

Figs 2a and 2b Zirconium restoration under natural (a) and transmitted (b) light.



Figs 3a and 3b Alumina restoration under natural (a) and transmitted (b) light.

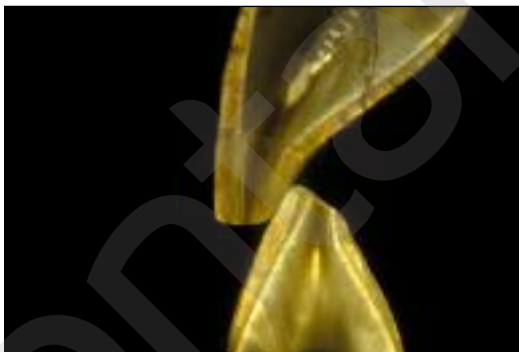


Fig 4 Cross sections of natural teeth under back light.



Fig 5 Due to its white color, zirconium is an ideal material for porcelain buildup.

Observe the differences between a zirconium prosthesis and an alumina prosthesis in normal day-light (Figs 2a and 3a) and transmitted light (Figs 2b and 3b). Both materials exhibit semitranslucency, which is ideal to fabricate natural-looking restorations. Alumina clearly has a warmer chroma than zirconium. This warmer saturation is also evident in natural teeth under transmitted light (Fig 4).

Due to its bright color (Fig 5), zirconium has a very high value. *Value* or *brightness* is the dimension of a color that represents its similarity to one of a series of achromatic colors, ranging from very dim (dark) to very bright (dazzling). In other words, value is the percentage of white in a certain color. More white means a higher value, while less white means a lower value.



Fig 6 Liners can be used to modify the brightness of zirconia.



Fig 7 Unprepared zirconium restoration. Note the lack of saturation.



Fig 8 Zirconium restoration after the chroma has been controlled using liners.



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Fig 9 Under ultraviolet light, zirconium copings show a dark shadow.

Fig 10 Fluorescent effects brighten the zirconium framework and improve light conduction.

Fig 11 Even the basal surface of the pontic is covered with fluorescent shoulder material.



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The chroma of zirconium is zero because of its very white and bright color (Fig 6). *Saturation* or *chroma* refers to the intensity of a specific hue. A highly saturated hue has a vivid, intense color, while a less saturated hue appears more muted. In other words, saturation is the percentage of a neutral substance (eg, water) in a certain color. More of a neutral substance in a certain color means less saturation. To communicate efficiently between the dental practice and dental laboratory, it is important that all parties understand these terms and their importance in tooth selection.

Figure 7 shows a “naked” unprepared restoration, with an extremely high brightness and no saturation at all. What steps should now be taken, considering that canines almost always have a higher chroma? First, a prewash or thin layer of dentin is applied. This prewash bonder application and firing step facilitates a strong

bond between the framework and layering porcelain. The second step is to layer fluorescent shoulder ceramic over the entire framework. For the canines and posterior region, fluorescent shoulder porcelain with higher saturation is used (Fig 8). This technique optimizes light transmittance.

Under ultraviolet light, zirconium copings produce an undesirable dark shadow (Fig 9). To retain the appearance of vital gingiva, strong luminosity is required, even under ultraviolet light. Thus, the zirconium coping is shortened or the scanner is activated in “short-scan” mode. *Fluorescence* is the capability of a body to receive radiation at one wavelength and emit radiation at another wavelength. Short-wave ultraviolet light (ie, black light), which is visible to the human eye, is part of daylight. When it makes contact with a natural tooth, it passes through the enamel, penetrates

First, the cast was analyzed in the articulator (Fig 22). This is the initial step of good treatment planning in the lab. The bipupillary line was used as a guide to determine the correct horizontal line of the maxillary incisal edges. To obtain an optimal width-length ratio between the anterior crowns, a diagnostic waxup was fabricated. This showed the ideal situation in terms of both function and esthetics. Procera zirconium crowns on natural dies and customized abutments were used. It is recommended to fabricate the custom abutments with casting resin rather than wax. Abutments made with casting resin are more stable and will not break when the abutment is screwed in and out. A waxed-up abutment is more fragile.

The abutments were milled into shape. Thanks to the soft gingival mask, it was possible to remove the stable resin abutments from the cast without any problems. The abutments were mounted on the scanner's appropriate holder (Fig 23), and the screw access hole was sealed with wax. After finishing, the data were transmitted to the closest Procera production center (Nobel Biocare).

