All-Ceramic Restorations Designed by CAD/CAM

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Everyone wants beautiful teeth—women and men, the young and the elderly. Esthetics are as individual as the patients are, but do they realize what they are asking of their treatment team? Technical skill as well as experience with both the required materials and equipment are very important for successfully achieving treatment goals. Dental esthetics are divided into white and pink components. Dental technology carries a part of that responsibility, even for pink esthetics.

Ceramics are the materials of the future, as patients ask for increased esthetics. Traditional dental technology is changing to innovative CAD/CAM systems (Figs 1 and 2). The dental technician designs with new materials, but always follows the proven rules. Function, esthetics, and precision are important issues for dentistry. Within a dental team, the dental technician works for a functional design with natural details. Dental technology is no longer a pure craft, but an integral part of dentistry.

The preferred base for restorations is densely sintered alumina (Fig 3); it is perfect for dentistry because of its flexural strength. Optically, the semitranslucence (Fig 4) of the copings offers a natural brightness in the core structure that enhances the ability to mask underlying structures, such as metal dies and discolored dentin cores. In general, clinicians and dental technicians talk a lot about translucency and transparency. However, the opacity of a restoration is just as important and too-often forgotten; too much translucency can ruin a restoration. In combination with modern, fluorescent veneering (Fig 5) these materials efficiently reduce the shadowing effect and result in a maintenance of healthy-looking gingival architecture and a long-term esthetic result (Fig 6).

Experienced ceramists have sorted through a huge selection of materials of all types. There is an overabundance of materials because ceramists always want the same qualities from an implant or ceramic system: user friendliness and the ability to produce perfect copings of a natural brightness, color saturation, tone, fluorescence, and opalescence.

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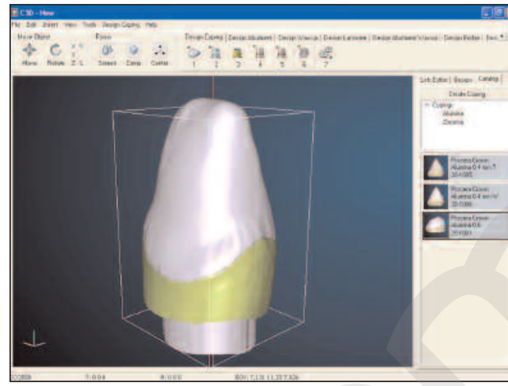

Figs 1 and 2 CAD/CAM technology. **[Au: Please provide figure legends.]**

Fig 3 Alumina coping on a natural root.

Fig 4 Coping and natural root in transmitted light.

Fig 5 Highly fluorescent natural root. The alumina coping, having no fluorescence at all, creates a shadow.

Fig 6 Cross section of a veneered alumina coping on a natural tooth. The impotency of the natural fluorescence is evident.

CASE REPORT 1

A young female patient presented with maxillary central incisors in very poor condition (Figs 7 and 8). They needed to be replaced and the patient expressed a desire to have the gap between the central incisors closed as well. To satisfy the esthetic demands of the patient, it was decided to perform a reconstruction with all-ceramic single crowns.

The central incisors were devitalized, built up with composite, and prepared accordingly (Figs 9


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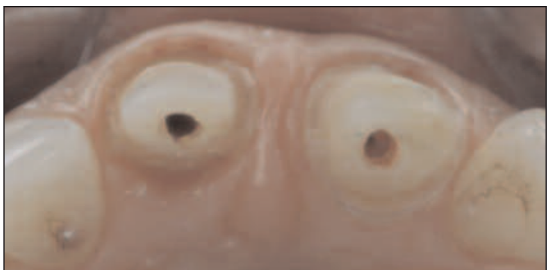
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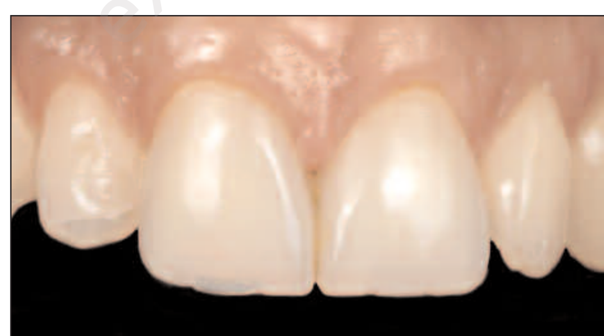
Figs 7 and 8 Maxillary central incisors in very poor condition. **[Au: Please provide figure legends.]**

