingiva, plenty of attached gingiva	Thick alveolar bone and thin gingiva, less amount of attached gingiva	Thin alveolar bone and thick gingiva, plenty of attached gingiva	Thin alveolar bone and gingiva, less amount of attached gingiva
No chance of gingival recession	Less chance of gingival recession	Less chance of gingival recession	More chance of gingival recession

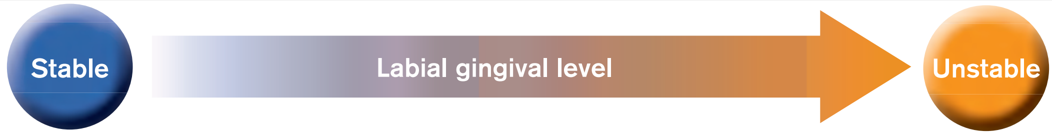


Fig 2 Relationship between gingiva and alveolar bone by classification of Maynard.[9] Figure reproduced from Obama.[7]

CASE 1 All-ceramic restoration for discolored abutment with thin marginal gingiva

Figs 3a to 3d The patient, a woman in her 40s, wished to have the esthetics of her maxillary anterior prosthesis improved. The gingival tissue around the maxillary right lateral incisor and the left central and lateral appear to be inflamed, but it is the color of the roots showing through her thin marginal gingiva. Shadowing of the root area can occur when opaque framework material is used, as in this case. Another option is to place the finish line deeper subgingivally; however, tissue management is more difficult, increasing the risk of gingival recession.

3a

3b

3c

3d

TABLE 2 Treatment Options for Management of the Gingival Framework Showing Changes Before and After Treatment

1: Prosthetic treatment

Before  After

2: Orthodontic treatment + Prosthetic treatment

Before  After

3: Surgical treatment + Prosthetic treatment

Before  After

4: Orthodontic treatment + Surgical treatment + Prosthetic treatment

Before  After

SURGICAL + ORTHODONTIC TREATMENT AND GINGIVAL FRAMEWORK

A surgical approach, such as periodontal plastic surgery, or orthodontic treatment is indicated if extensive improvement of the periodontal tissue is required for esthetics, while some esthetic cases can be managed with prosthetic treatment alone. In Table 2, prosthetic treatment is combined with different treatment options and their limitations are presented.

Summary of Table 2

Improvement of the gingival framework is seen in all cases in Table 2. However, there is clearly a range of improvement. The gingival line is determined by the tooth position and its surrounding periodontal condition. Case selection is important for successful prosthetic tissue management. Since the surgical approach is limited by the tooth position, the gingival framework is improved only in the coronal-apical direction. Orthodontic treatment, which can change the position of teeth three-dimensionally, can achieve more drastic esthetic and functional improvement (Table 3).

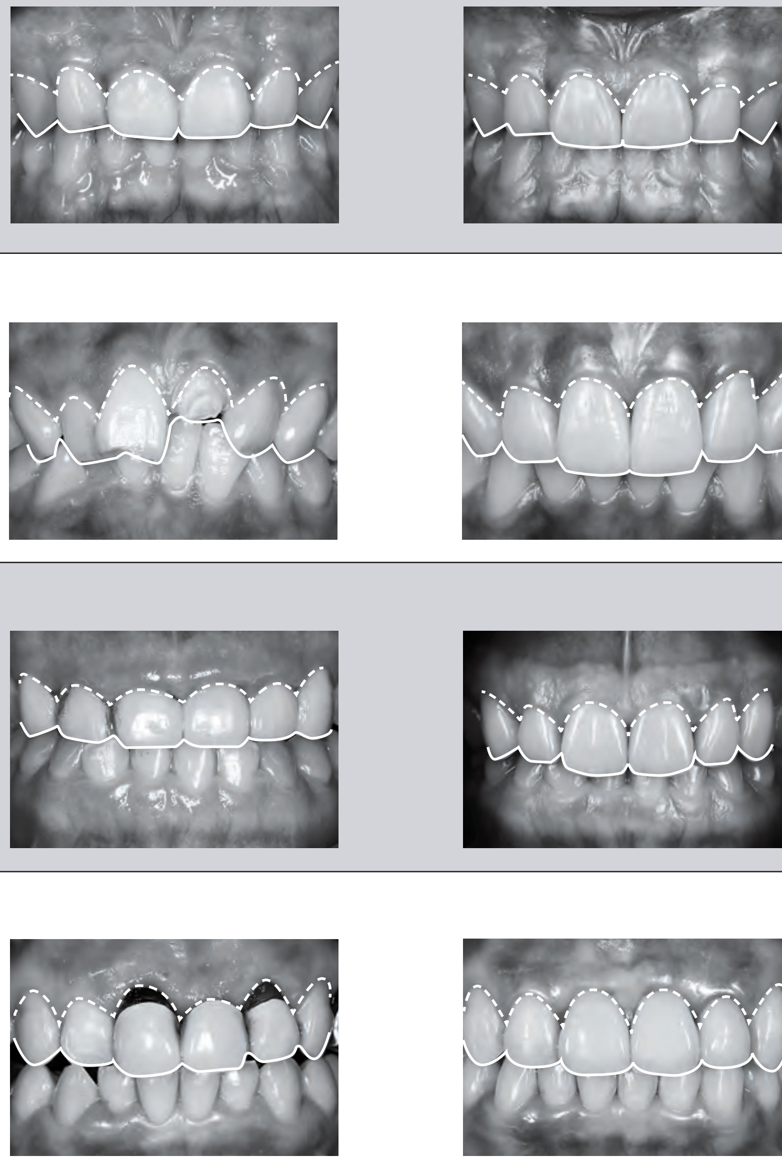


TABLE 3 Limitation of Each Treatment Approach (Frontal View)

Prosthetic treatment	Indication is limited and only up to 1 to 2 mm of gingival-level change is expected
+ Surgical treatment	Change of gingival framework in coronal-apical direction is possible
+ Orthodontic treatment	Change of gingival framework in coronal-apical and mesial-distal directions is possible; more effective esthetically and functionally than other treatment approaches

Fig 4 Decision-making factors of subgingival contour.

CONCEPT OF SUBGINGIVAL CONTOUR

Over the last 40 years there has been a lot of discussion in the literature about crown contour and gingival response. Subgingival contour after subgingival abutment preparation has a major impact on the gingiva. Excellent marginal fit, smooth surface texture, and adequate pressure to support the marginal gingiva are necessary to obtain intimate contact between the prosthesis and gingiva to achieve periodontal harmony. There is a range of "adequate contour" between undercontour and overcontour that allows prosthetic control of the marginal gingiva without causing inflammation or gingival recession. Peri-implant periodontal tissue has a greater range of "adequate contour" than that of natural teeth due to the different biologic conditions. The *(1)* placement of finish line, *(2)* thickness of marginal gingiva, and *(3)* design of the gingival edge (position, morphology) are the main factors for achieving "adequate pressure" according to biotype (Figs 4 and 5).

In 1977, Wagman stated that the prosthesis should maintain subgingival contour not exceeding 1/2 of the thickness of marginal gingiva for adequate support.[9] He found marginal gingiva tends to be a roll shape with a flat subgingival contour not adequately supporting it. Proper subgingival contour protects the gingival sulcus and it forms a knife-edge like free gingiva, which is important for plaque control.[10] A subgingival profile is designed depending on the placement of the finish line and it is not always a convex shape. Wagman's statement "subgingival contour not exceeding 1/2 of the thickness of marginal gingiva" (Fig 6) is a guideline followed at the author's practice.

The morphology of the prosthesis has two components: "subgingival morphology according to biotype" and "supragingival morphology," which are divided at the level of the free gingival margin. The subgingival area of the final prosthesis is produced after precise diagnosis and information from the provisional restoration (Figs 7a to 7c).

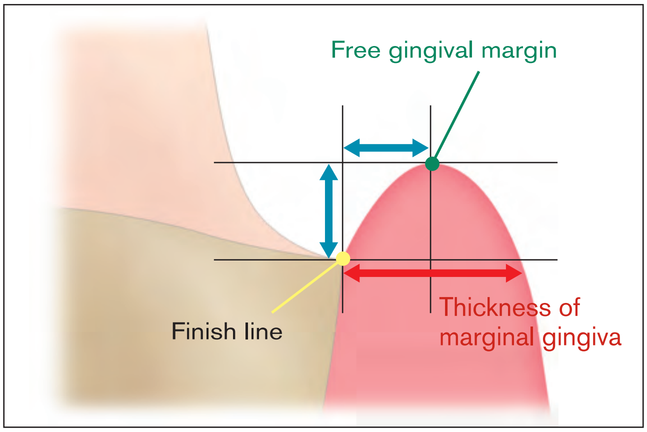


Fig 5 Relationship of factors to design subgingival contour. Capturing the precise position of the free gingival margin is very important.

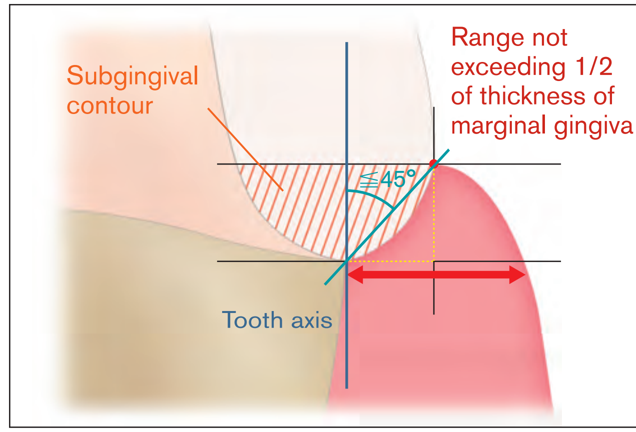
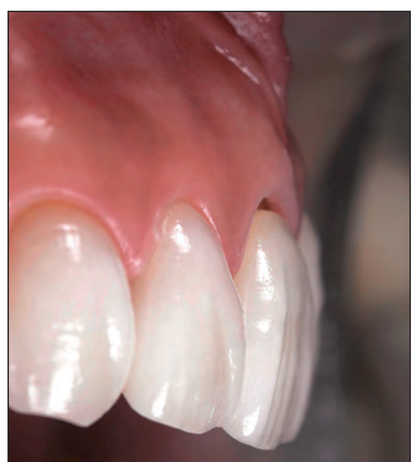


Fig 6 Illustration of subgingival contour based on the statement of Wagman.[9] If the angle of subgingival contour exceeds 45 degrees, it is difficult to maintain the height of free gingival margin.

7a

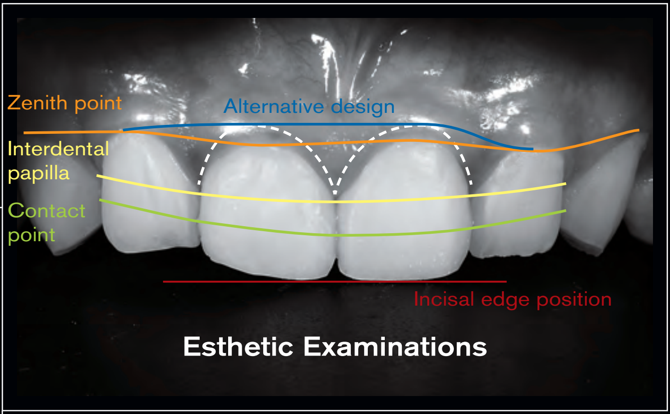


7b

7c

Figs 7a to 7c Proper transition of crown axis surface morphology from the subgingival contour.

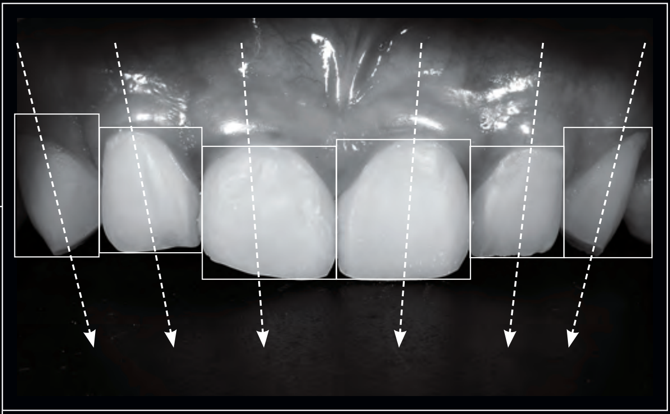
CASE 2 Improvement of gingival level by prosthetic treatment



8b

8a

8c



8d

Figs 8a to 8d The patient, a woman in her 20s, was not happy with the color of her maxillary central incisor crowns. After esthetic analysis, it was decided to extend the clinical crowns apically to improve the gingival framework. The symmetry and uniformity of the dentition were within normal limits, and the periodontal condition seemed to be adequate from the position of the interdental papillae. *(d)* Analysis by Aki Yoshida's technique as presented in Sulikowski and Yoshida.[11]


8e


8f


8g


8h


8i


8j

Figs 8e and 8f ***Preoperative diagnosis.*** The central incisors were nonvital and the probing depth of the labial aspect was 3 mm. The cementoenamel junction (CEJ) was apical of the finish line of the prosthesis. Both incisors were diagnosed as having altered passive eruption. After consideration of this and the biotype, the gingival framework was managed by a prosthetic approach alone without any surgical intervention. The direct mock-up technique was used to reproduce the ideal clinical crown length and gingival level to determine placement of the finish line.

Figs 8g and 8h ***Provisional restoration.*** After direct mock-up, the final gingival line and finish line were determined. The gingival architecture was carefully modified subgingivally with the provisional restoration.

Figs 8i and 8j ***Monitoring.*** Condition of the gingiva after insertion of the provisional restoration. The gingiva was responding well without any inflammatory reaction. The marginal gingiva was properly reshaped by the provisional restoration. Precise chairside tissue management enabled a smooth transition to the final prosthesis.

8k

8l

8m

8n

8o

8p

8q

8r

8s

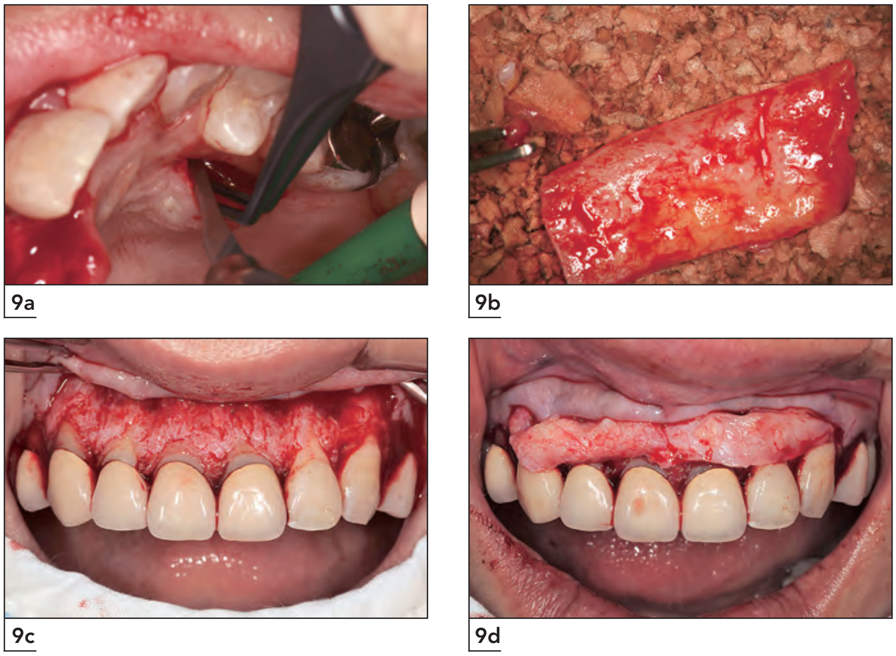
8t

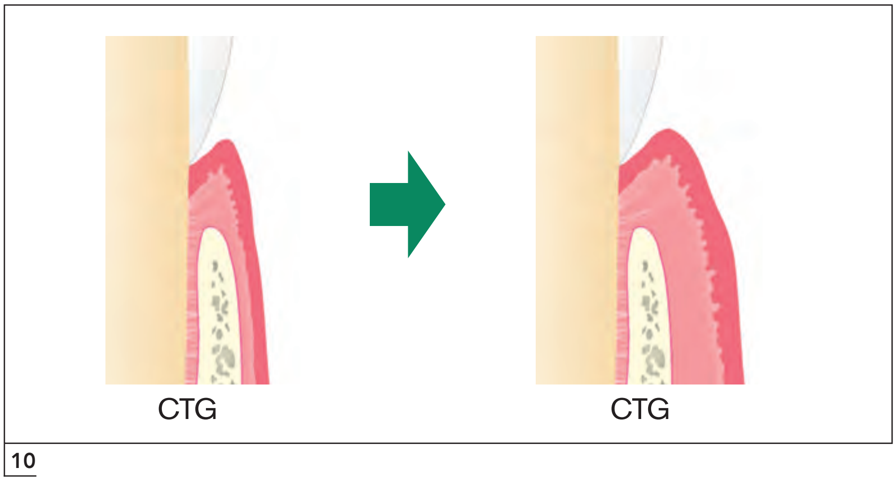
8u

8v

Figs 8k to 8t ***Final restorations.*** Subgingival contour is designed with great attention to the marginal gingival morphology managed by the provisional restoration. It is designed to apply adequate pressure on the gingiva.

Figs 8u and 8v Three months after final prosthesis placement. The gingival response is excellent, and a healthy periodontal condition can be seen. A well-harmonized gingival framework was achieved, restoring proper length of the incisors by a precisely formed subgingival contour (IPS e.max Press, Ivoclar Vivadent).





Figs 9a to 9d Periodontal plastic surgery. *(a)* Connective tissue is taken from the palate. *(b)* Subepithelial connective tissue graft. *(c)* Maxillary labial gingival flap is opened. *(d)* Connective tissue graft placed in the recipient site. Drastic change of soft tissue is expected. (Photos courtesy of Dr Kotaro Nakata.)

Fig 10 Increased gingival thickness by surgically modified tissue biotype (CTG, connective tissue graft).

PERIODONTAL PLASTIC SURGERY AND PROSTHETIC MANAGEMENT

Periodontal plastic surgery is used to eliminate periodontal problems and create a better periodontal condition in order to obtain a better esthetic and biologic result with restorative treatment. Careful prosthetic management after surgical treatment is necessary in cases in which the tissue biotype is changed significantly by surgery. For instance, great caution is required if surgical treatment involves an apically positioned flap or connective tissue graft, which will change the gingiva–alveolar bone relationship extensively (Figs 9 and 10).

As stated previously, subgingival management involves tissue support based on the thickness of the marginal gingiva. If the thickness of the marginal gingiva is greatly increased, the profile of the supporting restoration needs to be adjusted accordingly to support and maintain it.

CASE 3 Improving esthetics by clinical crown lengthening and prosthetic management

11a

11b

11c

11d

11e

11f

Figs 11a and 11b The patient, a woman in her 30s, was not happy with the esthetics of her six anterior restorations. She presented with extensive gingival inflammation and a gummy smile. It was clear that deep subgingival preparation had been performed to lengthen the clinical crowns, violating biologic width. Prosthodontic treatment was performed after crown lengthening to expose an adequate amount of clinical crown.

Figs 11c and 11d After the flap was raised, the clinical length was determined using the surgical template. Alveolar bone resection and reshaping were then performed, respecting the biologic width. It is clear that the finish line of the existing restorations was placed rather deep.

Figs 11e and 11f Condition after the surgical procedure. A well-balanced teeth-gingiva-lip relationship with healthy periodontal condition was created. An adequate amount of attached gingiva was secured from the width of keratinized gingiva. Enough marginal gingiva (thickness and height) to design the final gingival framework was maintained after definitive surgical treatment using the surgical stent. However, a red band, which often appears after periodontal surgery, can be observed. After the gingiva matured, the final finish line was placed according to the gingival framework designed using the provisional restoration.