When fabricating individual abutments, good communication between the periodontist/prosthodontist and dental technician regarding the emergence angles and soft tissue support is required. If the implants are placed in the proper positions, selecting and designing an appropriate abutment is not problematic. In general, the desired position of the crown margin should be 0.5 mm below the gingiva at the labial side and level with the gingiva at the lingual and palatal sides. If the crown margin is lower, the prosthodontist will have difficulty visualizing and trimming any excess cement or composite. A qualified dental technician should be aware of this when designing the abutments.

It is important that there be sufficient space from the labial side for the crown and veneering material. There must be at least 0.5 mm between the desired margin of the abutment and the gingiva. If there is inadequate space, the gingiva will shift in the apical direction, leading to an automatic discrepancy in the gingival tissue levels. It is important to create a periodontally friendly mar-

gin. Concave contouring and shaping of the abutment at the area below the preparation margin extending to the base of the implant should be carried out. The requisite preparation for long-term success is a shoulder preparation with rounded edges (Figs 24a and 24b).

The use of a biocompatible abutment material is advised for transmucosal soft tissue adhesion. Along with excellent tissue adhesion, zirconium brightens the gingiva due to its bright, white color. If the biotype is thin, the material underneath may shine through. In these cases, titanium abutments or cast abutments in an alloy would have a negative effect on the pink esthetics by creating a shadow or a grayish color at the gingiva.

To evaluate the paradigm shift in abutment design, Rompen et al¹ examined the effect of a concave transmucosal profile on the vertical stability of soft tissues at the facial aspect of dental implants (Curvy Abutment, Nobel Biocare). In a pilot phase, grooves were individually milled using a diamond bur into the concave subgingival area between the preparation margin and implant base (Figs 25a and 25b). This stabilized and promoted the soft tissue seal. Note that Curvy Abutments are available only in titanium.

In each phase, the silicone index of the waxup was used as a reference (Fig 26). The position of the zirconium crowns should be in relation to the desired tooth shape and size to ensure correct support of the ceramics. The framework was reduced approximately 2 mm incisally and 1.5 mm labially and lingually. The framework must be accurately dimensioned to prevent fracturing.

Correct implant placement allows for individually designed all-ceramic abutments on each implant. Thanks to the industrial-grade precision of CAD procedures, the all-ceramic crowns arrive with a cement gap (50 to 60 μ m in width) that is consistently maintained between the prepared die or abutment and coping, providing 100% passive retention without friction. The computer-controlled precision of fit ensures that the cement gap is optimal (Fig 27).

Since all-ceramic materials such as alumina and zirconium have no fluorescence, it is important to



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Fig 28 Under ultraviolet light, zirconium crowns produce a dark shadow, and fluorescent ceramic powders brighten up the cervical areas.

Fig 29 The contact surfaces of the crowns were controlled on an unsectioned master cast.

Fig 30 Acrylic key used to transfer the abutment in the mouth.

Fig 31 Individual zirconium abutment in place on the implant.

brighten the "critical" gingival zones to prevent shadows and improve light conduction. In ultraviolet light, the crowns produce a dark shadow, especially in the cervical area, which will affect the final esthetic result (Fig 28). Strong luminosity is needed to produce a vital-looking restoration. All-ceramic restorations cannot tolerate shadows.

The rubber-polished crowns were placed on the unsectioned master cast for fine adjustment of the marginal ridges and contact surfaces and to produce the final shape. The contact area between the crowns was particularly long, extending from the remaining papillae and nearly approaching the incisal edges. The contact surfaces of single crowns should always, without exception, be controlled on an unsectioned cast. The solid cast eliminates the die movement inherent in all sectioned

casts. In addition, the solid cast allows the crown to be designed within the context of the soft tissues. This produces correct line angles for elegant restorations and closed interdental spaces. Unesthetic black holes should not be tolerated. After bisque firing, the crowns were ready to be sent to the dental clinic on the master cast (Fig 29).

Using an acrylic key fabricated on the master cast by the dental technician, the abutment can be transferred in the patient's mouth quickly and easily (Fig 30). The acrylic key ensures the correct fit of the abutment on the implant. The connection was extended to the natural dies, and the screw access hole was open to screw the abutment on top of the implant.