Figs 9 to 12 Preparations of teeth. **[Au: Please provide figure legends.]**

Fig 13 Provisional acrylic crowns.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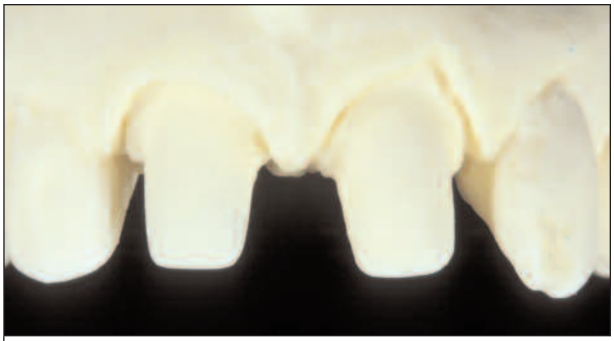
to 12). The desired marginal preparation is generally a rounded shoulder or a chamfer design to assure the stability of the alumina copings. The preparation must be adapted to the clinical situation. Because the natural dies had no discolorations or dark posts, the base was ideal for an all-ceramic restoration.

Provisional acrylic crowns were made for the transitional period until the final restoration was ready (Fig 13). The central diastema was closed, giving the central papilla a little space, and the volume and the length of the teeth were corrected. The lip line and phonetic function served as a guide.



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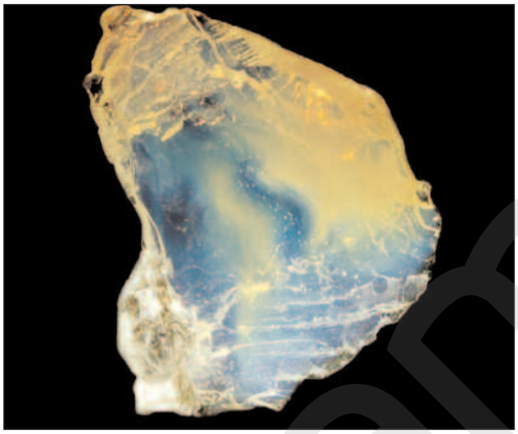
Figs 14 and 15 An overview of the dies on the cast before defining the preparation margins. **[Au: Please provide figure legends.]**

Fig 16 [Au: Please provide figure legend.]

Figures 14 and 15 provide an overview of the dies on the cast prepared in the laboratory, before defining the preparation margins. The teeth were prepared for all-ceramic crowns, provided the principle of rounded inner angles and edges was maintained. The permanent all-ceramic crowns were started on a non–saw-cut master cast (Fig 16). Solid casts allowed the gingiva and papillae to guide the emergence profile, ensuring, even at the planning stage, that the restoration would harmonize with the vital tissue. Once the all-ceramic crowns were seated, the individual ceramic structures could be finalized using the appropriate ceramic layering techniques.

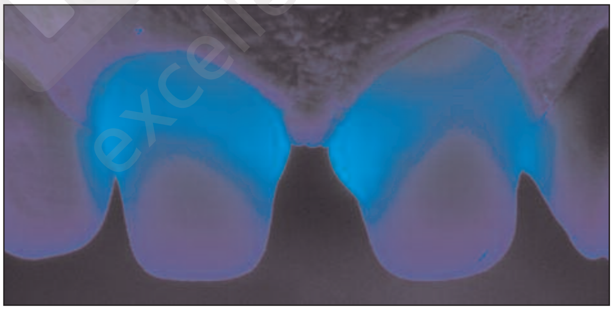
For the next restorations the Vita VM7 all-ceramic veneering porcelain (Vident) was used, since it was designed for all-ceramic framework materials with a coefficient of thermal expansion (CTE) range of 7.2 to 7.9. VM7 is a micro-fine particle ceramic with enamel-like abrasive behavior. Other properties, such as acid resistance, milling capability, and surface texture, have been studied and have produced very good results. **[Au: Reference?]** The low solubility of VM7 ensures a high level of durability in the oral environment, producing a long-wearing surface.