11g

11h

11i

Figs 11g to 11i Trimming of the model and gingival framework design. Trimming is based on the symmetry and uniformity of the gingival level and line. The subgingival contour was determined after confirming that enough gingival thickness was secured when designing the final marginal gingival morphology.

Biotype changes after surgery in this case

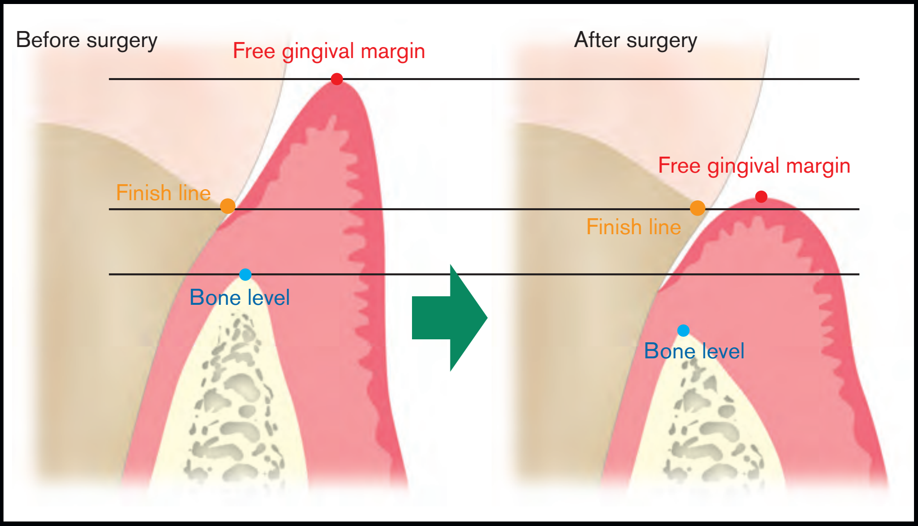


Fig 11j Substantial change in the periodontal tissue condition can occur after periodontal plastic surgery by altering the relationship of hard and soft tissue. In cases of surgical crown lengthening, the gingiva and peak of alveolar bone are apically repositioned, resulting in thicker keratinized soft tissue (free gingiva and attached gingiva). With this dramatic change in biotype, specific morphologic consideration is required for prosthetic management. If surgical treatment involves an increase of soft tissue, as with placement of a connective tissue graft, further consideration is necessary.

11k

11l

11m

11n

11o

Figs 11k to 11o One year posttreatment. Appropriate gingival framework is provided by well-designed subgingival contour. The red band that appeared after surgery has subsided completely by applying proper pressure on the thickened marginal gingiva. The prognosis is good due to the mature, healthy periodontal condition (IPS e.max Zirpress, Ivoclar Vivadent).

Consideration of subgingival contour

This case

11p

Natural dentition

11q

Figs 11p and 11q Natural dentition usually has a slight bulge (subgingival contour) with a smooth transition from the root surface to the CEJ. In this case, however, there was a clear discrepancy between the long axis of the tooth and subgingival contour of the prosthesis. Biotype has to be checked carefully to design subgingival contour, especially if soft and hard periodontal tissues have been altered by surgery. The angle of the subgingival contour of this case shows the support for increased gingival thickness. Recontouring of the prosthesis is often required when the biotype is altered from thin to thick. The relationship between the marginal gingiva and finish line should be considered carefully with the concept to "provide adequate contour according to the thickness of the marginal gingiva."[12,13]

CONCLUSION

Subgingival management in prosthetic treatment has been presented and analyzed in detail with case presentations. As has been shown, careful chairside treatment is most important for successful prosthetic treatment that is in harmony with the periodontal tissue.

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Digital Workflow for 3D-Printed Interim Immediate Complete Dentures: The One-Appointment Approach

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The 3D-printed interim immediate complete denture allows complex rehabilitations to be executed in a single visit while providing superior restorative precision. The following case presentation describes the steps involved.

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1a


1b


1c


2


3

Figs 1a to 1c Extraoral views of patient upon presentation to the clinic.

Fig 2 Intraoral view of failing dentition.

Fig 3 Intraoral maxillary scanning.

4a

4b

Figs 4a and 4b Intraoral scanning showing patient in centric relation and the existing vertical dimension of occlusion.

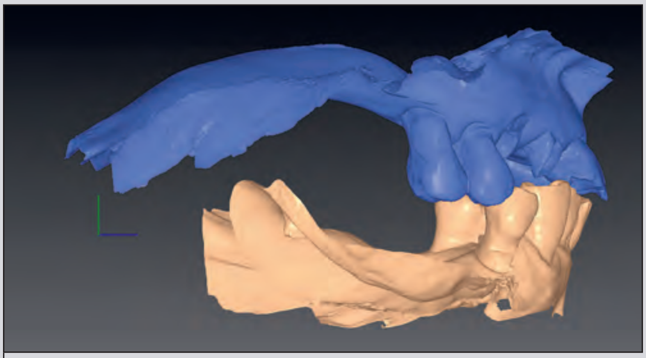
CASE PRESENTATION

The patient presented to the clinic with severe caries and loss of periodontal attachment (Figs 1 and 2). The treatment plan called for extraction of all teeth in the maxilla due to the poor prognosis followed by placement of a maxillary interim immediate complete denture.

Scanning was performed with the Medit i500 intraoral scanner (Figs 3 and 4). The patient was then referred for extraction of the maxillary teeth while the restorative team designed (Figs 5 and 6) and fabricated the interim immediate complete denture, according to the following sequence (Figs 7 to 10):

1. Matching
2. Trimming
3. Landmarks
4. Verification
5. Teeth set-up

Design and Fabrication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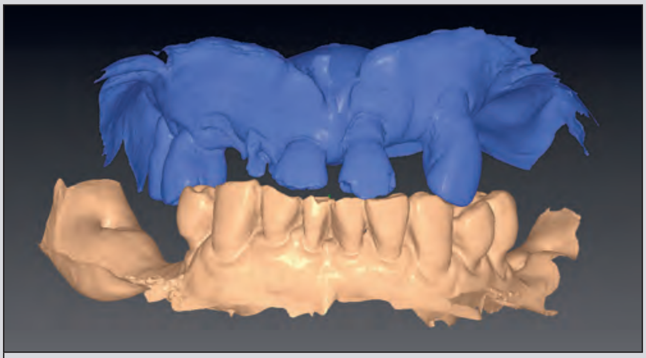
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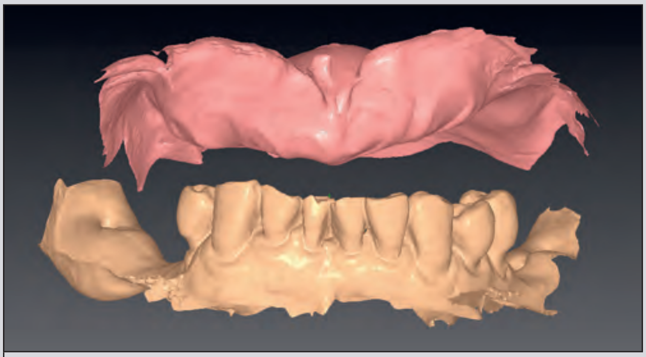
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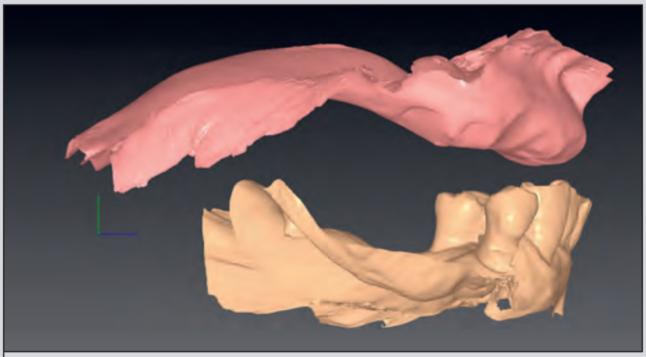

6b

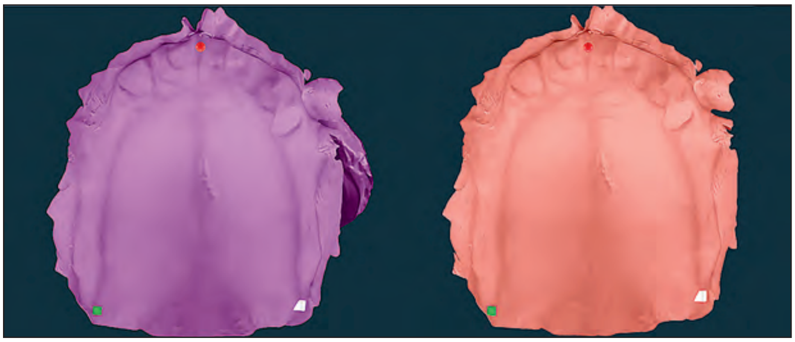
Fig 5a STL files are transferred to the denture design software (www.dentcadesign.com).

Fig 5b Lateral view of the maxillary and mandibular arches in centric relation.

Fig 6a STL file of maxillary and mandibular arches depicting maxillary teeth digitally removed.

Fig 6b Lateral view in centric relation.

Matching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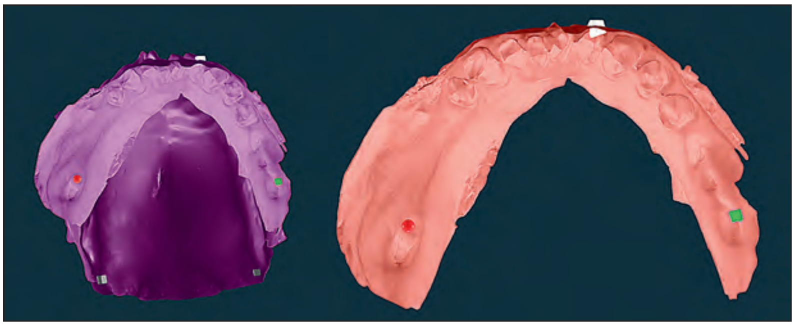
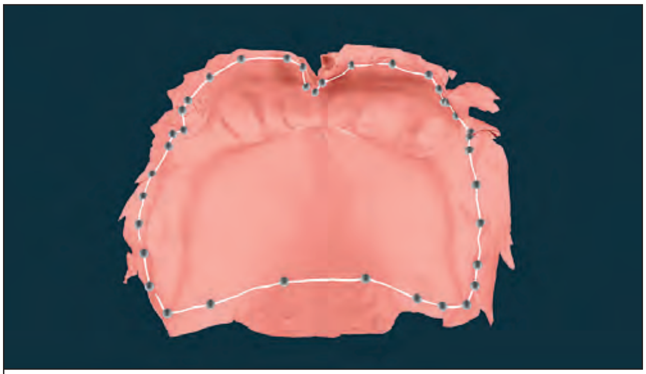

7b

Figs 7a and 7b The alignment is matched using three matching points (green, red, and white dots) between the STL of the patient in occlusion (purple) and the images of the ridges (salmon) for both maxillary and mandibular arches.

Trimming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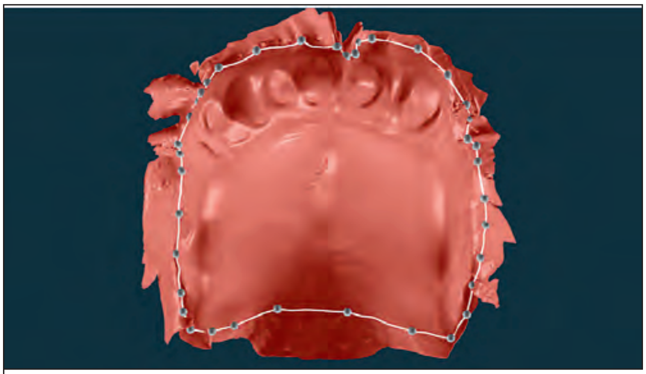
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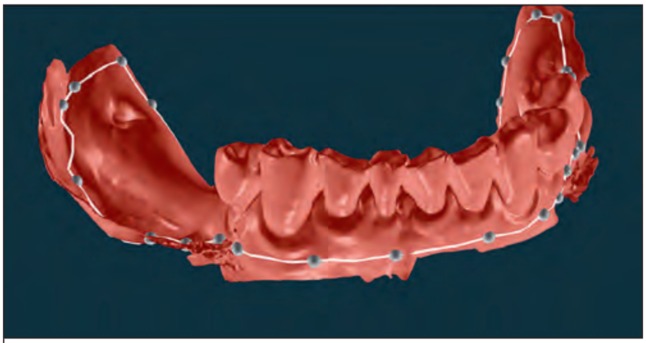
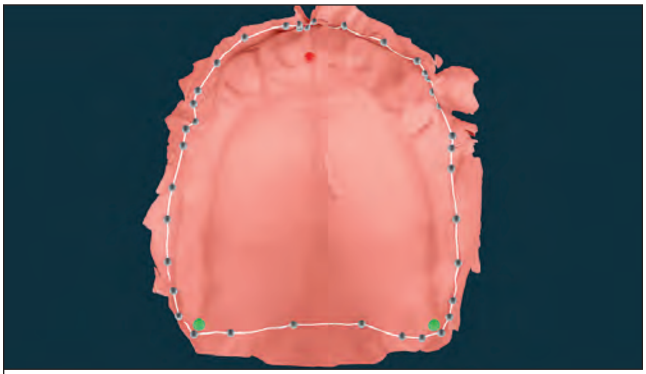
Figs 8a to 8c Trimming is performed at the depth of the vestibule, and the excess information of the STL file is then eliminated for both maxillary and mandibular arches.


8c

Landmarks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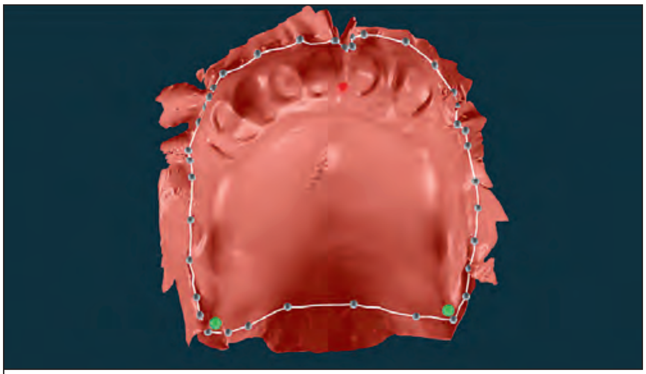
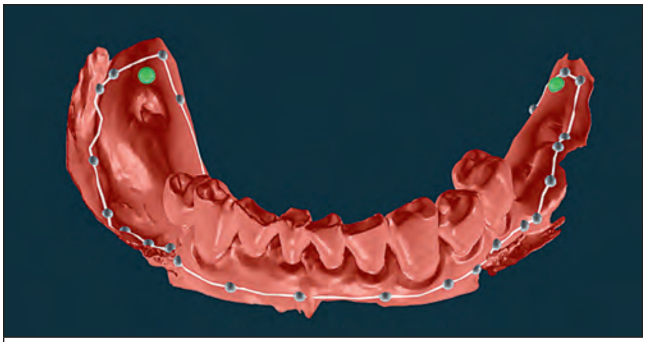

9b

Fig 9a Right and left hamular notches are identified (green dots) in the image of the patient in occlusion.

Fig 9b Similarly in the STL of the ridges, the right and left hamular notches are identified.

Fig 9c In the mandibular file, the center of the pear-shaped pad is identified and marked (green dots).

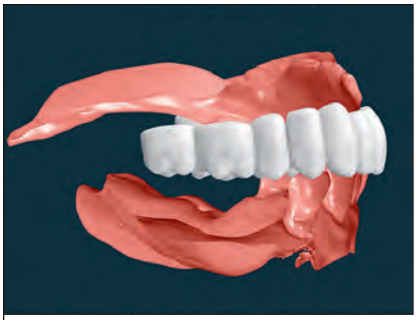

9c

Verification

During the verification phase, the restorative team selects the type of desired anterior overjet (Class I, Class II, or Class III), followed by the teeth mold and shape (universal, square, oval) and teeth arrangement (standard, masculine, or feminine).

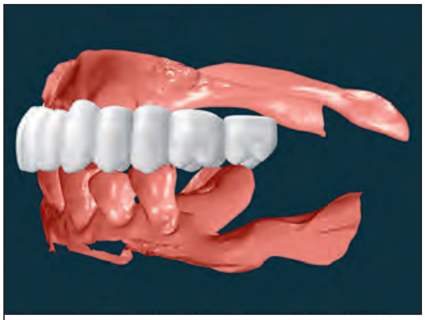
Teeth Set-up

The teeth position is verified in relation to alveolar ridge, anatomical landmarks, and opposing dentition. During the teeth set-up, the operator is able to move the teeth as a block (anterior or posterior) or individually, and evaluate the occlusal contacts.



10a

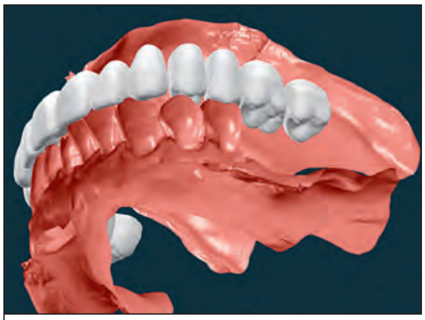
10b



10c

10d

10e



10f

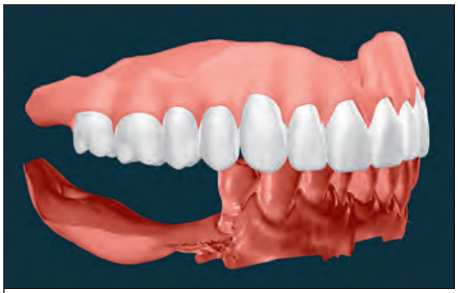
10g

10h

Figs 10a to 10c Frontal and lateral views of digital teeth set-up.

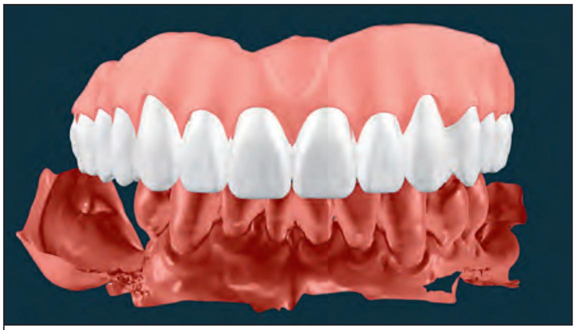
Figs 10d to 10f Occlusion, overbite, and overjet are verified digitally.

Figs 10g and 10h Additional views of the teeth set-up.



11a

11b

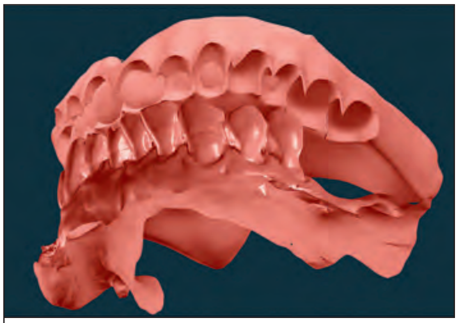


11c

Figs 11a to 11c Final design, frontal and lateral views.

12a

12b



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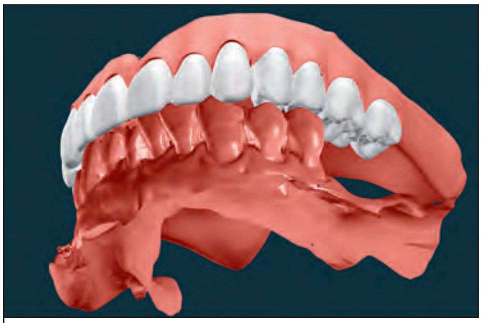


12d

Fig 12a Relationship between the base only and opposing dentition, showing the appropriate interocclusal space for setting the teeth.