Figure 31 shows the situation before try-in of the bisque-bake restorations. The hollow neck

**32****33****34a****34b****Fig 32** Occlusal view showing the custom abutments and natural tooth dies.**Fig 33** Try-in of the bisque-bake restoration.**Figs 34a and 34b** The gingiva quickly adapted to the abutments and crowns.

preparation is perfect for an all-ceramic restoration. The preparation margin of the abutment defined in the lab was located slightly subgingival, approximately 0.4 to 0.5 mm from the labial side. With this type of preparation, the dental technician has sufficient space to design a corresponding margin. The technician can scan any type of preparation; however, copings tend to crack more with tangential preparations. Customers should be informed of this drawback.

Figure 32 shows the custom zirconium abutments and natural stumps prior to insertion of the crowns. The oral situation has been expertly prepared by the periodontist. Using a predefined torque of 35 Ncm, the prosthodontist placed the abutment onto the implant. Try-in of the bisque-bake crowns is highly recommended (Fig 33). Not

only does this allow the patient to evaluate the restoration, but it is also the ideal phase to adjust both the occlusal and interdental contact points and contact surfaces. On this topic, the authors recommend the work of Tarnow,² who described the relationship between the distance from the bony margin to the interdental contact point and the ability of the papillae to regenerate. In this case, the gingiva adapted quickly to the zirconium abutments and instantly made a visually healthy impression (Figs 34a and 34b).

One important question is whether the dental technician needs direct access to the patient for anterior crown reconstructions. The answer, of course, depends on the desired results. The authors prefer to see patients in the lab. This way, the shape and surface can be adjusted according



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Fig 35 Coating natural teeth with gold powder reveals the micro- and macrostructures on the labial surfaces.

Figs 36a and 36b All-ceramic restoration after glaze firing.

Fig 37 Immediately after cementation, there was still space between the crowns for the papillae to regenerate.

Fig 38 A few months after cementation, the papillae had fully regenerated.



36a



36b



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to the patient's wishes. Further, it is important for technicians to take many photographs to better understand the natural oral situation. For example, by viewing teeth coated with gold powder, new details can be discovered and incorporated into daily work (Fig 35). The vertical marks identify the grooves and ridges, which correspond to the microstructure. The macrostructure consists of fine horizontal growth lines.³

In this case, the layering was kept simple, relying instead on the effects created by the vitality in the incisal area and the harmony of the tooth shape. The crowns were separated by a delicate incisal triangle. The emergence profile turned out well, and the contact surfaces were ideal (Figs 36a

and 36b). The overall layering, especially in the incisal area, was designed to be particularly lifelike. Ceramic stains should never be used in the incisal area, because they restrict the depth of reflection and light transmittance.

After placement of the restoration, there was still space between the crowns for the papillae to regenerate (Fig 37). Oral hygiene and regular checkups will ensure the long-term success of treatment and maintain the bone, periodontium, and teeth. After a few months, the papillae between the implant crown and the natural die were restored (Fig 38).

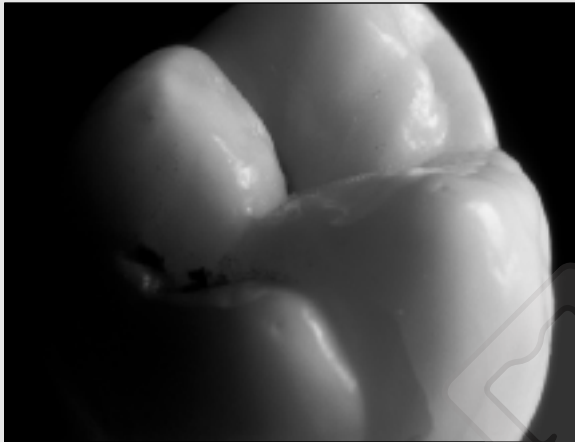
The emergence profile, ie, the natural physiologic profile of the crown emerging through the



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Fig 39 Zirconium restoration in the maxilla. Note the excellent emergence profile.

Fig 40 Natural-looking laminate veneers in the mandible.

Fig 41 Functional factors such as canine guidance and build-up of the occlusal surfaces are just as important as esthetics.

Fig 42 Final result.

gingiva, has a major influence on soft tissue regeneration. The best conditions for gingival and papillary healing is when the emergence profile is correct and the crown contours support the gingiva. The interdental contact surfaces shifted significantly in a cervical direction, sealing the interdental spaces and giving the restoration a natural appearance. Figure 39 shows the final result in the maxilla.

In the mandible, the prosthodontist used a minimally invasive preparation. Laminate veneers on refractory die material were fabricated. The same tooth shade that was used for the maxillary crowns was used for the mandibular laminate veneers, as well. This bright shade does not detract from the appearance, thus illustrating how shape trumps

shade. As is standard for laminate veneers, the gingiva was untouched and showed a pink and healthy appearance. Fourteen days after cementation, the gingival situation was healthy (Fig 40).