With VM7, the micro-fine particles of its two-glass matrix are evenly distributed. The particles are small enough that projections of individual beads are not noticeable, even in the lifting due to etching. They can be distinguished only by the bright or dark shadows produced during a particular phase. The technical advantages of the micro-fine particle ceramic include excellent stability during buildup and a very homogeneous surface after firing. It is easier to mill this softer and less resistant ceramic. The Goldman School of Dental Medicine at Boston University studied the abrasion behavior of various ceramics in comparison with natural tooth enamel; VM7 got the best score. **[Au: Reference?]** Its micro-fine structure demonstrated ideal, enamel-like behaviour. VM7 has a flexural strength about 20% greater than Vitadur Alpha porcelain (Vident). Such a result guarantees the stability of the layered restoration.



Figs 17 and 18 Cross sections of new veneering materials, in daylight and in transmitted light.

Figs 19 and 20 Completed coping with application of liner at the margin.



Figs 21 and 22 Gingival-area liner on cast, in normal light and under ultraviolet light.

The micro-fine particle ceramic also increases wear comfort for the patient. The veneer's homogeneous surface feels smoother and makes tongue contact very agreeable, just like natural dental enamel. The finer and substantially more homogeneous distribution of the different glass beads in its structure, created by modifications in the production process, distinguish the Vita micro-fine particle ceramics (VM9 for zirconium and VM13 for porcelain-to-fused-metal restorations) from traditional dental ceramics. Figures 17 and 18 show cross sections of the new veneering materials, in daylight and in transmitted light.

The coping was shortened 0.1 mm at the margin and completed with liner (Figs 19 and 20). In this way, the buildup started from a whitish-beige margin. As liners also control fluorescence in the restoration, the goal was to apply them in the gingival area to support the light distribution (Fig 21). The importance of liners becomes very clear when a restoration is put under ultraviolet light. The light distribution from the liners can even be noticed in the stone cast (Fig 22).

Figs 23 and 24 Comparison of natural tooth, liner sample, and a cross section of a natural tooth, in direct light and under ultraviolet light.

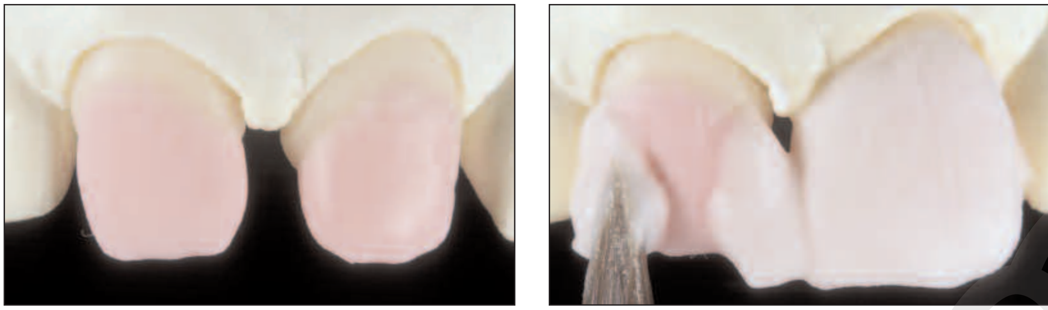
Figs 25 and 26 Liner samples, in direct light and under ultraviolet light.

Fluorescence, the capacity to receive radiated energy and to emit it in another wavelength, is a fascinating phenomenon. Figure 23 shows a comparison under direct daylight of a natural tooth, a sample of liner, and a cross section of a natural tooth. Their brightness is substantially influenced by changing light conditions (Fig 24). With regard to natural white dental fluorescence, it is important for ceramists to position it correctly. In natural tooth the root and dentin show the strongest fluorescence, and the enamel's fluorescence is the weakest.