Fig 12b Same view with teeth in place.

Fig 12c Occlusal relationship between the base only and opposing dentition.

Fig 12d Same view with teeth in place.

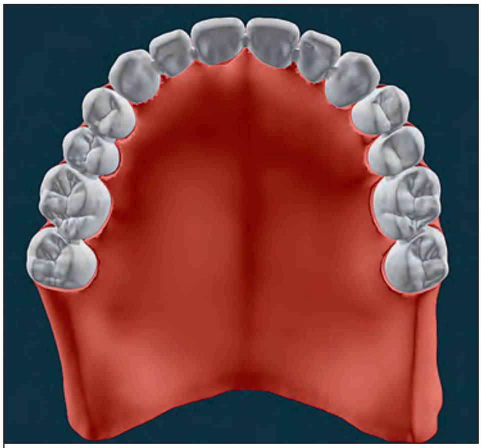
FINAL DESIGN

Once the teeth position is approved by the operator, the software generates the final design of the interim complete denture including the denture base. One can then evaluate the relationship between the base and the digital teeth, including festooning (Figs 11 to 14).

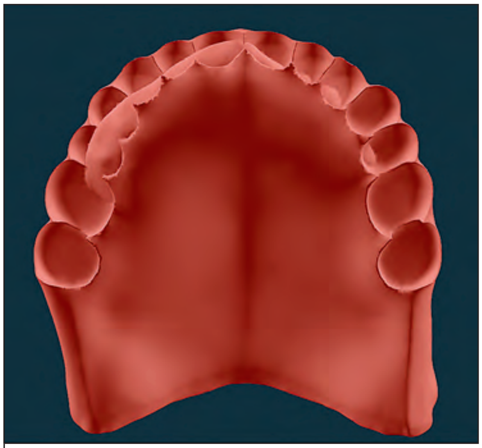
The interim immediate complete denture after 3D printing is shown in Figs 15a and 15b, and the smiling patient in Fig 16.

13a

13b



14a



14b

14c

Figs 13a and 13b Right and left lateral views of the occlusal relationship, overbite, and overjet of the final design.

Fig14a Occlusal view of the final design of the interim complete denture.

Fig 14b Base design of the interim complete denture.

Fig 14c Frontal view of the final design.

CONCLUSION

Digital technologies have revolutionized the way in which dentures are executed. The all-digital 3D-printed interim immediate complete denture represents a new benchmark for the rehabilitation of patients with failing dentition. The physical impression, pouring of casts, conventional teeth set-up, and denture processing are completely eliminated, resulting in superior time efficiency and a high-quality final outcome.

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Figs 15a and 15b Interim immediate complete denture after 3D printing.

Fig 16 Final outcome of smiling patient with 3D-printed digital interim immediate complete denture fabricated in a single appointment.

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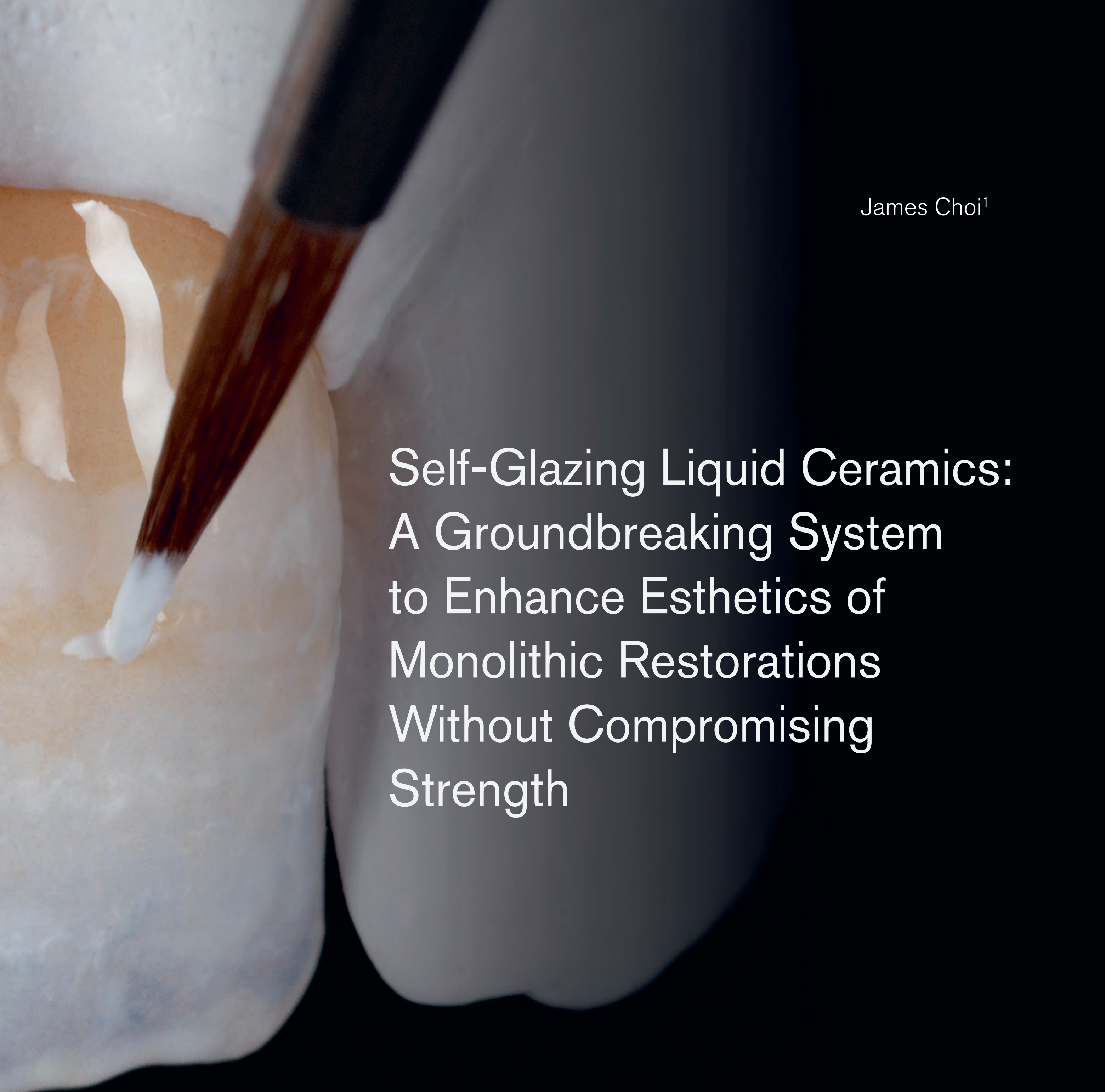


James Choi[1]

Self-Glazing Liquid Ceramics: A Groundbreaking System to Enhance Esthetics of Monolithic Restorations Without Compromising Strength

A balance between strength and esthetics is important for the longevity of the definitive restoration. While monolithic restorations provide the benefit of strength, they have limitations in terms of esthetics.

In the typical monolithic procedure, the restoration is fired after the addition of stains and again after glazing. Stains are a set of colors that are added to some areas to build thickness to achieve the saturation of color and then fired to set the color in place. Glaze is applied when color saturation and placement are achieved, after which another firing cycle is required. Although these procedures improve the appearance of monolithic restorations, the inability to control the surface texture during staining procedures makes it difficult to mimic nature. Another option to improve esthetics is to cut back the monolithic restoration; however, this significantly decreases the overall strength of the final restoration. For these reasons, clinicians and technicians have been limited in their ability to achieve greater esthetics without using traditional ceramic materials overlaying zirconia substructure or lithium disilicate glass-ceramic materials.

1a

1b

2

Fig 1a Sintered monolithic zirconia restoration before application of liquid ceramic.

Fig 1b Monolithic zirconia restoration after application of self-glazing liquid ceramic.

Fig 2 Surface texture created by the technician with the MiYO liquid ceramic system.

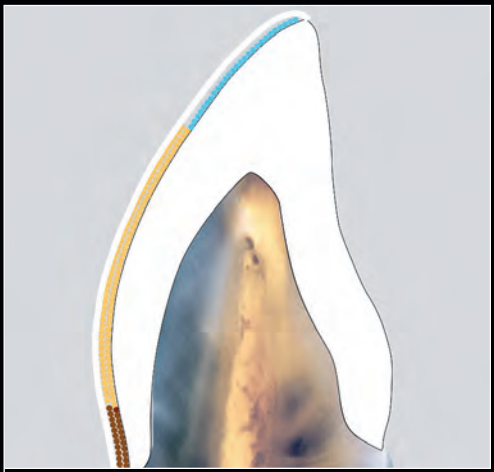
LIQUID CERAMIC SYSTEM

Recently an innovative self-glazing liquid ceramic (MiYO, Jensen Dental) was developed as an alternative to layered ceramics to improve the esthetics of monolithic CAD/CAM or pressed-ceramic restorations. Based on glazing material, this liquid ceramic allows tooth shade and shape modifications, accentuated character, and customization while simultaneously enhancing the surface texture of the monolithic restoration (Figs 1 and 2). The liquid ceramic creates an ultrathin ceramic layer that eliminates the need for framework cutback. This is an important factor, since the strength of the ceramics will not be modified through cutback techniques. All color saturation and customization can be achieved at a thickness of 0.1 to 0.2 mm on the ceramic surface (Figs 3a and 3b).

Different color schemes with translucent, semi-translucent, and opaque self-glazing colors were created to improve the color, shade, and shape of zirconia-based and lithium disilicate ceramics (MiYO Liquid Ceramic Color), as follows:

- *High opacity:* Used for mamelons (Mamelon Wheat, Mamelon Coral, Mamelon Pumpkin), hypocalcifications (Snow), and pits, fissures, and stains (Fissure).
- *Medium opacity:* Used for incisal halo (Halo Spring, Halo Autumn) and crack lines (Linen).

3a



3b

Fig 3a Sixteen colors and one structure paste were applied to the central incisor; four colors and one structure paste were applied to the gingiva. No cutback is needed to create the necessary esthetics.

Fig 3b Cross section of the central incisor.

- *Translucent:* Used for modification or enhancement of hue (Shade A, B, C, and D), plus other colors for incisal translucency or cervical characterization (Sage, Straw, Lotus, Clementine, Smoke, Storm, Cobalt, and Slate); Lumin and Lumin Plus can raise value without adding opacity.
- *Structure:* Building materials with different translucency adding light-scattering properties to create and/or modify the restoration's shape, line angles, and surface texture detailing (Window, Enamel, Ghost, Ice, and Blush).

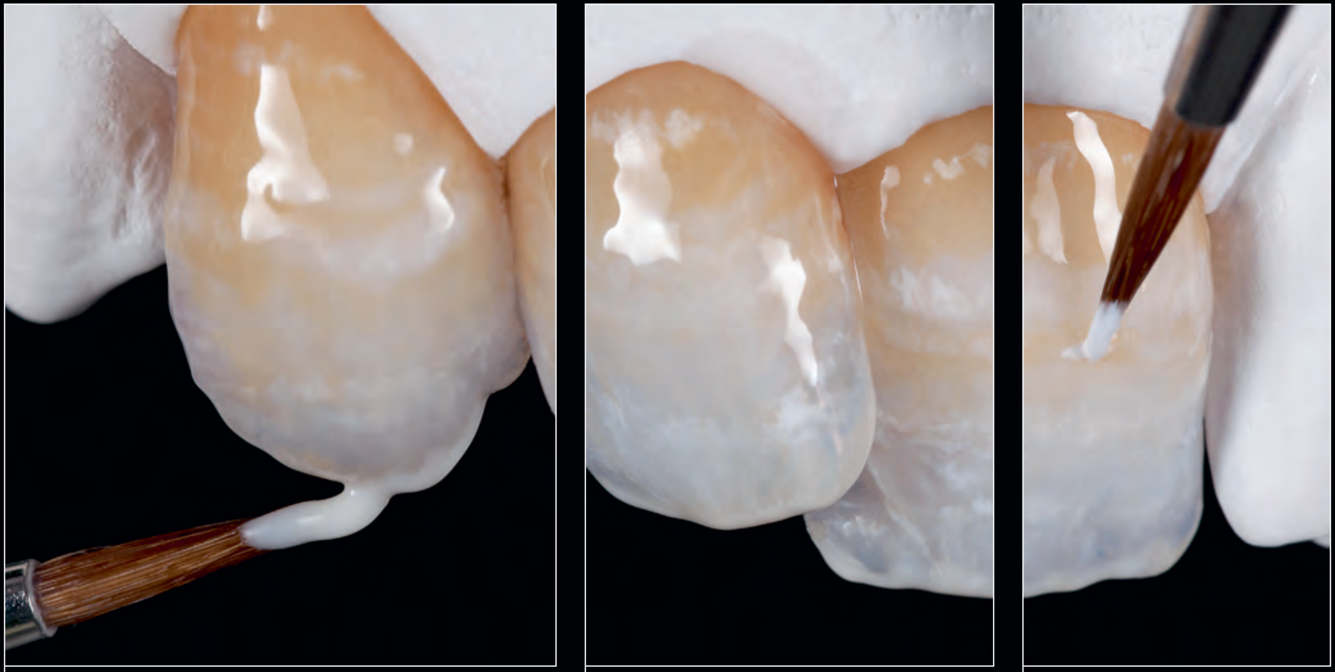
Self-glazing liquid ceramic allows modification of a restoration's desired color and value without adding opacity. The final outcome can be visualized before firing, allowing predictability and improved control of the esthetics of a monolithic restoration (Figs 4 and 5). The characteristics of traditional ceramic (the ability to layer depth) and stains (the ability to see the outcome prior to firing) have been developed in this liquid ceramic system (Figs 5 to 7).

Specific self-glazing liquid ceramic colors of different translucencies and opacities were also created to improve the esthetics of gingival tissues (MiYO Pink Liquid Ceramic for Tissue):

- *High opacity* (Flamingo, Crimson, Plum, Merlot, Sorbet, Salmon, Sable, Thistle)
- *High translucency* (Midnight, Raspberry, Copper)
- *Structure* (Orchid, Rouge, Frost)
- *Glaze*

The case presentation describes the ease of use of this new system for monolithic restorations and the esthetic results that can be obtained.

4



5a 5b 5c

Fig 4 Desired color and glaze can be achieved with one firing.

Figs 5a to 5c With the liquid ceramic concept, all color is applied at one time, with the ability to layer depth and to see the final outcome prior to firing.

Fig 6a Surface texture created prior to the firing cycle.

Fig 6b Directly after the firing cycle. Surface texture and glazing have been achieved at the same time.

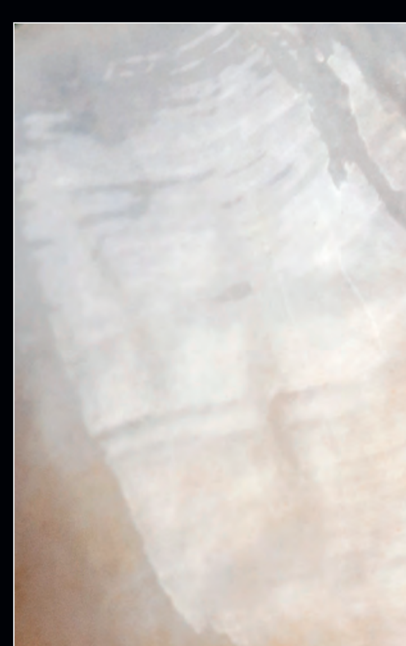
Fig 7a Close-up of texture created prior to firing.

Fig 7b Close-up of texture and glaze after firing cycle.

6a

6b

7a



7b

8

9a

9b

10

11

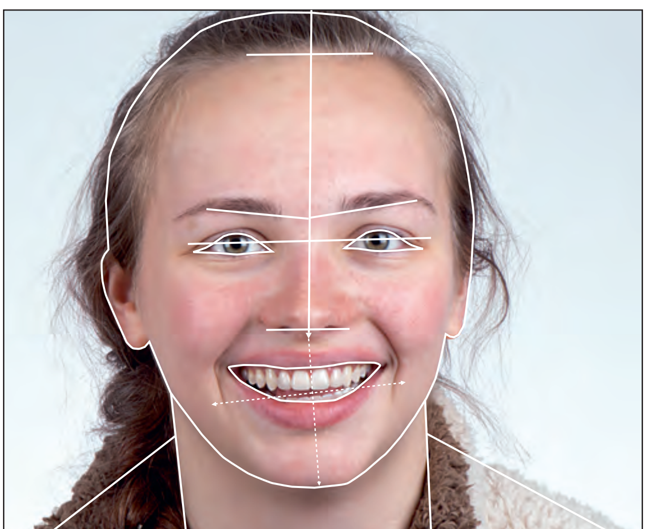


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Fig 8 Shade is taken for teeth using the mandibular anterior teeth as a reference (Dr Brian Vence).

Figs 9a and 9b Shade is taken for gingiva using the mandibular and maxillary arches as a reference.

Fig 10 First restoration finished on the model.

Fig 11 Try-in and evaluation for corrections to be made.

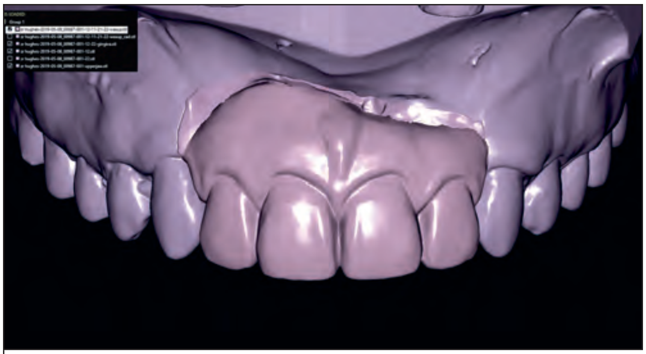
Fig 12 Evaluation to achieve facial balance.

CASE PRESENTATION

A 22-year-old female patient lost her maxillary incisors due to trauma (falling down stairs) at the age of 14. She went through several unsatisfactory removable denture restorations before having two implants placed in the area of the maxillary lateral incisors. Unfortunately, due to osseous and gingival tissue defects, a new restoration was required to improve the white and pink esthetics.

A provisional restoration was fabricated using polymethyl methacrylate (PMMA), and several corrections were made to serve as a template for the definitive restoration. The shade of the mandibular anterior teeth was used to create the new color scheme for the maxillary anterior restoration (Fig 8). Gingival pink shade selection was accomplished based on both the maxillary and mandibular arches (Figs 9a and 9b).

13



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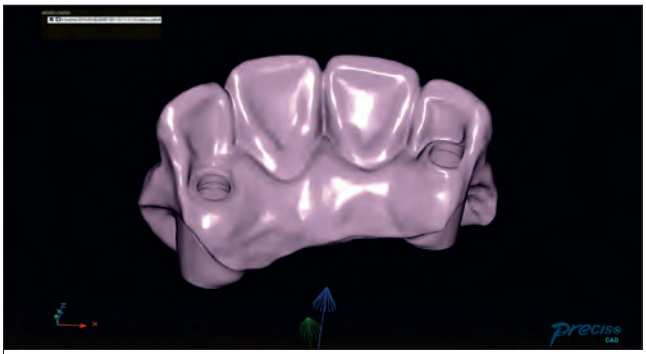

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Fig 13 Correction on the wax-up (from the original scan).

Fig 14 Digital scan file of the corrected wax-up.

Fig 15 Sintered zirconia with ceramic extension on the gingival region.