The functional requirements were met with classic anterior tooth guidance. The palatal surfaces guide the central incisors in protrusion. The posterior region discludes during canine guidance (Fig 41). The lengths of the maxillary central incisors differed to ensure even anterior tooth guidance. Esthetically, harmony between the pink and white esthetics transformed a good result into an outstanding result—one that could only be achieved with teamwork. The final result shows a natural, harmonious appearance (Fig 42).⁴

CASE 2 (Figs 43 to 59)**43**

Fig 43 Initial situation with an existing porcelain-fused-to-metal restoration.

Figs 44a and 44b After extraction, two implants were placed at the lateral incisor sites.

**44a****44b****45a****45b**

Figs 45a and 45b Finished abutments on the gypsum master cast.

Case 2

The patient presented with an inadequate porcelain-fused-to-metal prosthesis (Fig 43). The prosthesis was removed, and two implants were placed at the lateral incisor sites (Figs 44a and 44b). To achieve optimal esthetic design of the pontic area in cases with unfavorable initial conditions, measures should be taken to augment gingival tissue supply and condition the site. In general, the periodontist will harvest an approximately 0.8-mm-thick connective tissue graft from the palate.

Before carrying out any modifications of the soft tissue, an impression was taken of the implants and poured in gypsum without the removable gingival mask. Often, gingival masks are too flexible and therefore reduce the stability of the restoration on the cast. The prosthodontist used a standard healing abutment and standard impression coping. This explains why the shape of the gingiva did not meet the requirements for a correct emergence profile. The extension of the planned cus-

tom abutments was traced. Figures 45a and 45b show occlusal and labial views of the finished abutments on the master cast. The shape of the abutment between the preparation of the margin and the implant base was concave to prevent the gingiva from being pressed in an apical direction.⁵

After scanning, the zirconium framework was designed using the Procera software (Nobel Biocare). The framework was immediately checked for an accurate fit (Fig 46). It is important to ensure that gingival support is provided in the pontic area. Otherwise, the tediously crafted gingival tissue architecture would quickly collapse. Next, selective grinding was performed on the pontic area of the second unsectioned master cast to prepare the shape for the ovate pontics.

Laminate veneers were planned for the canines and first premolar. Figures 47a and 47b show the silver galvanized dies on the master cast. In cases of combined implant and veneer treatment, it is important to choose an adequate cast system that allows the technician to make an exact copy of

Fig 46 Zirconium restoration on the unsectioned master cast.

Figs 47a and 47b Silver galvanized dies on the master cast. The gypsum can be trimmed at the two central incisors to create space for the ovate pontics.



47a



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47b

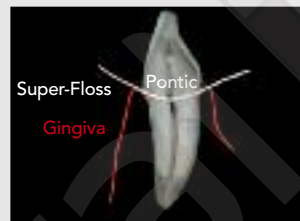
Fig 48 The original galvanized silver dies were replaced with refractory dies.

Fig 49 Ideal pontic design. The cross section of the basal aspect must imitate that of a natural tooth at the level of the gingival margin.

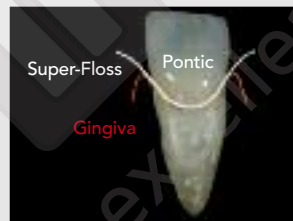
Fig 50 Labial view of a natural tooth showing proper gingival support.



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the master die in refractory die material with ceramic pins. These ceramic pins guarantee a good overview while layering and an exact fit on the master cast before and after the firing procedure. Figure 48 shows the refractory dies with the all-ceramic restoration in place and ready for layering.⁴

An ovate pontic is an egg-shaped, convex component, which—after proper gingival tissue conditioning by the periodontist—can achieve compelling functional and esthetic results. For a dental technician, it is important to know how to create an ovate pontic. There is more to it than simply filling a gap. The pontic must approximate the cross section of a natural tooth at the level of the gingival margin. Figure 49 shows a lateral view of the basic design of an ovate pontic. Observing the emer-

gence profile of the pontic construction, it is clear that the gingiva and the pontic are in alignment. This should resemble the emergence profile of natural teeth as much as possible, ie, the pontic should appear to be growing out of the gingiva. The labial view of a natural tooth shows how the pontic should support the gingiva (Fig 50).⁶ Depending on the circumstances, the egg-shaped site of the ovate pontic should extend approximately 1 to 1.5 mm subgingival to the labial margin.