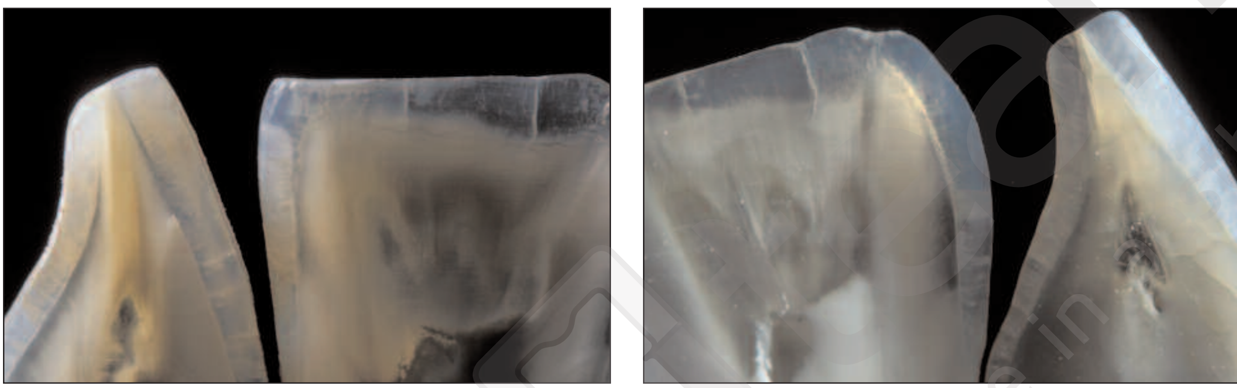
Figures 25 and 26 show samples of a few shades of liners in normal daylight and under ultraviolet light. The beautiful natural fluorescence of the liners is created by the short-wave light in daylight that interacts with the fluorescent structures in the dentin and the enamel. The liners simply distribute the light into the gingiva and the papillae. White is esthetic and pink is esthetic as well; it is no longer limited to white esthetics.

The new Vita porcelain system omits opaque dentin, but includes Base Dentine with a heavier saturation and Dentine with a higher translucence. These properties provide new layering opportunities, especially when customized to specific situations. When there is a lack of space for the veneering material, Base Dentine can be used to achieve the right value, saturation, and hue, without using Dentine.

Base Dentine was applied in the appropriate shade over the entire surface of the coping and built up to a reduced tooth form, making sure that it did not completely encroach on the liner in the gingival area (Fig 27) and reduce the fluorescent effect. Covering the liner with a little Dentin controlled the contrast. Different buildup opportunities are available when dentin materials of higher or lower values, or different chromas are used on the lateral mesial or distal line angles (Fig 28). The tooth shade itself lies in the center of the tooth. The tooth form was built up with the dentin materials. Once the correctly contoured anatomic form was achieved, the cut-back was made irregular to enhance the internal effects.



Figs 27 and 28 Application of dentin material.



Figs 29 and 30 Cross sections of natural teeth showing the light and the dark enamels.

Figs 31 and 32 Application of enamel mixed with a bluish opalescent translucent powder.

The VM7 porcelain system has only two enamels, a light enamel with a softer color and a dark enamel with a greyish color, both of which are found in natural teeth (Figs 29 and 30). The enamel materials provide a higher level of translucence which makes an artificial tooth look natural. In this case, after completing the buildup, the enamel was mixed with a bluish opalescent translucent powder, Effect Opal Blue, in a ratio of 1:1 (Fig 31). This mixture made the enamel more translucent and opalescent, producing a stronger contrast with the other characteristics to be applied. To compensate for firing shrinkage, the anatomic form was somewhat overdeveloped (Fig 32).

Opalescence gives the tooth its vividness. In some cases, enamel can be mixed with a bluish-grey translucent material or with Translucent Opal (Fig 33). Natural tooth (Fig 34) shows the bluish-grey enamel on the surface. The opalescence, based on the internal prism-like structure of the enamel, is especially visible under black light. The impression of color changes depending on the light. The resulting blue-amber color is a component of natural teeth (Fig 35). The remaining por-

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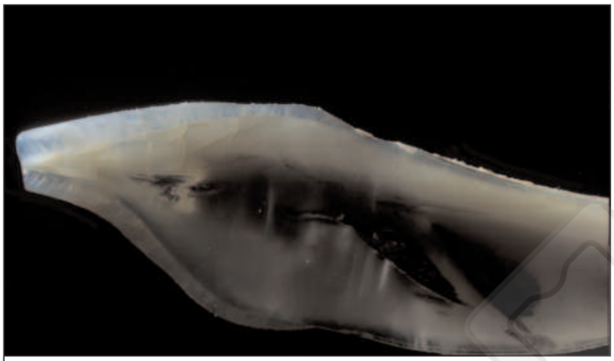
Fig 33 Samples of Translucent Opal. The sample on the left is an intense enamel and the sample on the right is a softer enamel.

Figs 34 and 35 Cross section of natural tooth, in direct light and under black light.

Figs 36 and 37 Sample of Effect Opal Blue, in direct light and under black light.