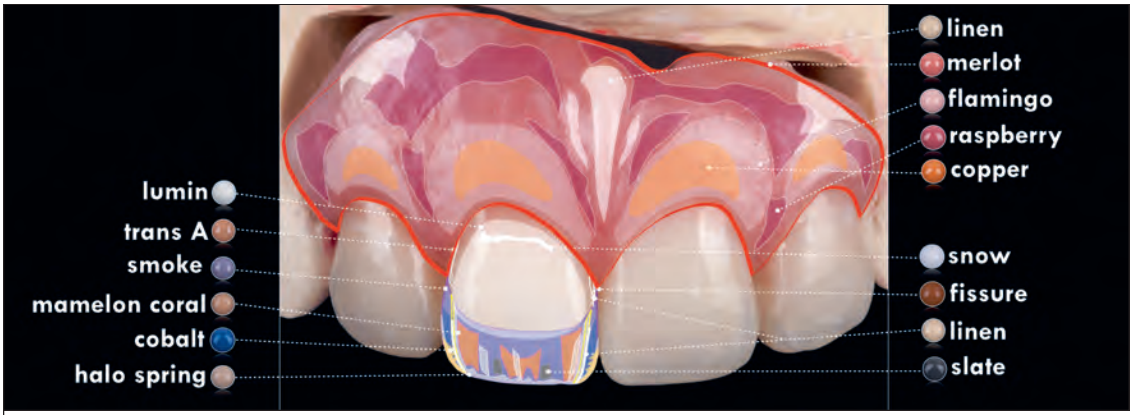
Fig 16 Digital scan file of the palatal view.

Fig 17 Polished palatal functional surface.

17

A monolithic zirconia restoration was fabricated (XT Zirconia, Jensen) and colored using the new liquid ceramic (Fig 10). The restoration was then tried in the patient's mouth and also verified with the patient's smile and face (Figs 11 and 12). The try-in revealed the need for the following adjustments: *(1)* increased coverage of gingival contour in the area of the left central and lateral incisors, *(2)* repositioning of the gingival zenith and lengthening of the incisal edges of the right central and lateral, and *(3)* slight modification of the midline.

It was decided to create a new wax-up to improve the appearance of the restorations (Fig 13). The new wax-up was scanned and a new monolithic zirconia restoration was milled (XT Zirconia, Jensen) and sintered according to the manufacturer's instructions (Figs 14 to 17). No cutback was performed on the zirconia framework, allowing the new



18

19a

19b

20a

20b

21a

21b

Fig 18 Schematic showing the liquid ceramic colors applied.

Figs 19a and 19b After application of *(a)* liquid ceramic colors and *(b)* structure paste to create surface texture.

Fig 20a Final outcome photograph (with no filters on camera) to evaluate all esthetic details.

Fig 20b Cross-polarized photograph.

Fig 21a Dynamic photograph to evaluate surface texture of the restoration compared to the surrounding natural dentition.

Fig 21b Cross-polarized photograph at dynamic angle to evaluate esthetic details.

22a

22b

Figs 22a to 22c Facial balance is achieved. Facial asymmetry needs to be evaluated by both the dental clinician and technician prior to fabrication of the restorations to successfully balance the smile with the facial structure as a whole.

ceramic extensions to better blend into the patient's gingiva. The restoration was then characterized using liquid ceramic (Figs 18 and 19) and fired as recommended by the manufacturer.

The final outcome revealed natural esthetics similar to what could be achieved with layered ceramics but without any framework reduction (Figs 20 to 22).

22c

CONCLUSION

Monolithic restorations provide the benefit of strength but are known to fall short in terms of their esthetics. Past outcomes using "white gold" have biased dental professionals against the use of full-contour monolithic restorations because of their esthetic limitations. Materials today are rapidly evolving to manage light transmission similar to ceramic systems. Mimicking nature with full-contour restorations now appears to be possible with the liquid ceramic approach, offering a solution to achieve strength and esthetics without compromising the patient's situation and esthetic demands.

Optimal Tooth Preparation with Different Tooth Reduction Guides: Case Presentation

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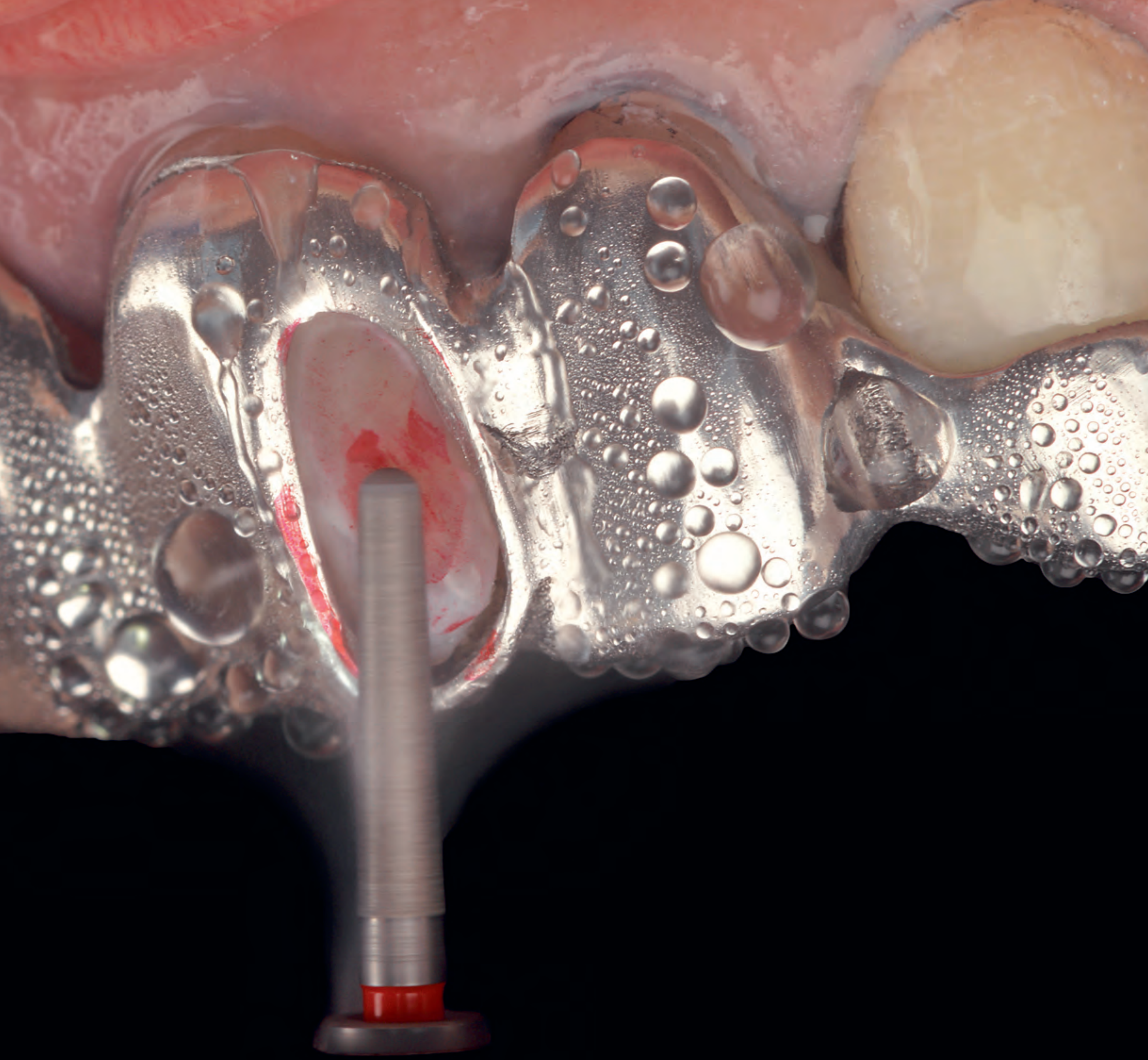


Optimal tooth reduction is a key requirement for esthetics, function, and longevity of fixed restorations, especially metal-ceramic and all-ceramic restorations.[1] Adequate tooth preparation can provide uniform reduction and sufficient clearance to allow the necessary thickness of the final restoration without disturbing the periodontal health, esthetics, and structural integrity.[2] The ability to re-treat the restored teeth should be considered by the clinician when choosing a conservative or an aggressive approach to treatment, especially for young adult patients.[3] It is highly suggested that a conservative approach be used on any occasion possible as an alternative to treatment options that may sacrifice tooth structure.[4] Veneers have become the most common conservative fixed restoration because they require only 25% to 50% of the tooth reduction necessary for complete-coverage crown restorations.[5] Nevertheless, adequate buccal reduction is important to create optimal adhesion. Excessive buccal reduction can lead to compromised bond strength due to penetration of the dentin.[6]

In the late 1920s, Dr Charles Pincus described the first porcelain veneers retained by a denture adhesive during cinematic filming.[7] Unfortunately, the restoration was fragile and it needed to be removed after filming because no adhesive system existed at that time for long-term attachment. Currently, veneer restorations show high survival rates. One study reported a success rate of 98.4% for 186 veneers placed over a period of 5 years.[8] Another study showed a 93% success rate for 3,500 veneers after 10 years.[9] The initial indications for porcelain veneers are for treating fractured, malformed, and discolored teeth. Today, veneers are included in more complex treatments such as full-mouth rehabilitations, restoration of endodontically treated teeth, and restoration of worn dentition.[10–12]

Tooth reduction guides are recommended to make uniform space for the restoration and avoid an undesirable situation, especially when the teeth are misaligned, tilted, rotated, or need significant alterations.[13,14] For a fixed dental prosthesis, an ideal contour is established by means of the diagnostic wax-up, including any modification in vertical dimension and orientation in the plane of occlusion.[15] Typical reduction guides are fabricated either with a polyvinyl siloxane (PVS) putty impression material or thermoplastic sheet.[15,16] The reduction guide is seated intraorally and the clearance for the future restoration is evaluated visually and quantified. The PVS putty impression material is preferred for prosthodontic procedures because it duplicates and accurately transfers the diagnostic wax-up; however, a silicone putty guide is bulky and not practical for posterior use and requires additional procedures for the fabrication of interim restorations.[17,18] A thermoplastic sheet is fairly easy to use on both anterior and posterior teeth. It allows adequate visual evaluation as well as measurement of the clearance using a periodontal probe placed through holes or slots made through the matrix. An accurate duplication of the axial/occlusal/incisal contours is obtained through pressure vacuum and intimate adaptation of the sheet over the duplicate cast of the diagnostic waxing, although the duplication of the occlusal/incisal surface details may be compromised. Evaluation of the reduction may not be accurate because the procedure is performed intraorally, the clear sheet blends with the tooth color, and the periodontal probe may not be calibrated for fixed restoration treatments.

Clinical verification of the tooth during preparation using a single type of guide can be problematic because the range of labial reduction for laminate veneers is small (0.3 to 0.9 mm). Veneer preparation without the use of reduction guides can result in either insufficient or excessive tooth removal.[19–21] Thus, the aim of this article is to describe different types of tooth reduction guides for effective preparation of anterior teeth.

CASE PRESENTATION

A 34-year-old female patient presented to the clinic with the chief complaint "I do not like my temporary crown and I want to improve my smile" (Fig 1a). The patient had recently moved to the United States and had unfinished dental treatment. She presented with a provisional crown on the maxillary right lateral incisor and was not satisfied with her smile. After detailed assessment, the diagnosis was Class I occlusion, generalized gingivitis, localized mild worn dentition of the maxillary anterior teeth, space between the maxillary right lateral incisor and canine, lack of tooth proportion, protruded maxillary right central incisor, rotated maxillary left central incisor, and stained anterior composite restorations (Figs 1b to 1e).

Treatment Plan

The patient was presented a comprehensive treatment plan that included oral hygiene instructions, dental prophylaxis, tooth whitening, orthodontic treatment, completion of the full-coverage crown on the maxillary right lateral incisor, and porcelain veneer restorations for the other five maxillary anterior teeth. The patient rejected tooth whitening and orthodontic treatment; she requested that only the prosthetic treatment be performed. She was informed that the diagnostic wax-up and mock-up would provide information about the tentative outcome.

Diagnostic casts were made and the diagnostic wax-up (Wax GEO Classic, Renfert) was fabricated to provide the patient with a harmonious smile, taking into account her wishes (Figs 2 and 3). After presentation of the diagnostic wax-up to the patient, a diagnostic mock-up was performed with temporary bis-acrylic material (Structur Premium, VOCO). The patient liked the initial result and consented to the treatment (Figs 4a and 4b).


1a


1b


1c


1d


1e


2a


2b


2c


3a


3b


3c


4a


4b

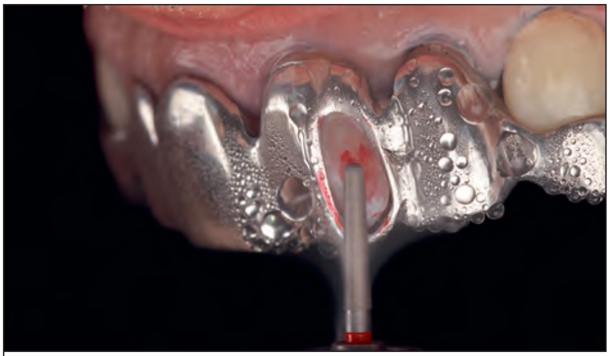
Figs 1a to 1e Patient's initial smile and intraoral views.

Figs 2a to 2c Diagnostic cast.

Figs 3a to 3c Additive diagnostic wax-up.

Figs 4a and 4b Diagnostic mock-up.


5a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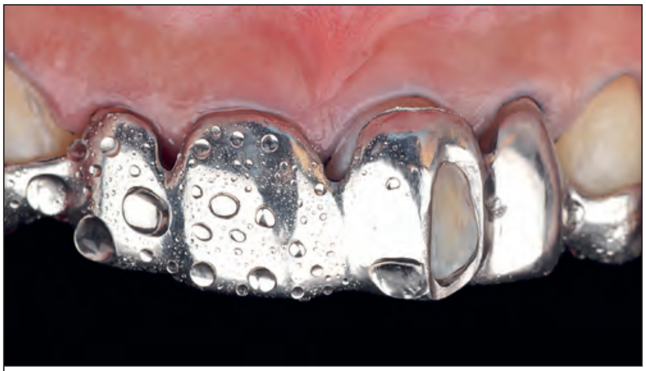
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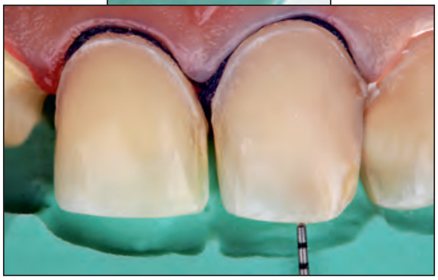
Figs 5a to 5c Metal reduction guide.

Fig 6 Clear thermoplastic reduction guide.

Figs 7a and 7b Putty reduction guide for facial and incisal surfaces.


7a


6


7b

Tooth Preparation with Reduction Guides

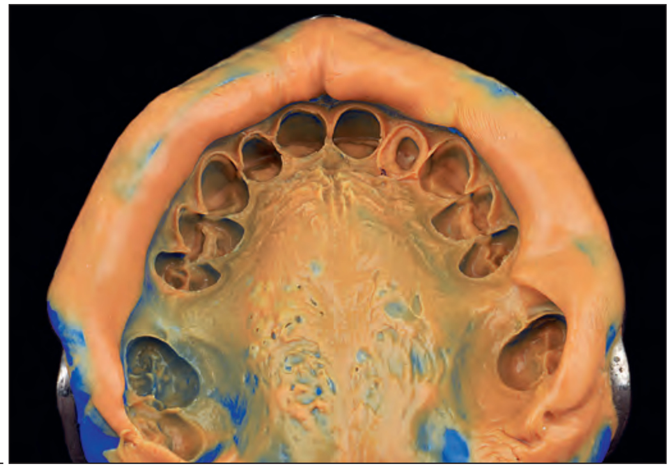
Following diagnostic mock-up removal, conservative tooth preparations were performed using different types of reduction guides. First a cast metal guide was fabricated using the lost-wax technique, and it was used to aid in the removal of the protruded surface of the maxillary left central incisor. The guide was placed and the protruded tooth surface was carefully removed with a fine diamond bur with a conical end (850, Jota AG) at high speed (Figs 5a to 5c). The main advantage of the cast metal reduction guide is that it is conservative and only allows for targeted tooth structure removal. Conservative tooth preparation (0.75 mm reduction) was provided on the facial surfaces of the six maxillary anterior teeth.

After initial tooth reduction, further reduction was performed with the aid of the clear thermoplastic reduction guide (Thermoplastics, Keystone Industries with 0.5 mm thickness). The guide was fabricated with a vacuum ma-

8a

8b

Figs 8a and 8b Double-cord impression technique.



9

Fig 9 Final impression.

chine (Pro-Vac, Vacuum Formers). It was placed on the anterior teeth to evaluate overall tooth preparation. Then it was perforated with a diamond bur (6 HP Round 51 mm Overall Shank 2, Brasseler) in specific zones in order to insert the periodontal probe (CP-15 UNC color-coded single end probe, Hu-Friedy Qulix) to take measurements (Fig 6). Moreover, putty matrix guides (Platinum 85, Zhermack) were fabricated and used to evaluate incisal and two-plane reduction. The final space available for the future ceramic restorations was 0.75 mm on facial and 1.5 mm on incisal surfaces (Figs 7a and 7b). Crown tooth preparation for the right lateral incisor was refined prior to final impression.

Final Impression and Fabrication of Restorations

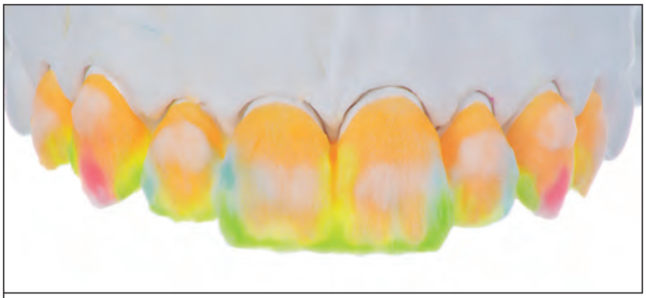
The final impression was made using the double-cord technique, first placing #000 cord followed by #0 cord on teeth with veneer preparation and #00 cord followed by #1 cord for the crown preparation (Retraction Cord Plain Knitted, Ultrapak) (Figs 8a and 8b). Impression trays (Rim-Lock Impression Trays, Dentsply Caulk) were loaded with PVS in heavy-body and light-body consistency (Virtual 380, Ivoclar Vivadent) and final impressions made (Fig 9). The final master cast was fabricated in type IV stone (Fuji-rock, GC America). Refractory feldspathic porcelain veneers

10a

10b

10c

10d



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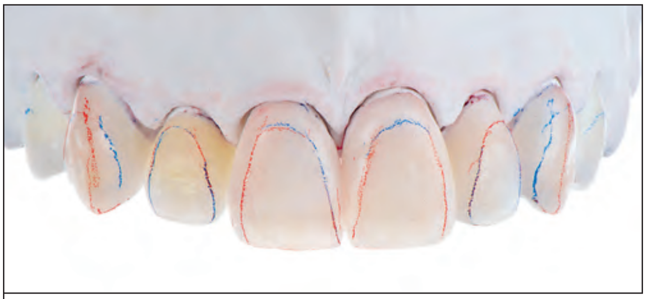

11a

11b

Figs 10a to 10e *(a)* Master cast and alveolar dies for *(b to e)* fabrication of feldspathic veneers.

Figs 11a and 11b *(a)* Defining line angles and finishing of *(b)* final feldspathic veneers.

were fabricated (Noritake Super Porcelain EX-3, Kuraray Dental) and the full-coverage crown was made of pressable feldspathic (Ex-3 Press, Kuraray Noritake (Figs 10a to 10e). Line angles were carefully defined during the finishing of the ceramic veneers (Figs 11a and 11b).


12a


12b


12c


12d


12e

Fig 12a Rubber dam isolation prior to bonding of ceramic veneers.