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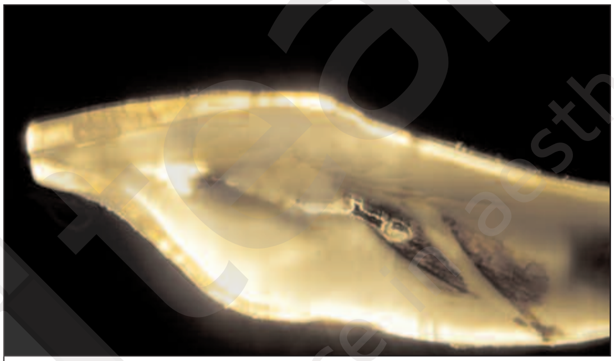

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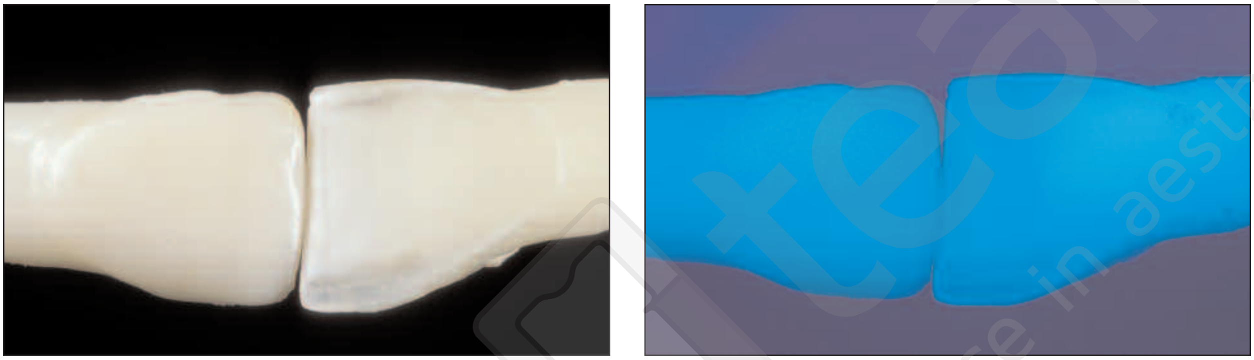
tion of the light spectrum passes through unhindered and determines the perceived color. In contrast, opalescence affects only the shorter-wave, blue portion of light, which is not absorbed but scattered. The small prisms in natural tooth enamel that scatter and diffract short-wave light are responsible for this effect. Using Effect Opal Blue, the opalescence of VM7 was quite appealing in direct light (Fig 36) and under black light (Fig 37).

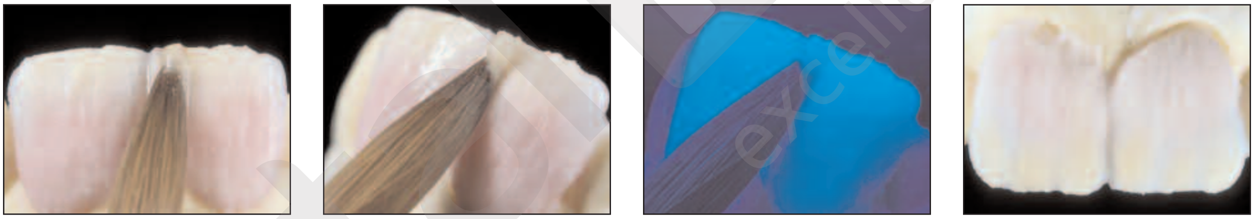
In nature, mamelons or other colored characteristics come in shades from ivory to yellow, orange, salmon red, and even soft brown (Figs 38 and 39). In general there are three mamelons for the central incisors, two for the lateral incisors, and one for the canines. The mamelons are located directly under the natural enamel (Fig 40). They are always more opaque than normal dentin and have a very high fluorescence, which is visible under ultraviolet light (Fig 41).

The mamelons should be more developed for the central incisors and less so for the lateral incisors. Applying mamelon materials (MM) to the

Figs 38 and 39 Colors of natural mamelons. **[Au: Please provide figure legends.]**



Figs 40 and 41 Comparison of mamelon sample and a natural tooth from which the enamel has been filed, in daylight and under ultraviolet light.