Fig 12b Placement of Teflon tape on adjacent tooth.

Fig 12c Bonding of final ceramic veneers for central incisors.

Fig 12d Placement of clamps on lateral incisors prior to bonding ceramic veneers.

Fig 12e All-ceramic restorations bonded under rubber dam isolation.

Bonding and Polishing

A dry try-in of the final restorations was performed to evaluate the fit and contours, and once the patient approved, the bonding procedure continued. A rubber dam (Dental Dam, Nic Tone) was placed from second premolar to second premolar and held with clamps (Clamp #00, Hu-Friedy) to achieve proper isolation. A clamp was also placed along the gingival margin of every tooth to be treated (Clamp B4, Brinker Hygenic), followed by sandblasting of the teeth with water and 29-micron aluminum oxide particles (AquaCare Aluminum Oxide Air Abrasion Powder, Velopex).

Surface treatment of teeth with veneers was carried out with total etch of the enamel using 37% phosphoric acid (Total Etch, Ivoclar Vivadent) for 15 seconds and gentle air drying, followed by primer application and gentle removal of excess with air. Fourth-generation adhesive was applied (Syntac, Ivoclar Vivadent), with gentle removal of excess by air. The ceramic restorations were etched with 37% phosphoric acid gel (Total Etch, Ivoclar Vivadent) for 15 seconds with gentle air-drying for 5 seconds, and then the light-shade bonding material was applied (Monobond Plus, Ivoclar Vivadent). Next, Variolink Esthetic LC (Ivoclar Vivadent) was applied to the veneers, and the restorations were seated in place. Excess was removed followed by light curing (VALO cordless 6 oz, Ultradent) on the facial surface for 20 seconds, floss was used to clean the interproximal surfaces, followed by another light cure time of 20 seconds on each surface (palatal, mesial, and distal) of the veneer restorations. The single full-coverage crown was cemented with a dual-cure resin cement (Panavia V5, Kuraray Noritake) (Figs 12a to 12e).

Excess of adhesive and cement material was removed. The occlusion was checked and adjusted, and restorations were polished with polishing points (Dialite Feather Lite, Brasseler) and polishing paste (Dialite Intra-Oral Polishing Paste, Brasseler).

13a

13b

13c

13d

14

Figs 13a to 13d Patient's final restorations and smile.

Fig 14 One-year follow-up.

Final Result

To protect the restorations, the patient was provided an occlusal guard to wear at night. She was pleased with the overall appearance of the restorations (Figs 13a to 13d). The 1-year follow-up evaluation displayed a good condition of the soft tissue and ceramic restorations (Fig 14).

DISCUSSION

The advancements in adhesive dentistry have enabled a more conservative approach to esthetic dental procedures. Patients seek esthetic treatments to improve their healthy appearance, dentofacial harmony, and physical condition—in dentistry as well as medicine. Esthetic-driven patients can easily recognize any small abnormality or discrepancy in the anterior teeth.

Adequate reduction of tooth structure for veneer preparations without the aid of a tooth reduction guide is challenging. Overpreparation of teeth is a common mistake when guides are not used; this may lead to dentin exposure and decreased bonding properties. On the contrary, underpreparation of teeth will promote overcontoured restorations. The use of reduction guides is always indicated when preparing teeth for porcelain veneers. The clinician needs to become familiar with the different types of guides in order to use those most adequate for a particular case. Putty guides are the most commonly used to evaluate thickness and incisal reduction; however, they do not give a 360-degree view as does the clear matrix guide. Clear matrices can be perforated in order to evaluate tooth reduction of a specific area. Despite the advantages of using these two types of matrices, both enable reduction of only a specific amount of tooth structure; therefore, in cases of protruded teeth requiring more reduction, a cast metal reduction guide or self-cured acrylic guide can provide the opportunity to selectively remove tooth areas that are protruded.

Controlled tooth preparation can provide the ideal space for final restorations fabricated conventionally by the dental technician or manufactured by milling. Moreover, conservative tooth preparation can save tooth structure that will be needed for future full-coverage crowns when the restorations need to be replaced. Since none of the current dental prostheses can be guaranteed to last forever, the clinician should always consider taking a conservative approach by controlling tooth reduction.

CONCLUSION

Ideal and conservative tooth preparations provide optimal space for adequate contour and thickness of the final indirect restorations. The use of different tooth reduction guides for the same tooth preparation will help the clinician tremendously to avoid over- or under-reduction of teeth for the fabrication of successful restorations.

ACKNOWLEDGMENTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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MASTERPIECE

Clinical Approach to Fulfill Esthetic Requirements: The Challenge of Nature's Beauty

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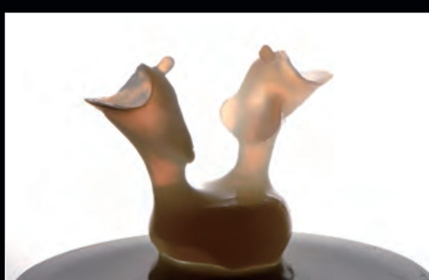
Fulfilling esthetic requirements is essential for anterior restorative treatment. It is necessary to study the fascinating natural beauty of the dentition and its composition in order to raise esthetic results to the next level, with the knowledge that some limitations or unfavorable conditions usually exist in reality. Improvement of the prosthetic condition plays an important role in the ability to carry out prosthetic treatment effectively. A comprehensive treatment approach with collaboration between the clinic and laboratory is instrumental to the result.

Part of the reproduction concept and the author's challenge to recreate nature's beauty are presented here, along with clinical cases illustrating the approach for fulfilling the esthetic requirements.

CASE 1 EXCELLENT OPTICAL PROPERTIES

— PLAY OF COLOR —

In this case, the central incisors were restored with all-ceramic crowns. The edge-to-edge occlusal relationship and shallow anterior coupling were taken into consideration in the framework design. The IPS e.max Press Impulse Opal 2 ingot (Ivoclar Vivadent) was chosen and the facial cutback technique was employed considering reproducibility of the color.



The advantage of the facial cutback technique is its high color reproducibility, maintaining the strength of IPS e.max Press. It is possible to choose the ingot according to the translucency of the incisal edge utilizing opaque porcelain. Impulse Opal ingot has superior optical properties in addition to high translucency, and the opal effect of natural teeth can be readily reproduced. Thus, utilizing the particular characteristic of the material precisely expands the range of clinical applications.

Dentist: Dr Hiroyuki Takino (Takino Dental Clinic)

EXACT REPRODUCTION OF NATURAL DENTITION

CASE 2

The maxillary right central incisor was restored with an implant in this case. Hard and soft tissue graft procedures were carried out to restore the V-shaped divulsion on the labial aspect. The prosthetic condition was dramatically improved by a proper surgical procedure. Maintenance and stability of the soft tissue depends on the implant superstructure. The abutment is a hybrid design with titanium base and bonded zirconia, and the crown is fabricated with the IPS e.max Press system.

Dentist: Dr Hiroyuki Takino

CASE 3

This patient had periodontal disease along with occlusal trauma and agreed to implant treatment. Comprehensive orthodontic treatment was carried out to establish a favorable functional condition after extraction and ridge preservation.

A bonded hybrid abutment was chosen in this case as well. A semi-custom titanium base is effective in cases of long clinical crowns. The lengthy axial surface increases the bonding surface, which has a direct impact on the strength of the superstructure.

Dentist: Dr Hiroyuki Takino

SURGICAL APPROACH FOR ESTHETIC RESTORATIONS

CASE 4

Connective Tissue Graft

This patient was concerned with the unesthetic appearance of an existing porcelain-fused-to-metal crown. It was determined that the discolored tooth root affected the appearance through the thin-biotype tissue. A connective tissue graft was carried out for stability of the prosthesis and to mask the root color. The IPS e.max Press crown was then completed with a layering technique after soft tissue management by the provisional restoration.

Dentist: Dr Kotaro Nakata (Nakata Dental Clinic)

CASE 5

IPS e.max Crowns

Harmony with Soft Tissue

The patient in Case 5 is a woman in her 70s. She presented for a second opinion concerning the prosthesis placed a few months earlier. Color mismatch of the crowns and disharmony of the gingival level were especially noted. A continuous gingival framework was designed for the four incisors, and a root coverage procedure was carried out for the left canine. The gingival shape was completed by subgingival contour of the provisional restoration, which was designed according to the diagnostic wax-up. Favorable harmony between the crowns and gingiva is evident after temporary cementation. This biologic harmony is established by superior fit, supra/subgingival shape, and biocompatibility of the ceramics.

Dentist: Dr Hiroyuki Takino/Dr Yusuke Yamaguchi (Yamaguchi Dental Care)

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Esthetics with Micro Restorations

Anabell Bologna, DDS, CDT[1]
Rafael Laplana, DDS[1]

It is a fact that software and machines make our laboratory processes faster and easier. Nevertheless, the human mind, with its infinite expertise, is still necessary to perform individual restorations with their differing esthetic requirements. Restoring a single tooth or a fragment of a tooth does not require a great deal of creativity, since either the contralateral tooth (in the case of a single crown) or the remaining tooth (in the case of a fragment) will be the principal reference. However, reproducing any shape and color by porcelain layering requires the ceramist to master the artistic skills—through knowledge, experience, and continual practice—to confidently achieve esthetically demanding results.

Bonded porcelain restorations have been proven, in medium- to long-term evaluations, to provide excellent esthetics, high patient satisfaction, and no adverse effects on the supporting tissues. They are also associated with maximum enamel preservation due to their ability to be acid etched and bonded to the dental structure. Bonding procedures allow us to replace old preparation concepts, based on restoration retention by friction, with a much more conservative approach, based on insertion pattern and positional stability, maximizing the preservation of the remaining tooth structure.[1]

This article describes the technical steps to develop minimally invasive ceramic fragments to restore the smile of a young girl.

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1

2

3

Fig 1 Preoperative facial view.

Fig 2 Preoperative smile view.

Fig 3 Preoperative intraoral view.

CASE PRESENTATION

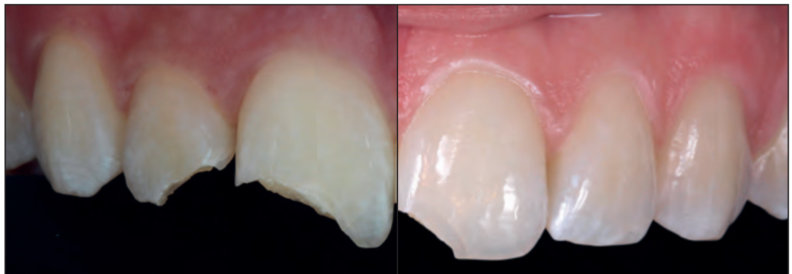
The patient, a 14-year-old young girl who suffers from coughing syncope, presented with fractured incisal edges of the maxillary central incisors and right lateral incisor after suffering a severe coughing episode that resulted in her fainting and falling down. The preoperative situation is shown in facial view (Fig 1), smile (Fig 2), and intraoral view with black contrast (Fig 3).

When the patient visited the restorative team, tests were done to confirm the vitality of the involved teeth. Teeth fragments were not recovered during the accident, so bonding those fragments to the remaining teeth[2] was not an option. Taking into account the young age of the patient, full-coverage restorations were not considered. Due to the need to restore substantial coronal volume and length,[3] the treatment plan was to develop three feldspathic ceramic fragments, following the refractory die technique, and to bond them to the remaining teeth, restoring the missing dental tissue.

Communication of Color and Photographic Protocol

Even with all the technological advances, the selection, communication, and reproduction of color can be challenging in some cases and can result in an unpredictable outcome. Effective communication between the clinical team and the dental laboratory is mandatory to achieve a successful shade match, with photography being an excellent communication tool for this.[4]

For reference photographs, it is important to note that those taken with a ring flash are good for basic shade information, as well as proportion and arrangement. However, they are not good for sharing information to reproduce



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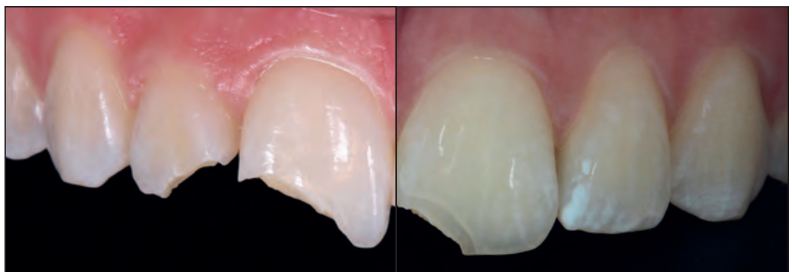


4b

Figs 4a and 4b Preoperative intraoral images taken with lateral and polarized light.

the color in a precise way. Lateral light photography is considered a better option, since it allows us to see through the layers of the tooth. Nowadays, cross-polarized light photography is highly recommended, since it reduces the glare, allowing visualization of the gradation of the chroma, which enables an easier and more precise dentin shade selection and layering map.[5] Comparative preoperative intraoral images taken with lateral light (Twin Lite MT-24EX, Canon) and with cross-polarized light (polar_eyes, Emulation) are shown in Figs 4a and 4b.

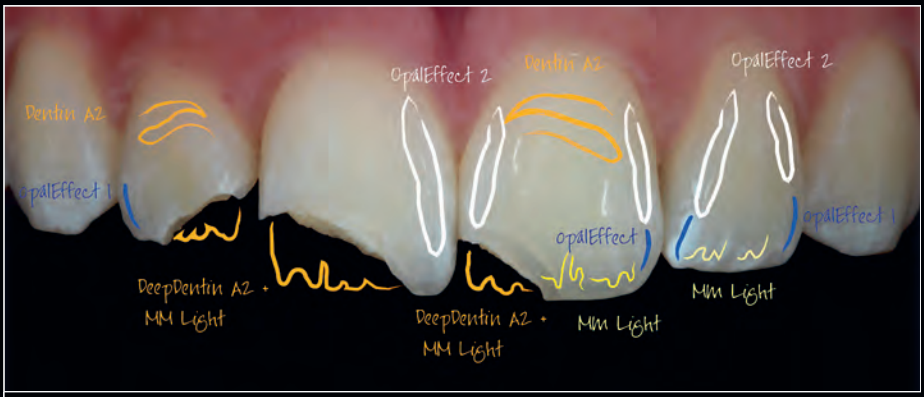
Shade Selection

When tooth selection is carried out in a conventional way, the knowledge and experience of each professional can make a difference. Conventional shade guides have limitations in communicating the color precisely, due to the significant variability of the shades they represent. For more precise information, shade selection with color scales constructed from the pure materials—for example, deep dentin, mamelon, dentin, incisals, and opals—is highly recommended.[6]

Layering Map—Chromatic Sample

Due to the amount of dentin structure lost vertically, while developing the layering map it was key to mix the Opaque Dentin with the Mamelon Light (the most reflective material of the system) to block the darkness of the oral cavity, thereby avoiding the risk of a low-value restoration (Figs 5a to 5c).

In any type of single anterior restorations, a chromatic sample is made immediately after the color selection to avoid any doubt as to the correct selection of color and future layering. To make this chromatic sample, once the shade is decided upon, a schematic stratification with the selected materials is made on a piece of tissue paper using the main colors and effects. Incisal is placed only in half of the layering to allow us to check, after the porcelain firing, the veracity of the internal stratification at the uncovered portion by the incisal layer and the correct enamel selection and thickness in the other half.[7] The firing process is carried out at 50°C above the regular firing temperature of the porcelain in order to obtain a shiny sample (Fig 6). This process allows us to detect any corrections required during the layering of the fragments.



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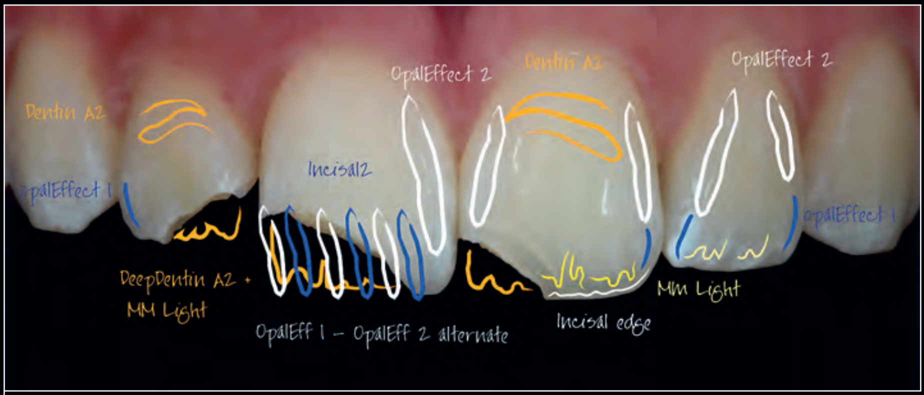


5b

Figs 5a and 5b Development of the layering map.

Fig 5c Opaque Dentin is mixed with the most reflective material, Mamelon Light, to counter the darkness of the oral cavity and resulting low-value restoration.

5c

Fig 6 Shiny chromatic sample, achieved by firing at 50°C above the regular porcelain firing temperature, to detect any corrections required during layering of the fragments.

7a

7b

8

Figs 7a and 7b Enamel recontouring following the fracture lines.

Fig 8 Alveolar model for fabricating the fragments in feldspathic porcelain on refractory die material.

Restorative Procedures

Enamel recontouring[8] followed a minimally invasive shoulderless preparation, smoothing only the sharp enamel angles caused by the fracture using soft abrasive disks (Super-Snap flexible disks, Shofu) and silicone points, thus creating a facial and proximal light chamfer directly following the fracture line (Figs 7a and 7b).

Impressions were taken using polyvinyl siloxane (Virtual, Ivoclar Vivadent). No retraction cord was required since the limits of the restoration did not involve the cervical area.

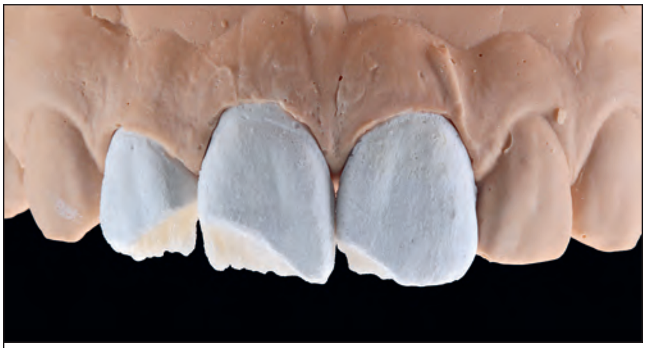
Laboratory Procedures

An alveolar model (Fig 8) was made from the final impression[9] to fabricate the fragments in feldspathic porcelain (IPS e.max Ceram, Ivoclar Vivadent) on refractory die material (G-Cera Orbit Vest refractory die material for crowns/veneers, DG Europe).

Porcelain layering on a refractory cast provides an excellent natural outcome, due to the possibility to control the stratification through all the layers using the patient's remaining natural teeth as the reference. However, this technique does not allow major corrections after the removal of the refractory material. Special care needs to be taken to control volume contraction and positioning of the different layers.


9a


9b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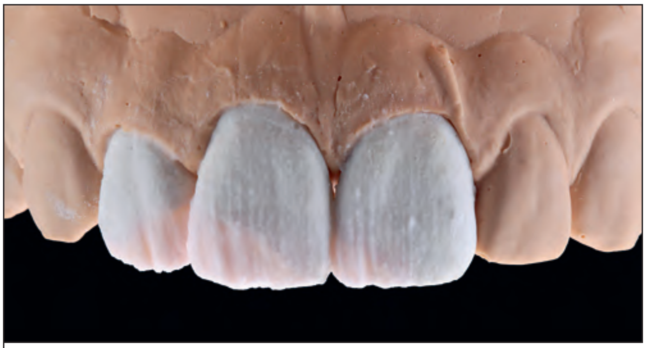

9d


9e


9f

Porcelain Layering Step-by-Step

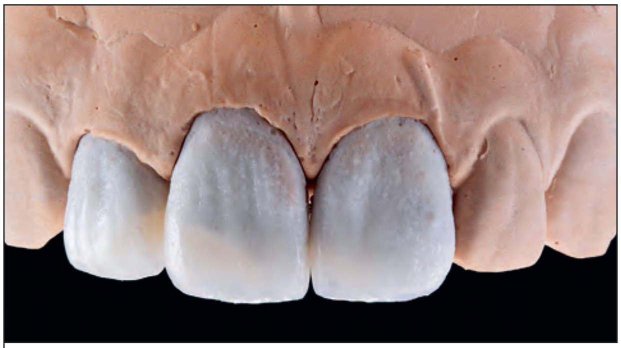
- The refractory dies are dehydrated, and the connecting firing with Opal Effect 1 is carried out at 800°C (Fig 9a).
- A first bake with opaque porcelains (Deep Dentin A2 and Mamelon Light in a 50% ratio) precedes the traditional layering. The purpose of this preliminary bake is to build up the vertical missing dentin of the fractured teeth with an opaque layer that blocks the light and adds chroma, avoiding the risk of excessive light absorption at the level of the missing natural dentin, which could lead to a low-value result. Better volume control of this layer is achieved by firing it separately (Fig 9b), which is carried out at 770°C. The opaque dentin cores after firing are shown in Fig 9c.
- Modified Dentin A1 with Mamelon Light in a 50% ratio is used to fully build the teeth (Fig 9d).
- The basic shape is then reduced in the incisal area (cutback) to generate the space for the incoming powders (Fig 9e).
- The vertical interproximal increment with Opal Effect 1 is shown in Fig 9f.
- Opal Effect 1 is applied as a thin layer over the concavity of the cutback, slightly oversized vertically (Fig 9g) to mimic the dentin-enamel junction (DEJ); this is the transparent zone of aprismatic enamel, over the outer layer in natural teeth,[10] which facilitates light circulation through the tooth's layers.[11]

9g

9h

9i

9j



9k

- Mamelon Light is placed to create subtle effects, similar to those seen in the opposite lateral and also in the remaining incisal portion of the contralateral central (Fig 9h).
- A preliminary enamel covering is applied using the selected incisal shade I2, extending it to the union of the middle and cervical thirds (Fig 9i).
- Vertical layering at the incisal third with Opal Effect 1 and 2 provides different opal translucent effects in this area, generating absorption and reflection contrast. The final shape must be oversized to compensate for the firing shrinkage (Fig 9j).
- The complete stratification was carried out at one bake at 770°C. Contraction took place as expected. Surface grinding was performed, following the shape characteristics of the remaining structures. Surface macro and micro morphology was adapted with fine diamond burs to the adjacent tooth structure for a successful integration of the ceramic fragments. The restorations were glazed at 725°C, with very little paste (Fig 9k).

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Fig 10 Longhair felt brush used for final mechanical polishing.

Fig 11 Porcelain fragments ready for try-in and then bonding.

Final mechanical polishing was carried out with a longhair felt brush, and porcelain was moisturized with glaze liquid, replacing the diamond paste (Fig 10), with the restorations still attached to the refractory dies.

The refractory material was sandblasted with 50-micron glass beads. The fragments (Fig 11) were adapted to the stone dies and solid model as well.

12a

12b

13

Figs 12a and 12b Function is checked and adjustments made after the final bonding.

Fig 13 Coarse- to fine-grained silicone polishing tips (NTI, Kahla GmbH) are used to refine the interface and finally polish to a high-shine finish.

Try-in, Bonding, and Finishing Procedures

The try-in was done and did not reveal any need for corrections.

Adhesive luting procedures were then performed. The internal surface of the feldspathic fragments were acid etched with hydrofluoric acid for 90 seconds. After copious rinsing, the restorations were placed in an ultrasonic bath with alcohol and distilled water for 5 minutes. After drying, the intaglio surface was silanized.

The enamel was acid etched, and dentin adhesive was used in the areas of dentin exposure. The internal surface of the restorations and the teeth involved were coated with adhesive resin and bonded using Variolink Esthetic LC neutral shade (Ivoclar Vivadent).

After the final bonding (Figs 12a and 12b), functional adjustments were made, with particular emphasis on maintaining the interrelation of centric occlusion, anterior guidance, and mandibular excursions using the patient's natural remaining dentition as reference. These adjustments were performed with fine diamond burs and polished with silicone points.

A subsequent appointment was planned to polish the vestibular interface. For this purpose, silicone tips are recommended, starting with the coarse-grained (green and blue) to refine the interface, and ending with the fine-grained (yellow) for a high-shine polishing (Fig 13). It is


14a


14b


15a


15b

Figs 14a and 14b Photographs aid in evaluating the polishing process.

Figs 15a and 15b Final intraoral photographs taken with twin flash and cross-polarized light.

important to polish the interface in the correct direction, from the ceramic restoration toward the tooth, smoothing the union until it becomes almost imperceptible. Polishing in the wrong direction may result in a negative effect by emphasizing the interface. Careful photographic evaluation during the polishing process is highly recommended (Figs 14a and 14b).

Comparative final intraoral photographs taken with twin flash (Twin Lite MT-24EX, Canon) and cross-polarized light (polar_eyes, Emulation) show the integration of the ceramic fragments with the dental structures (Figs 15a and 15b). Final extraoral (Fig 16) and facial views (Fig 17) show the esthetic result.

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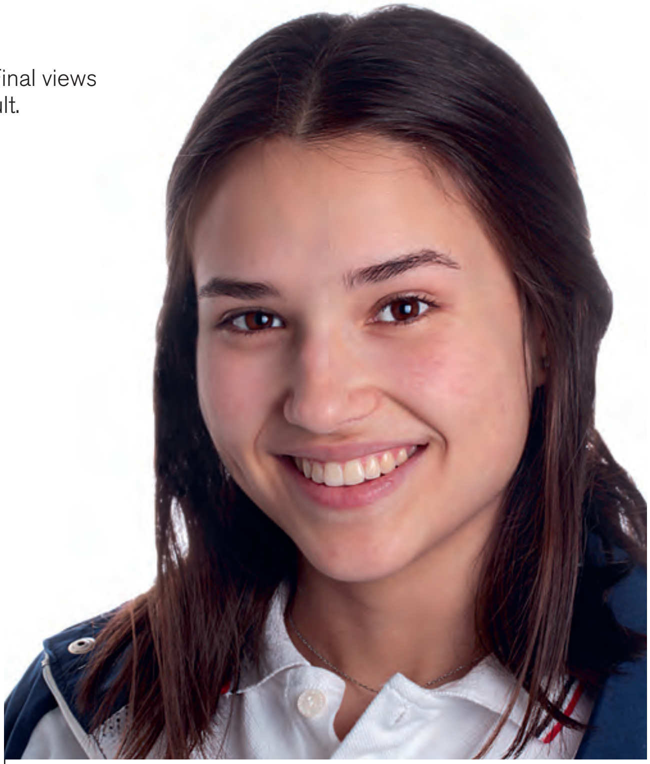
16a

16b

17a

Figs 16 and 17 Final views of the esthetic result.



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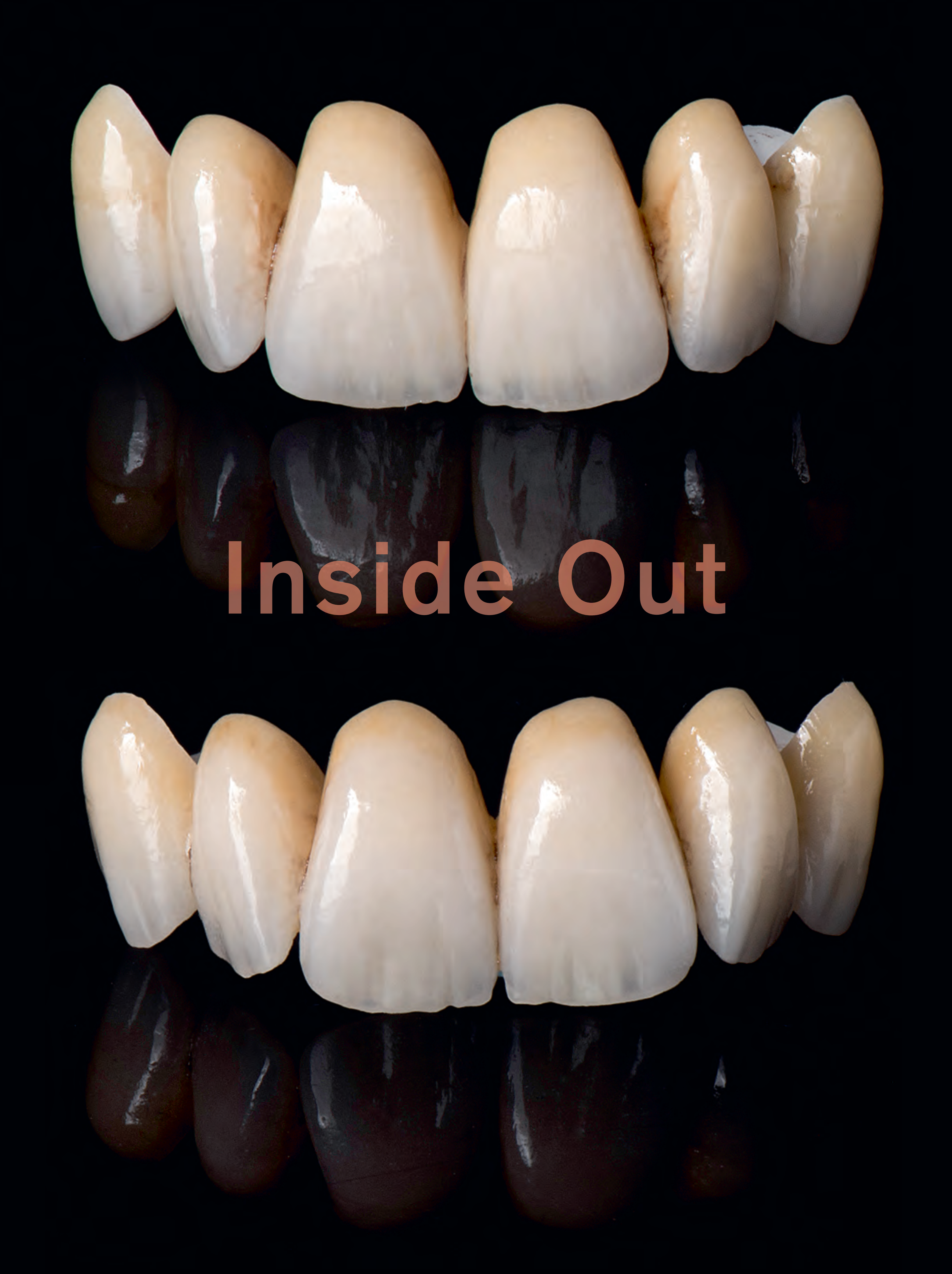

Inside Out

A Technique for Faster and More Predictable Layering

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Technology has emerged in our profession in an irreversible and positive way. The digitalization of our laboratories has brought greater productivity while democratizing ceramic restoration—meaning that the average laboratory, thanks to this technology, has managed to scale its product and more easily maintain greater regularity in quality.

Facing this reality, the dental technician often asks: Does ceramic layering have a future? Will it resist the monolithic restoration? The answer is not simple, but we are still far from having a monolithic material that provides the same esthetic quality as a good layering.

This article demonstrates a simple protocol that will give technicians the ability to benefit from digitalization (increase production and maintain consistent quality) in ceramic layering as well.


1a


1b


2a


2b


2c

Figs 1a and 1b Before and after photographs of clinical case (Dr Oriol Llena) demonstrate dentin layering with little prominence of enamel.

Figs 2a to 2c Before and after photographs of clinical case (Dr Jon Gurrea) demonstrate layering with prominence of enamel.

INCISAL EDGE POSITION

The diagnostic wax-up provides a great deal of information about a restoration:

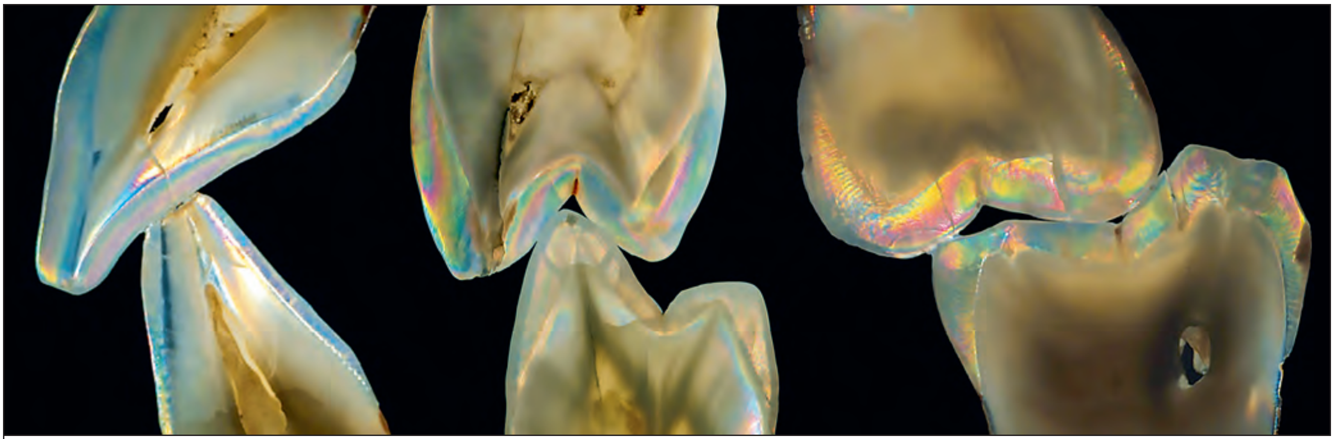
- Emergence profile
- Volume
- Shape
- Length
- Amplitude
- Incisal edge position

A good layering with that information should guarantee success. However, while many authors have developed protocols to guide the ceramist in copying the diagnostic wax-up, unfortunately the results obtained are usually somewhat approximate.

Without a doubt, the incisal edge position is the most important information provided by the wax-up. The location of the incisal edge will be decisive for the success of layering. Consider the before-and-after images of the two clinical cases shown in Figs 1 and 2. If asked what we like best about the definitive restorations (Figs 1b and 2b), each of us will focus on something different—some on the layering, others on the mamelons. In the end, we will have a set of details that together provide a well-balanced, successful result.

Consider next a natural tooth, which is basically formed of two structures—the internal dentin and the enamel. A sagittal cut illustrates these two layers and the intimate relationship between them (Fig 3). In any such example it is apparent that the proportion of enamel and dentin is not symmetric, and that the dentinal structure loses volume as it is projected to the incisal edge, the enamel being the main protagonist. For this reason, it is important to locate the position of the incisal edge in space when layering, since all the internal layers must be projected toward that point. The success of any layering, whether simple or complex, is based on the balance between internal and external masses (Fig 4).

Technicians frequently use palatal silicone keys to maintain the incisal position throughout the layering process. With these keys, the position of the dentin is 100% guaranteed (Fig 5). Once the dentins are added, we must continue applying masses beyond the incisal edge to compensate for the vertical contraction of the ceramic. To do so requires removing the silicone key, so the remainder of the layering will be done without any reference (Fig 6). This



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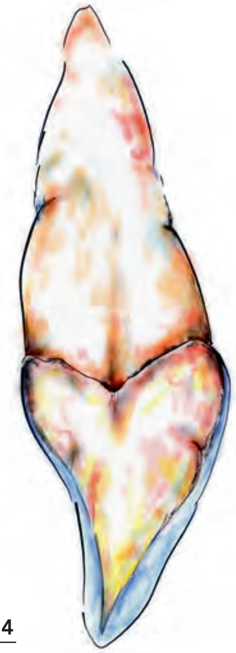

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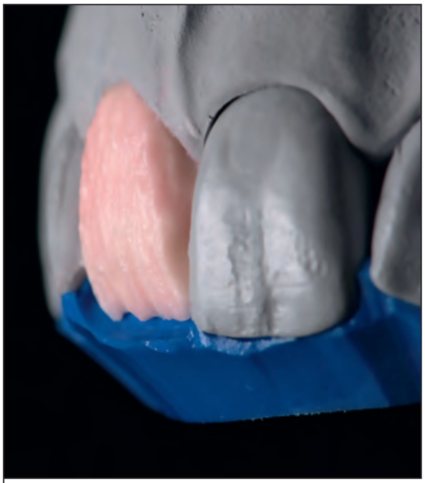

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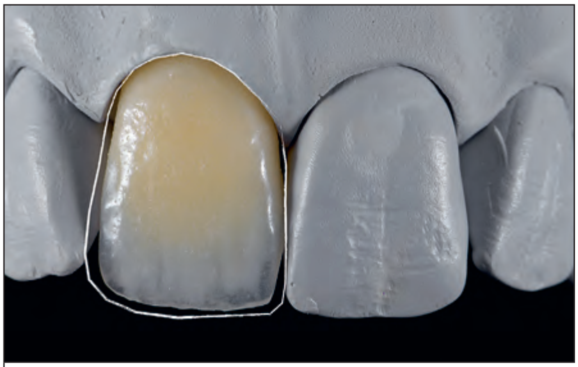

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Fig 3 The amounts of dentin and enamel are not symmetric in the natural tooth.

Fig 4 Layered internal masses must project toward the incisal edge to achieve balance between internal and external masses.

Fig 5 With a silicone key it is easy to place the internal masses.

Fig 6 Extending a restoration to compensate for the vertical contraction of the ceramic must be done without the silicone reference.

Fig 7 If the silicone key can remain in place when layering, the result will be a good balance of color and quicker restoration.

is not a problem if a restoration requires only two crowns, since the remaining teeth provide many references to control the correct position of the internal masses. But the references are lost in a larger rehabilitation, such as six anterior units, and it is easy to lingualize or vestibularize these masses. If all the layering is done with the silicone key as a guide, there will be a good color result but the crown in this case will be approximately 1.5 mm short of the desired length (Fig 7).


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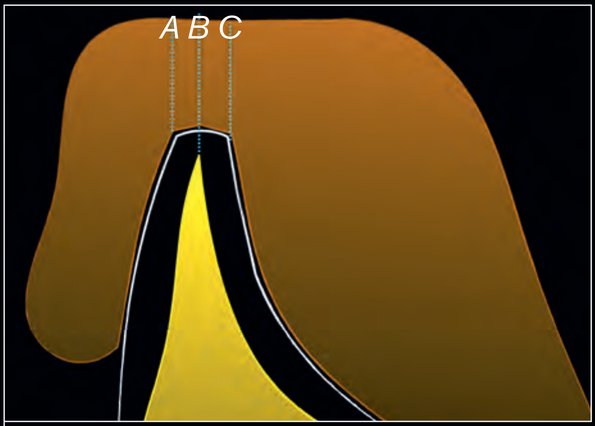

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Fig 8 The diagnostic wax-up indicates the future incisal position.

Fig 9 Vertical contraction of the ceramics is compensated for by adding wax. In this case, 1.5 mm is added.

Fig 10 A silicone key is made for use as a support throughout the layering.

Fig 11 Three cutting options for the silicone key incisal edge: *(A)* vestibular, *(B)* center, and *(C)* palatal.

Fig 12 Two silicone keys, the enamel (A) and dentin (B), are removed.

THE INSIDE OUT CONCEPT

The Inside Out concept uses silicone keys that compensate for the vertical contraction of the ceramic and can remain in place to guide the layering process. For this, the amount of contraction of the ceramic being used must be known or can be approximated by measuring a crown before and after baking. In the case illustrated, using IPS e.max (Ivoclar Vivadent), the contraction will be approximately 1.5 mm.