Figs 42 to 45 Application of enamel materials. **[Au: Please provide figure legends.]**

dentin-enamel layer mimics natural characteristics. In this case, MM 3 was applied with a pinpoint technique to obtain the desired shade effect in the incisal area. Mamelons should always create a warmer opaque sensation. For this young patient, the appropriate combination included Blue Foundation Halo with blue transparent Effect Enamel 10 (Silver Lake Blue). These shades can be strengthened, however, with Vita Interno materials or can be chromatized. Interno materials are strongly fluorescing and come in 12 fine-grained, intensive shades. The incisal material was applied in a very thin layer or wash. It is essential during layering to arrange the characteristics— in this case the mamelons—on the incisal plate. This automatically sandwiches the mamelons between the incisal and transparent materials to obtain a natural-looking restoration, where incidental light flows around the effects. The visual effects, together with the fluorescence, determine the character of the restored incisal edge. The strongly fluorescing mamelon materials customize the incisal area and add shade characterization (Figs 42 to 45).

Pure Effect Chroma (Pearl Banana) was applied to the palatal area. These materials are used to

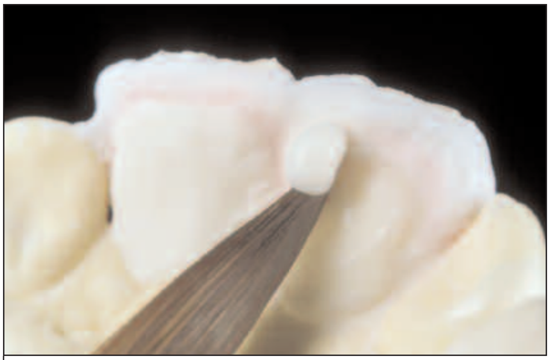


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Fig 46 Application of chroma material to palatal surface.

Figs 47 and 48 Samples of chroma materials compared to palatal surface of extracted teeth.

Figs 49 and 50 Application of enamel materials to palatal surface.

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highlight the shade of specific cervical and dentin areas of the restoration (Fig 46). These strongly shaded materials are layered directly onto the coping. They are designed for the tightest space relationships on the palatal surfaces. The palatal buildup proceeded once labial layering was finished. First, the surplus ceramic was trimmed back even with the coping. The Effect Chroma materials are available in colors from white to yellowish, orange to brownish (Figs 47 and 48). The warm chroma of these materials gives the palatal surface depth of colour that radiates from underneath.

The all-ceramic crowns were completed on the palatal side with a mixture of Enamel Light and Effect Chroma Blue in a 1:1 ratio (Figs 49 and 50), and the palatal contour was developed. As the palatal side is very important to phonetics, the shape had to correspond to its natural form. Separated layering offers many advantages. If after the first firing the applied characteristics do not match

Fig 51 Restorations after first firing.

Fig 52 Samples of translucent materials. The sample on the right, Window, is much more translucent or even transparent when compared to the sample on the left, which is less transparent and a little more grey. **[Au: Please verify right-left placement of samples.]**

Fig 53 Application of translucent materials.

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the expectations, they can be filed off the incisal layer with a diamond bur. That provides the opportunity to layer the effects on the incisal plate in such a way that the results become more predictable. If the restorations are already overlaid with translucent material before these assessments have been made, the technician will have to file through the translucent layer. These corrections, however, always introduce visible filing marks.

If excessive shrinkage occurs with a translucent layer in place, either in the mesiodistal plane or even from the labial plane, there are unfortunately no solutions and the restoration cannot be salvaged. Even if the shrinkage could be compensated with another transparent layer on the existing layer and the correct shape could be achieved, the overall effect would be low-value, dull grey crowns.

The restoration went well through the first firing (Fig 51), and was followed by the first correction firing. The final form was completed by touching up with a few translucent materials. Often, simplicity is best. Depending on the desired result, a choice could be made between Neutral (less transparent and more greyish) and Window (translucent, or even transparent) translucent materials (Fig 52). The application of translucent or even transparent materials (Fig 53) is very important because it imparts a natural-looking depth, especially in the incisal area. Translucent materials should receive minimal firing to protect the character of the opalescence and transparency. If fired too often, their effects diminish.

After the second firing (Figs 54 and 55), only minor form corrections should be necessary. It is important to check the contact surfaces on a non–saw-cut master cast. Creating interdental spaces needs special attention. The contact points on occlusal surfaces were developed, and the interdental space was closed as far as the papilla. This is the only way to avoid the unsightly black triangles between the central incisors that


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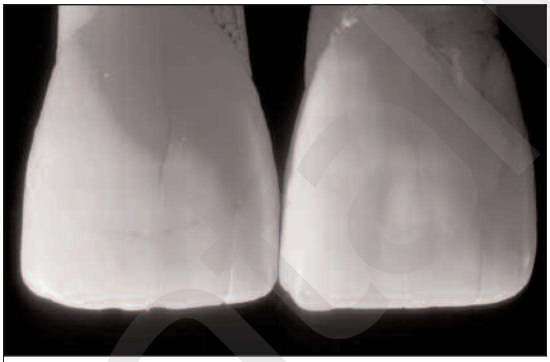
Figs 54 and 55 Restorations after second firing.

Fig 56 Try-in of bisque-baked crowns.

Figs 57 and 58 Macrostructures and microstructures. **[Au: Please provide figure legends.]**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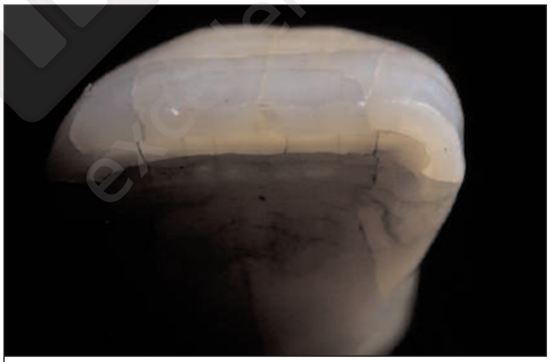
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can also cause phonetic problems or even food impaction. The advantage of the non–saw-cut master cast is that the important information of the gingiva and the papillae remains untouched.

The bisque-baked crowns were tried in situ (Fig 56). In addition to the usual corrections decided by the clinician and the dental technician, it was determined if further improvement would be possible or if there were differences between the provisional and bisque-baked crowns. At this try-in, esthetics were discussed with the patient, including the length of the teeth, shade, etc. The bisque-firing test revealed the importance of technique: incisal characteristics were achieved using a pinpoint technique. In this case, both the dentist and the patient were completely satisfied with the try-in of the bisque-baked crowns.

Another factor that affects the reflective behavior of the restoration is the surface structuring. In natural teeth both macrostructures and microstructures are noticeable (Figs 57 and 58). Two or three macrostructures are visible vertically on


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Figs 59 and 60 Restorations after glaze firing.

Figs 61 and 62 Restoration margins.

Fig 63 Natural shapes visible in black-and-white photography.


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the labial surface. The microstructures are much finer and are horizontal over the labial surface. Adolescent teeth present a rougher surface; they have an unworn appearance. The texture of middle-aged teeth is softer, and for elderly teeth, the texture is worn and has disappeared. Some time was devoted to creating the surface. After glaze firing (Figs 59 and 60), the restoration was further refined with a rubber polisher. The luster intensity can also affect the reflective behavior of the restoration. After glaze firing, a brush and diamond polishing paste can be used to obtain the desired luster intensity.

The interdental gap between the central incisors was closed successfully with restoration margins within the sulci (Figs 61 and 62). This also enhanced the emergence profile better than supragingival margins. The finished restoration was ready; papillae and gingiva were healthy, and the brightness of the crowns was right on the mark.

Black-and-white photographs (Fig 63) are particularly helpful for studying natural tooth shapes.

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Fig 64 Palatal surface of restorations.

Figs 65 and 66 Definitive restorations.

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Focus is primarily directed to the shape and surface texture of the restoration. The functional development of the palatal structures of the replacements, essential for pronunciation during speech, was clearly visible (Fig 64). A little of the palatal surfaces had been stained to match its natural example.

Esthetics is the science of beauty. The maxillary anterior dentition now presented a coherent overall image (Figs 65 and 66). The space was closed up and the restoration harmonized with the lip line, the oral environment, and the patient's appearance. The all-ceramic crowns created a much more striking impression than before. The surfaces of the central incisors fit well with the neighboring teeth. One advantage of the micro-fine particle ceramic is a density that permits restorations to be easily rubber wheeled and polished, as seen in the finished restoration.