Starting from a diagnostic wax-up (Fig 8), the vertical contraction is compensated for by lengthening the incisal contour 1.5 mm with wax (Fig 9) and then making a silicone key that will register this new incisal position (Fig 10).

The next step is to cut the silicone key. There are three cutting options at the incisal edge, as shown in Fig 11: *(A)* the vestibular aspect; *(B)* the center of the incisal edge, where the dentin is projected; and *(C)* the palatal aspect. Think of a simple layering of two masses using two, instead of one, silicone keys—one cut in the vestibular aspect (A, which we will call enamel key) and another cut in the center of the incisal edge (B, which we will call dentin key). First the dentin key (B) is filled with the internal masses, then it is changed to the enamel key (A) and filled with the incisal (Fig 12).

For a complex layering, the procedure would be the same except that on the dentin key (B) all the internal masses are placed (as shown in Figs 13 to 15), resulting in an extremely simple and fast exercise. The dentin key is replaced by the enamel key (A), where the space for the external masses is generated (Figs 16a and 16b). The next step is simply to fill the silicone with the incisals chosen.

After the bake, the incisal position of the restoration is the same as in the diagnostic wax-up (Figs 17a and 17b). Note the balance between dentin and enamel, thanks to the guided layering. Finishing of the restoration can then be accomplished and the restoration completed in a shorter amount of time.


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14a


14b

Fig 13 The dentin silicone key in place.

Fig 14a A mixture of e.max Ceram Power Dentin A1 + Oc Dentin Orange 50% is added in the cervical area.

Fig 14b Power Dentin A1 pure, a high-value dentin, is placed.

Fig 15a In the incisal area, a translucent dentin (DA1 + TN 50%) is placed.

Fig 15b The placement of all the effects necessary to build a restoration is quick and easy with the guidance of the silicone keys.

Figs 16a and 16b Once the internal layering is completed, the dentin key is replaced by the enamel key to generate the space necessary for the external layer.


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15b


16a


16b


17a

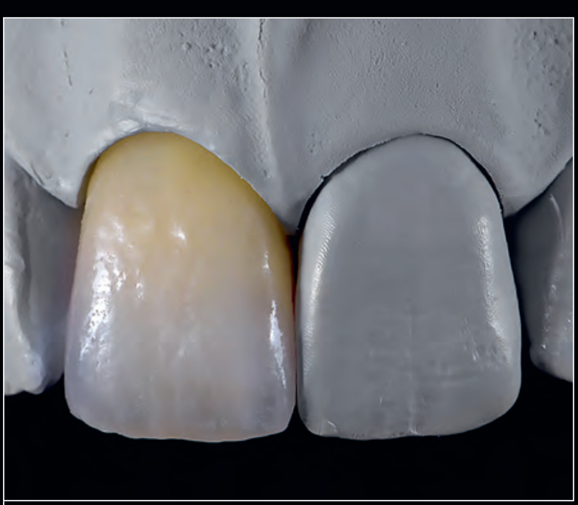
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Fig 17a Final result after bake.

Fig 17b The final result after finishing is very predictable.

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Fig 18 The result obtained by different technicians is surprisingly similar.

Fig 19 The color is checked using the eLAB technique developed by Sascha Hein and minimal difference is found.

It is interesting to see the results obtained by different technicians using the same model, masses, and silicone keys. As shown in Figs 18 and 19, the results obtained are quite similar. A numerical reading of the color results indicate minimal difference, which demonstrates that using the Inside Out technique will allow technicians to scale ceramic restorations in their laboratories in a predictable way. Not only does the technique provide predictability, but approximately 30% savings of time.

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Fig 20 Preoperative view of patient with lateral agenesis. Canines have been moved orthodontically to replace the lateral incisors. (Case by Dr Oscar González.)

Fig 21 Only the canines will be prepared for the veneer restoration from premolar to premolar.

Fig 22 Diagnostic wax-up from which the enamel key is obtained.

MINIMALLY INVASIVE RESTORATIONS WITH INSIDE OUT

Cases requiring very little ceramic layering are now common. But this does not mean they are any less difficult; seeking balance between the interior and the exterior layering is still required. To use the Inside Out technique with minimally invasive restorations, some parameters must be taken into account.

In general, minimally invasive restorations will lack internal dentin, requiring only the completion of some nonexistent volume (for example, an incisal contour), increasing the enamel volume and nothing more. The intermediate bake technique can be used for greater control of the transition between the restoration area with support and the area that does not have support. If Inside Out is used for this, in most cases it will not be necessary to work with both silicone keys, or at least as described so far.

Consider the case shown in Fig 20. In this patient with lateral agenesis, the canines were moved orthodontically to replace the lateral incisors. The treatment plan was to restore the teeth with veneers from premolar to premolar with preparation only of the canines to facilitate their transformation into laterals (Fig 21). It was also planned to increase the value of the veneers by a minimum of two shades.

As always, a diagnostic wax-up is the first step. Already knowing that there will not be enough space derived from preparation, space will need to be generated by increasing the volume of the vestibular aspect in order to clarify the patient's dentinal color. In this situation, an intermediate bake is in order. The enamel key will be obtained directly from the diagnostic wax-up and cut, as described previously, on the vestibular aspect of the incisal edge. The objective of this key is to provide the incisal position of the diagnostic wax-up and the final volume of enamel (Fig 22). Once we have this silicone key, the diagnostic wax-up model is copied and 1.5 mm added to compensate for the

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Fig 23 Diagnostic wax-up is copied.

Fig 24 Compensation for contraction is begun.

Fig 25 Average contraction is 1.5 mm.

Fig 26 Compensation of the vertical contraction of the ceramic.

Fig 27 The dentin key is made.

Fig 28 The center of the incisal edge will be cut.

Fig 29 Note the space generated for the first bake.

vertical contraction of the ceramic (Figs 23 to 26). Next, as shown in Figs 27 to 29, the dentin key that will support the internal layering is made. With these two silicone keys ready, the ceramic layering can begin.

The silicone key is placed and the entire incisal area is lengthened with dentins and effects (Figs 30 and 31). Once the intermediate bake is done, all the vertical contraction that has been obtained can be seen (Fig 32). When the

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36a

36b

Fig 30 Layering of dentins.

Fig 31 After baking, internal characteristics, including mamelons and bluish triangles, are added.

Fig 32 After intermediate bake, the vertical contraction is evident.

Fig 33 Note how this first bake is perfectly located in the diagnostic wax-up.

Fig 34 Once the enamel is applied, the restorations follow the incisal guide generated in the diagnostic wax-up.

Fig 35 Veneers recovered following the incisal guide.

Figs 36a and 36b The volumetric resemblance of waxing and finished veneers is evident.

dentin key is replaced with the enamel key—remember that it was made using diagnostic wax-up without compensating for the contraction—you can see how everything done internally is perfectly placed (Fig 33). The space generated by the enamel key is filled and the restoration baked, demonstrating how simply the diagnostic wax-up was replicated (Figs 34 to 39).

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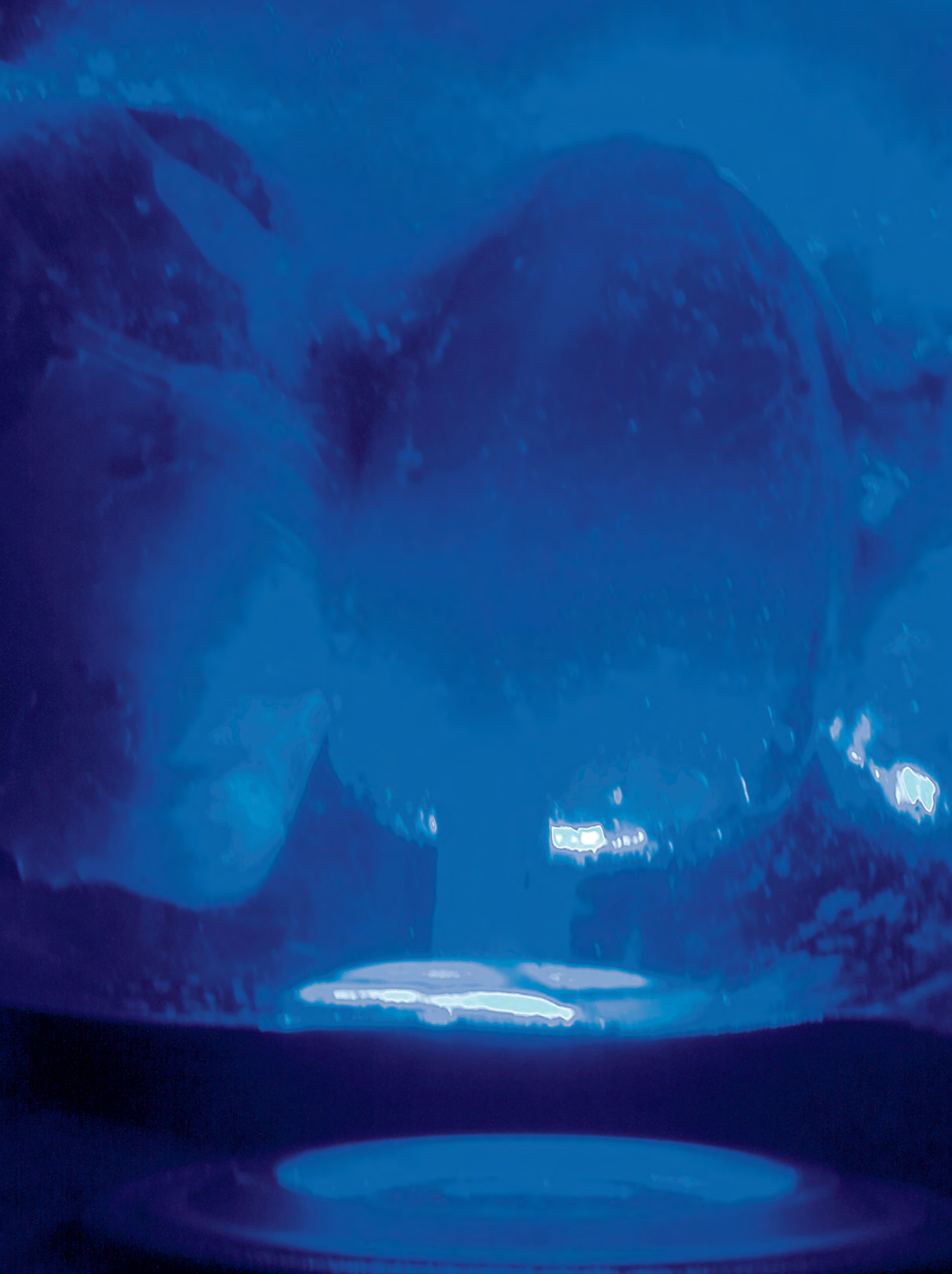
Fig 37 Ceramic restorations so thin will have little color effect. In this case, the value was increased.

Figs 38 and 39 Definitive restorations a few weeks after being cemented: veneers 0.2 mm/0.4 mm thick, without preparation and supragingival final cementation.

CONCLUSION

With Inside Out, all the morphologic information and space position of the incisal edge of a diagnostic wax-up can be transferred to the ceramic restoration regardless of the layering complexity. This technique not only simplifies the ceramic layering, but also provides savings of about 30% of our working time and makes the outcome more predictable.

Inside Out generates a similar effect to digitalization, in that it offers the possibility of increased laboratory productivity and makes the technician's hand less decisive in terms of final quality. Using this technique, differences in results by technicians within the same laboratory decrease, since they are all guided by the same proportions of dentin and enamel. The great difference between the technicians will be in how they place and contrast the ceramic colors.



The Injection Resin Technique: A Novel Concept for Developing Esthetic Restorations

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John M. Powers, PhD[2]
Markus B. Blatz, DMD, PhD[3]

The concept of using an injectable molding technique to manufacture various parts has been around for over a century.[1,2] The first injection-molding machine was developed and patented by John and Isaiah Hyatt in 1872 for producing celluloid plastic parts.[1,3] The next half-century saw the adoption of this process for the manufacture of items such as collar stays, buttons, and hair combs.[3] Over the course of its development, injection molding has been used by designers and engineers for myriad applications with a host of materials—including glass, metals, confections, elastomers, and thermoplastic and thermosetting polymers—to fabricate a variety of complex shapes with high dimensional precision. It has been used in a variety of manufacturing industries, including aerospace, automotive, jewelry, avionics, biomedical, orthodontics, pharmaceutical, scientific, electronic, and computer technology. In dentistry, this technique has been used in the laboratory fabrication of prosthetic appliances such as complete dentures, partial dentures, laboratory-processed acrylic and composite provisional restorations, and ceramic restorations.[1,2]

Continued developments in adhesive technologies, the design of resin composite formulations, and innovative application techniques have revolutionized the delivery of minimally invasive direct resin composite restorations while improving the practice of dentistry. In some cases, complicated layering techniques are required that are dependent on the clinician's skill and artistic ability. The injectable resin composite technique provides a simplified, precise, and predictable method for developing natural esthetic composite restorations while reducing chair time. Although not a panacea for all restorative challenges, this technique provides the patient and clinician with an alternative approach to various clinical situations. This technique is a unique and novel indirect/direct process of predictably translating a diagnostic wax-up or the anatomical form of the natural dentition of a preexisting diagnostic model into composite restorations.

There are myriad applications for this technique using a highly filled flowable (injectable) resin composite, including

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Fig 1 Preoperative facial view of the maxillary anterior segment of a 63-year-old patient who presented with incisal wear and fracture of the maxillary anterior teeth. The patient requested a conservative esthetic enhancement without orthodontic treatment. Clinical evaluation revealed multiple diastemas and cervical corrosion on the central incisors from lemon sucking.

Fig 2 Development of a diagnostic wax-up that established new parameters (ie, esthetic, functional) for the final restorations.

Fig 3 A clear polyvinyl siloxane matrix was fabricated to replicate the diagnostic wax-up.

emergency repair of fractured teeth and restorations; modification and repair of prototypes and provisional restorations, composite restorations (Class III, IV, and V; veneers), and pediatric composite crowns; resurfacing of occlusal wear on posterior composite restorations; establishment of incisal edge length prior to esthetic crown lengthening; orthodontic space management; development of composite prototypes for copy milling; fabrication of an implant-supported composite provisional restoration; and repair of fractured or missing denture teeth.[1,4–6] In addition, this technique can be used to establish vertical dimension and to alter occlusal schemes (anterior guidance and posterior disocclusion) prior to definitive restoration.[1–3] Furthermore, this noninvasive technique is an integral tool for enhancing communication between the patient and the restorative team during treatment planning.[1,2,4]

Developing transitional resin composite restorations using the injectable technique is an excellent method for increasing the patient's understanding of the planned clinical procedure and anticipated final result.[7] Transitional composite prototypes establish parameters for occlusal function,[8] tooth position and alignment,[9] restoration shape and physiologic contour,[10] restorative material color and texture, lip profile, phonetics, incisal edge position, and gingival orientation. This process also eliminates confusion and misunderstanding between the patient and the restorative team during the treatment-planning stage.[7] It can reduce the potential for patient dissatisfaction and litigation because the process is reversible, can be performed without preparation, and allows the patient to accept the visual and functional result before the definitive restorations are fabricated. In addition, the simple procedure helps to regulate the dimensions of the preparation design, ensures uniform spatial parameters for the restorative material, and increases the potential for a more conservative preparation design.[4]

This injectable technique can also be used in the development and management of soft tissue profiles and in the design of the definitive restoration.[11–14] The clinician and technician can use the technique as a guide for developing a preapproved functional and esthetic definitive restoration.[15] In some cases, these transitional restorations can be worn for months or even years during long-term interdisciplinary rehabilitation.[2,4] However, this material and tech-

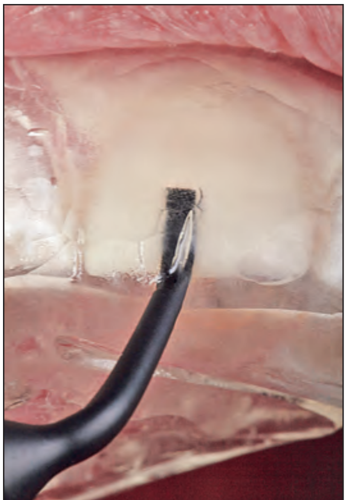

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Fig 4 Upon completion of the adhesive protocol, the clear silicone matrix was placed over the arch and an opacious shade A2 flowable resin composite (G-aenial Universal Flo, GC America) was initially injected through a small opening above each tooth, followed by mixing with a shade B1 flowable resin composite (inverse injection layering technique). The resin composite was cured through the clear resin matrix for 40 seconds.

Fig 5 Completed composite veneer restorations with optimal anatomical form. The inverse injection layering technique allowed the establishment of harmonious proportions of the transitional restorations and the surrounding biologic framework.

nique should not be utilized as a final restorative material for full-mouth rehabilitation.

In certain clinical situations, this technique can be performed intraorally without anesthesia. A clear polyvinyl siloxane (PVS) impression material is used to replicate the diagnostic wax-up, the anatomical form of the natural dentition, or a preexisting diagnostic model. The clear matrix can be placed intraorally over the prepared or unprepared teeth and used as a transfer vehicle for the flowable resin composite to be injected and cured[1,2] (Figs 1 to 5).

EMPIRICAL DATA

Flowable composite materials have been evaluated in numerous studies[16–40] since their inception. Although early flowable formulations demonstrated poor clinical performance,[1,16] some of the more recent studies[34,37,38] indicate that the clinical performance of specifically tested next-generation flowable (injectable) resin composites have similar or improved performance to specifically tested universal resin composites. Attar and others[23] showed that different flowable composites possessed a wide range of mechanical and physical properties. Earlier studies by Gallo et al[24] on specific flowable resin composites suggested that these materials should be limited to small- and moderate-sized restorations having isthmus widths of one-quarter or less of the intercuspal distance.[31] However, Torres et al[38] reported that, after 2 years of clinical service, no significant differences were found between Class II restorations restored with GrandioSO (VOCO) conventional nanocomposites and those restored with GrandioSO Heavy Flow (VOCO) flowable hybrid nanocomposites. A study by Karaman et al[34] showed similar clinical performance over 24 months in restorations of noncarious cervical lesions restored with conventional nanocomposites (Grandio, VOCO) and those restored with flowable material (Grandio Flow, VOCO). A more recent study by Sumino et al[37] indicated that the flowable (injectable) materials G-aenial Universal Flo (GC America), G-aenial Flo (GC America), and Clearfil Majesty Flow (Kuraray Noritake) had significantly greater flexural strength and a higher elastic modulus than the corresponding conventional nanocomposite materials, Kalore (GC America) and Clearfil Majesty Esthetic (Kuraray Noritake). The wear and mechanical properties of these specific universal injectable resin composites suggested an improved clinical performance compared with that of the universal composites.

Several in vitro studies conducted at GC Research and Development comparing specific flowable material properties of several conventional composites found results similar to those of Sumino et al. Of the next-generation flowable systems studied, G-aenial Universal Flo (GC America) and Clearfil Majesty ES Flow (Kuraray Noritake) showed superior gloss retention and similar wear resistance to the conventional nanocomposites tested, which included Filtek Supreme Ultra (3M ESPE), Herculite Ultra (Kerr), Clearfil Majesty ES-2 (Kuraray Noritake), and G-aenial Sculpt (GC America).

According to these studies, the recently developed specific nanohybrid flowable resin (or universal injectable) composite systems (ie, Clearfil Majesty ES Flow and G-aenial Universal Flo) may possess properties that meet the aforementioned mechanical, physical, and optical requisites. These properties and the clinical behavior of the biomaterial formulations are contingent on their structure. New resin filler technology allows higher filler loading because of the surface treatment of the particles and the increase in the distribution of particle sizes. The unique resin filler matrix allows the particles to be situated very closely to each other, and this reduced interparticle spacing and homogeneous dispersion of the particles in the resin matrix increases the reinforcement and protects the matrix.[41–43] In addition, the proprietary chemical treatment of the filler particles allows proper wettability of the filler surface by the monomer and thus an improved dispersion and a stable and stronger bond between the filler and resin.