CASE REPORT 2

The second case involved an all-ceramic crown on a maxillary left central incisor. The tooth presented an abutment of a harmonious natural-looking, basic shade that did not require discoloration masking (Fig 67). After layering and filing the crown in the right position on the master cast, the shape and luster was checked (Fig 68 and 69). The adaptation for the luster was prepared in the laboratory to match the tooth to the rest of the dentition. Initially, the papilla had not closed the space between the two teeth (Fig 70), but after 2 weeks, the papilla had regenerated perfectly (Fig 71). Brightness is portrayed very clearly in black-and-white photography, and the shade does not divert attention from the basics (Fig 72). The all-ceramic single crown blended imperceptibly with the natural dentition (Figs 73 to 75). The individual shape of the crown was copied from the adjacent tooth (Fig 76).

Fig 67 Abutment with a harmonious, natural-looking shade.

Figs 68 and 69 Restoration on the master cast, after layering and filing crown.

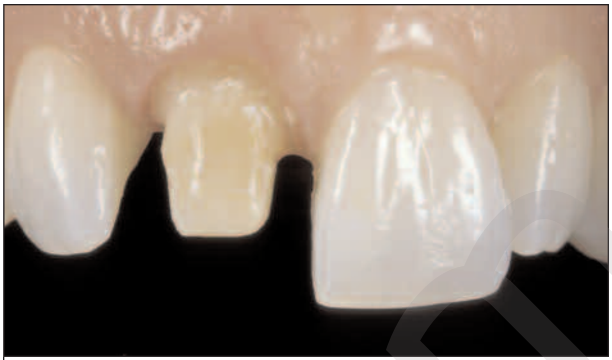
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Fig 70 Diastema visible right after placement of restoration.

Fig 71 After two weeks, visible regeneration of gingiva.

Fig 72 Brightness portrayed in black-and-white photography.


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Figs 73 to 75 Definitive restoration.

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Fig 76 Unique shape of crown duplicated from adjacent tooth.


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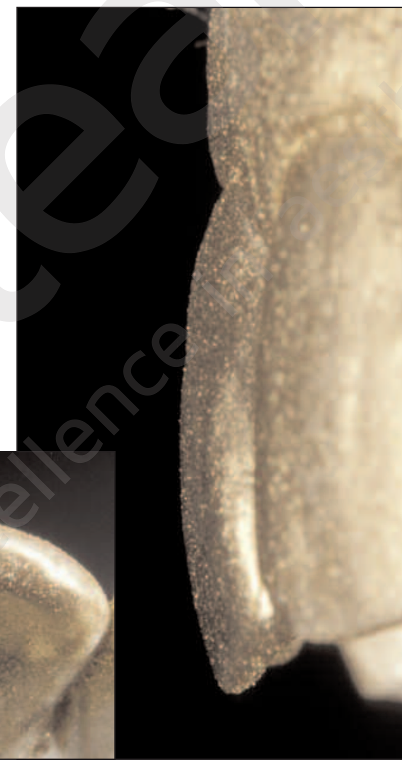
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Fig 77 **[Au: Please provide figure legend.]**

Fig 78 Natural abutments.

Figs 79 to 81 Master cast coated in gold powder, revealing surface details.

CASE REPORT 3

A female patient presented to correct the esthetics of her maxillary central incisors, wanting them shortened due to their palatal position (Fig 77). After preparation, the decision was made to manufacture two all-ceramic crowns (Fig 78). The central incisors were built up with the same technique described above. When the master cast was coated with gold powder, the very fine but important details of the surface structure and the emergence profile became visible. Texture has an indirect effect upon the appearance of the restoration (Figs 79 to 81).The finished restoration harmo-

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Figs 82 and 83 Definitive restoration.

Figs 84 to 86 View of the restoration in normal smile line. There are also all-ceramic crowns on the two maxillary premolars.

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nized perfectly with the gingiva, and the clinical and esthetic appearance of the permanent restoration was very natural looking (Fig 82). In a normal smile line, the restoration of the central incisors is visible, as well as two all-ceramic crowns on the premolars (Fig 83). Smile symmetry is achieved when a restoration blends into the oral environment, following the lower lip line, the mouth angle, the incisal line, and the line of papillae. Esthetics also requires subjective input from the patient, clinician, and ceramist, because it is, after all, something personal and subjective (Figs 84 to 86).

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