Studies[43–47] clearly indicate the importance that filler content and coupling agents represent in determining characteristics such as strength and wear resistance. Recent studies[19,31,48] report that flowable (universal injectable) composites have comparable shrinkage stress to conventional composites. According to the manufacturers, these next-generation flowable (universal injectable) composite formulations are purported to offer mechanical, physical, and esthetic properties similar to or better than those of many universal composites.[49] The clinical attributes of universal flowable composites include easier insertion and manipulation, improved adaptation to the internal cavity wall,[50] increased wear resistance, greater elasticity, color stability, enhanced polishability and retention of polish, and radiopacity similar to enamel. Furthermore, the clinical indications for these next-generation flowable resin composites are increasing as the properties of the materials and the bond strength of adhesives to dental tissues improve. With improved mechanical properties reported,[37] these highly filled formulations are indicated for use in anterior and posterior restorative applications.[5] The clinical applications of these specific next-generation universal injectable composites include sealants and preventative resin restorations; emergency repair of fractured teeth and restorations; fabrication, modification, and repair of composite prototypes and provisional restorations[4]; anterior and posterior composite restorations; composite tooth splinting[51]; and intraoral repair of fractured ceramic and composite restorations.[51] In addition, these composites can be used to repair denture teeth,[51] establish vertical dimension, alter occlusal schemes before definitive restoration,[5] manage spatial parameters during orthodontic treatment, eliminate cervical sensitivity,[51] resurface occlusal wear on posterior composite restorations,[51] establish incisal edge length before esthetic crown lengthening,[51] develop composite prototypes for copy milling,[5] and place pediatric composite crowns.[6]

Since the past provides information to improve the future, the lack of evidence-based research and clinical trial data on flowable biomaterials requires clinicians to evaluate the individual mechanical properties of these materials to determine whether their properties are equal or superior to those of existing materials. As the clinical performance of these next-generation flowable materials has improved over time, the research data have concurred. Although no direct correlation has been found between a material's mechanical and physical properties and its clinical performance, such a correlation might suggest the potential success of a restorative biomaterial for a specific clinical situation.[16] However, clinical longevity for restorations developed with these biomaterials remains to be determined through clinical studies for each specific clinical application.

Future clinical applications of this novel technique with these next-generation flowable materials may provide clinicians and technicians with alternative approaches to various clinical situations while allowing them to deliver improved and predictable dental treatment to their patients. Although the long-term benefits of this novel injectable composite technique remain to be determined, the clinical results achieved by the first author in the last 12 years and the aforementioned supporting empirical data for these next-generation nanocomposite flowables are extremely promising. Cases 1 to 5 illustrate some of the many clinical applications of the injectable resin composite technique using various highly filled formulations of flowable composite materials (Figs 6 to 41).

CASE 1 Developing the Functional Composite Prototype (Figs 6 to 12)

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Fig 6 Preoperative facial view of the maxillary anterior segment of a patient who presented with incisal wear and fracture of the maxillary anterior teeth.

Fig 7 Development of a diagnostic wax-up that establishes new parameters (ie, esthetic, functional) for the final restorations.

Fig 8 Clear PVS matrix (Memosil 2, Kulzer) was fabricated to replicate the diagnostic wax-up.

Fig 9 Flowable composite resin material (Filtek Supreme Ultra, 3M ESPE) was injected through a portal in the matrix, allowing the material to completely cover the conditioned unprepared enamel surface.

10a

10b

10c

11

12

Figs 10a to 10c Functional resin composite prototype was completed and inspected in centric relation and protrusive and lateral excursions.

Fig 11 Functional resin composite prototype established the optimal esthetic parameters for a natural smile.

Fig 12 Facial view at 6-year follow-up.

CASE 2 Orthodontic Space Management (Figs 13 to 18)

13a

13b

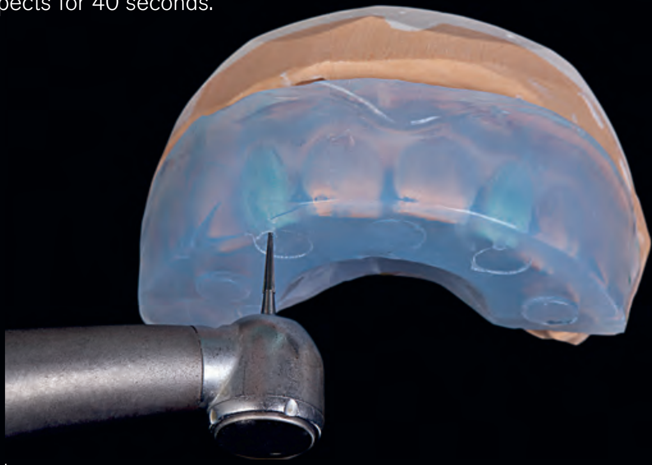
Figs 13a and 13b Preoperative facial views prior to interdisciplinary orthodontic treatment of 11-year-old patient, who presented with a tooth size discrepancy on the maxillary anterior segment and caries on the proximal surfaces of the maxillary lateral incisors. During orthodontic and restorative evaluation, the patient and parent were explained the significance of achieving specific space requirements so the orthodontist could position the teeth in the most optimal restorative position that will require a minimal preparation design. It is important that the appropriate and anticipated result be decided prior to the placement of the orthodontic appliances.

Fig 14 After review with the patient, parent, and orthodontist, a diagnostic wax-up was designed to modify the size and shape of the maxillary lateral incisors. This wax-up allowed the restorative team to evaluate form and function.

Fig 15 A clear PVS matrix was fabricated to replicate the diagnostic wax-up. A small opening was made above each tooth that was to be restored using a needle-shaped finishing bur (ET Series bur, Brasseler USA).

Fig 16 After the adhesive protocol was completed, the clear silicone matrix was placed over the arch and shade A1 flowable resin composite (G-aenial Universal Flo, GC America) was injected through a small opening above each tooth. The resin composite was cured through the clear resin matrix on the incisal, facial, and lingual aspects for 40 seconds.

14



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16

17a

17b

Figs 17a and 17b Completed resin composite restorations with optimal anatomical form for the 11-year-old patient. The composite injection technique allowed the establishment of harmonious proportions of the transitional restorations and the surrounding biologic framework. Use of the technique for tooth size discrepancies in the preorthodontic treatment-planning stages simplifies the understanding and management of this restorative dilemma for the patient and the interdisciplinary team.

Fig 18 Seven-year follow-up of composite transitional restorations after orthodontic treatment. Note the minimal wear.

18

CASE 3 Restoring Posterior Primary Tooth with an Injectable Composite Crown (Figs 19 to 24)

19a

19b

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Figs 19a and 19b Preoperative occlusal view and radiograph of the primary mandibular second molar of 78-year-old patient with an existing Class II composite restoration and caries on the distoproximal surface of the tooth. Upon initial consultation with the periodontist, the recommended treatment included an implant and bone graft, and the patient needed to temporarily discontinue his warfarin regimen. After subsequent medical history and radiographic review and discussion with the patient and periodontist, it was decided that the injectable resin technique would be a viable alternative treatment for this clinical situation, and the patient agreed.

Fig 20 A clear PVS (ExaClear, GC America) matrix was fabricated to replicate the preoperative diagnostic model, and an opening was made above the primary mandibular second molar with a tapered diamond bur (6847, Brasseler USA).

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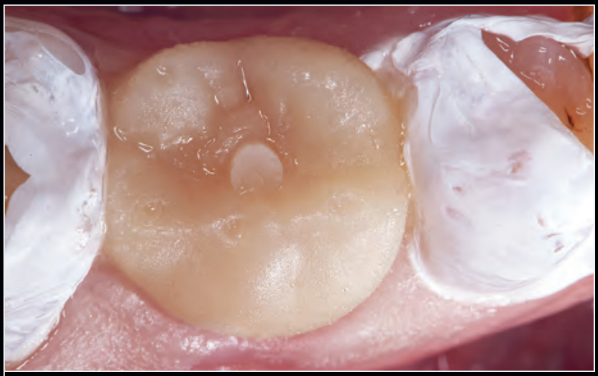

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Fig 21 Adhesive preparation design included removal of preexisting defective composite restoration and carious dentin and enamel; occlusal reduction of 1.5 to 2 mm; a circumferential chamfer 0.3 mm in depth; vertical proximal, buccal, and lingual walls with slight convergence toward the occlusal; all internal and external line angles rounded and cavity walls smoothed; and unsupported enamel walls removed to improve the path of material flow.

Fig 22 After the injection process was completed, the matrix was removed and the excess polymerized resin composite was scoured on the facial, lingual, and interproximal regions with a scalpel blade (#12 BD Bard-Parker, BD Medical) and removed with a scaler. The occlusal composite sprue was removed using an 8-fluted pyramidal-shaped finishing bur (H274, Brasseler USA).


23a


23b

Figs 23a and 23b Completed primary composite crown. The radiograph reveals ideal proximal contours and contacts with an optimal marginal integrity at the restorative interface.

Fig 24 Clinical follow-up at 18 months. The patient was pleased with the results achieved using this minimally invasive injection technique.


24

CASE 4 Single Anterior Implant Immediate Placement Technique (Figs 25 to 30)


25


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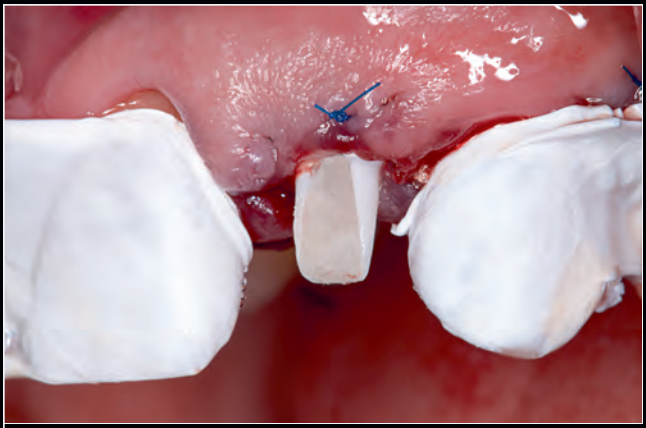
Fig 25 Facial view of the maxillary anterior segment and surrounding tissue of a 28-year-old patient.

Fig 26 Diagnostic wax-up was used for presurgical planning of the interrelationship between the definitive restoration and the oral structures and to fabricate the provisional restoration.



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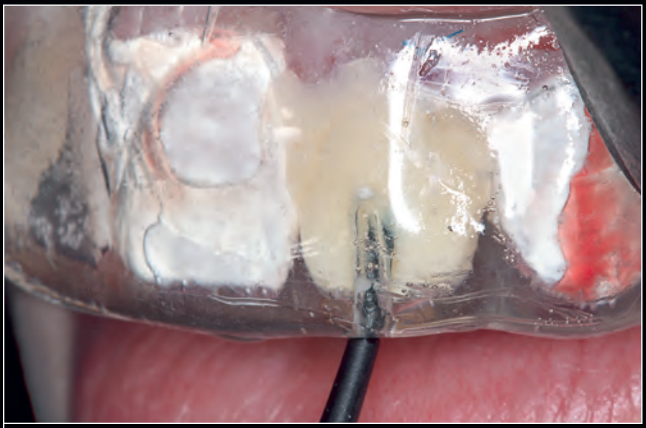

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Fig 27 Prefabricated zirconia abutment was placed and secured in position, and the access opening was sealed. Sterilized Teflon tape was applied on the adjacent teeth to separate the abutment, and glycerin was applied to the entire surface of the abutment.

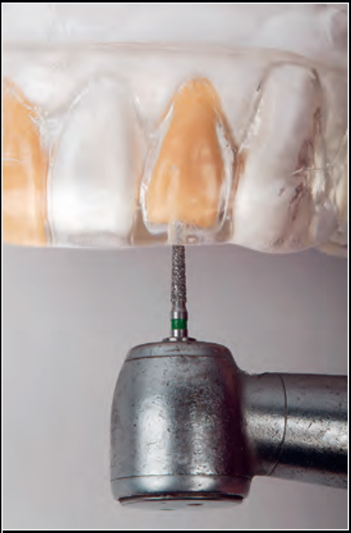
Fig 28 A clear silicone matrix was placed over the anterior segment of the maxillary arch, and an opacious shade A3 flowable resin composite (G-aenial Universal Flo, GC America) was injected through the small opening above the abutment, followed by a translucent A3 flowable resin composite. The resin composite mix was cured through the clear matrix on the occlusal, buccal, and lingual aspects for 40 seconds each using an LED curing light.

Fig 29 Biointegration of the provisional composite crown with the peri-implant architecture after 3 months.

Fig 30 Final results after placement of the implant-supported restoration, revealing optimal hard and soft tissue integration.

CASE 5 Restoring Anatomical Form and Color (Figs 31 to 41)

31



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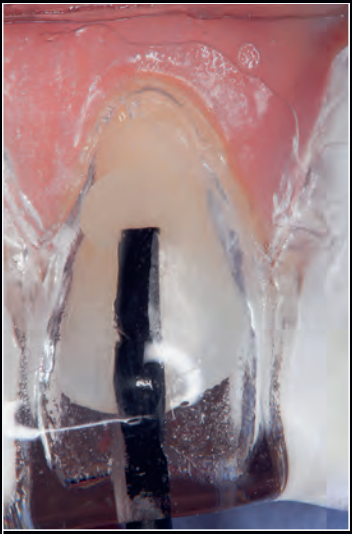

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Fig 31 Preoperative facial view of the maxillary anterior segment of a 47-year-old patient who presented with cosmetic concerns regarding his smile. The patient requested a conservative esthetic enhancement without orthodontic treatment.

Fig 32 A clear polyvinyl siloxane matrix was fabricated to replicate the diagnostic wax-up using a non-perforated tray. A small opening was made above the lateral incisor that was to be restored using a tapered diamond bur (6847, Brasseler USA). It is important to clean the internal surfaces with a microbrush to prevent silicone debris incorporating into the flowable material.

Fig 33 After intraenamel preparation and adhesive protocol, the clear silicone matrix was placed over the maxillary arch and an opacious shade A1 flowable resin composite (G-aenial Universal Flo, GC America) was initially injected through a small opening above the preparation, followed by mixing with a shade B1 flowable resin composite (injection layering technique). The resin composite was cured through the clear resin matrix on the incisal, facial, and lingual aspects for 40 seconds, respectively.

Fig 34 The completed resin composite veneer with optimal anatomical form.

Fig 35 At the following appointment, the final restoration was completed by using a composite cutback technique. The artificial enamel layer of the composite veneer was removed and a corrugated chamfer 0.3 mm in depth was placed around the entire margin with a long, tapered diamond.

Fig 36 The entire composite surface was etched with 37.5% phosphoric acid (Gel Etchant) for 15 seconds and rinsed for 5 seconds. Etching of the existing composite cleans the surface.

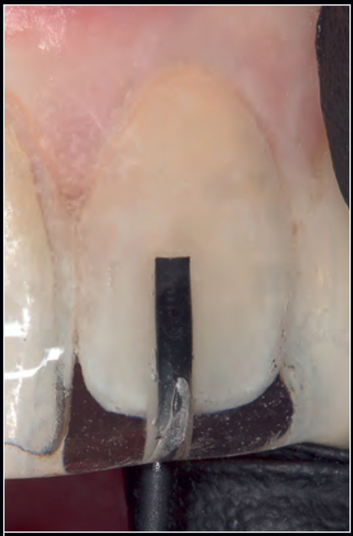
37

Fig 37 Silane was applied to the composite surface and lightly air dried. An adhesive was applied to the composite surface and allowed to dwell for 10 seconds, air dried for 5 seconds, and light cured for 10 seconds using an LED curing light.

38a

38b

38c



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Figs 38a to 38c Internal characterization was performed according to the appearance of the contralateral tooth and a shade-mapping diagram. A diluted gray tint (Renamel Creative Color, Cosmedent) was placed along the incisal edge and proximal regions with a size 08 endodontic file and light cured for 40 seconds. A diluted white tint (Renamel Creative Color) was placed along the incisal edge, proximal regions, and in the body with a size 08 endodontic file, and light cured for 40 seconds to stabilize the color and prevent mixing of the tints. A diluted yellow tint (Renamel Creative Color) was placed at the cervical and in the incisal third with a size 08 endodontic file and light cured for 40 seconds. It is the color variation from these modifiers and tints that creates the three-dimensional effect and the nuances within the incisal edge.

Fig 39 A new clear silicone matrix fabricated after the connective tissue surgical procedure was placed over the anterior segment of the maxillary arch, and a clear translucent flowable resin composite (Amaris Flow HT, VOCO) was injected through a small opening over the artificial dentin layer.

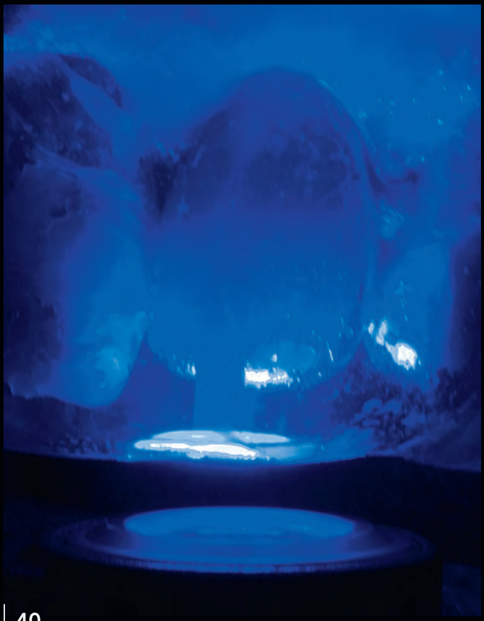

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Fig 40 The resin composite was cured through the clear resin matrix on the facial and incisal aspects for 40 seconds each.

Fig 41 Three-year follow-up of the composite resin veneer with an ideal anatomical form and color. Note the nuances in the incisal edge created by using the composite cutback technique.

CONCLUSION

In the past, with the use of conventional resin composites and the direct bonding technique, the clinician had to combine the hybrid and the microfill because of the inequities of the materials of the time. However, polychromatism was achieved from this early concept of anatomic stratification with successive layers of different restorative composites of varying refractive indexes, shades, and opacities.[52–57] This development of the polychromatic restoration from the inequities of the different composite resin systems (hybrid and microfill) stimulated scientists, researchers, clinicians, and manufacturers to explore and develop restorative materials that are not only applied in relationship to the natural tissue anatomy, but that have similar physical, mechanical, and optical properties to that of tooth structure.[53,58] Today, these highly filled formulations of injectable composite materials can be used to improve adaption and color integration as a result of internal adaptation and the mixing of colors. As we compare the old and the new in history, only the material of the time with the proper technique can provide optimal natural esthetic restorations. Knowledge of a concept of the past and a desire to create are limited by the materials clinicians have available to them for restorative procedures. Advancements in resin composite technology continue to improve the practice of dentistry. Continuing technological breakthroughs allow the clinician not only to comprehend the building blocks of the ideal composite restoration but also to implement and maximize the potential of new materials to attain more predictable and esthetic results.

Although new ideas and concepts continually flood the marketplace, one should not discount the power a new biomaterial may have on planning, design, or procedure. These developments promise to simplify the clinical applications for esthetic and restorative techniques and ultimately improve the level of health care provided for the contemporary dental patient. Only the passage of time can determine the long-term benefits of these new flowable resin formulations.[1] The clinical applications provided in this article demonstrate the potential of these flowable nanoparticle composite formulations to expand treatment options for a wider range of clinical situations.

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