The basal surface and gingival tissue seal tightly, preventing food impaction. The convex ovate pontic is the most sensible shape for pontics in the anterior arch. Due to the convex shape, the patient can easily clean the basal surface of the ovate pontic with dental floss. The technician

CASE 3 (Figs 60 to 76)**60**

Fig 60 Initial situation with severe damage to the labial tissue and an existing porcelain-fused-to-metal restoration.

**61a**

Figs 61a and 61b Provisional acrylic resin crowns were fabricated to restore the smile line and occlusal plane. The cervical profile of the restoration serves to further contour and condition the peri-implant soft tissue architecture.

**61b****Case 3**

The patient presented with very poor oral conditions (Fig 60).⁷ Because of the high degree of destruction, extraction of some teeth was unavoidable. The initial analysis revealed that the existing maxillary teeth could be retained after periodontal treatment. Clinical examination also revealed an amalgam tattoo at the right lateral incisor.

The maxilla required complete restoration with an all-ceramic reconstruction. As part of the full-mouth perioprosthetic rehabilitation, the patient received a laboratory processed long-term provisional restoration for dental, periodontal, and occlusal pretreatment. Provisional crowns were fabricated to restore the correct smile line and occlusal plane (Figs 61a and 61b).

As is often the case in modern esthetic implantology, natural abutments were directly next to implants. This poses a special challenge to both the dentist and dental technician. The universal aim is to ensure the greatest mechanical stability while providing natural esthetics. Figure 62 shows

the unsectioned master cast and custom abutments. The correct position of the abutment in relation to the desired tooth shape and dimension is based on the natural abutment. Because of the implants' labial axial alignment, the screw access hole was located toward the labial aspect (Fig 63a). From a palatal view, the abutments look just like natural prepared teeth (Fig 63b). A small slit was cut into the cast to check if the abutment was tightly seated on the cast.

The abutment had nearly the same dimensions as the prepared natural tooth (Figs 64a and 64b). The cast was once again sent back to the dentist so the pontic site could be reduced in preparation for the planned gingival tissue manipulation. No one can judge the oral situation better than the dentist. The dimensions of the custom abutments depend on the biotype of the gingiva. It goes without saying that in order to optimize the tooth size and length and improve the geometric distribution of the peri-implant space and crown, an optimized setup or waxup should be used for esthetically challenging situations. Additionally, it



Figs 70a and 70b Cross section of a natural tooth under ultraviolet (a) and back (b) light.



Figs 71a and 71b Ceramic crowns mounted on the master cast after layering.

shows that dentin in natural teeth has fluorescence, as do the mamelons located at the incisal edge (Fig 70a). The influence of the fluorescent natural dentin is higher in the cervical area, because the layer of natural enamel is thinner in this area. The enamel layer gets thicker at the incisal edge, and the influence of the fluorescent dentin is reduced.

Further, natural enamel shows an opalescent effect based on the interprismatic structure of the enamel (Fig 70b). The interprismatic structures of the enamel act like a spectrum filter, reflecting the short waves of light, ie, the blue waves. Long-wave orange-red light, on the other hand, penetrates the tooth enamel. The resultant blue-amber

effect is a primary component of the appearance of natural teeth. This explains the blue-gray gleam of enamel under incidental light. Under transmitted light, enamel shows a warm, orange shade.

After layering, the incisal area showed a natural appearance due to the fluorescent beige-orange mamelons and opalescent bluish-gray enamel (Figs 71a and 71b). The lateral incisors were somewhat more chromatic than the central incisors, and the canines showed a somewhat warmer chroma due to their structure. Final touch-ups were then carried out. In general, translucent materials should be used sparingly to prevent the loss of brightness and saturation. Nevertheless, translucent materials



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Fig 72 Occlusal view of the finished all-ceramic ceramic restorations.

Figs 73a and 73b Prior to placement of the definitive superstructure, excellent peri-implant soft tissue conditions and a natural emergence profile were observed.



73a



73b

are important because they provide a natural-looking depth effect, especially in the incisal area. Transparent materials should receive minimal firing to protect the character of the opalescence. If fired too often, their effects will diminish.

The zirconium restoration was then placed onto the abutments. The occlusal surfaces followed an international color-code occlusal compass concept. In the natural waxup technique, each functional direction is registered with a specific color. The German technician Dieter Schulz⁸ came up with the idea of using colors to transfer the individual directions to the respective tooth segments. In this case, the restoration exhibited proper cusp-fossa contacts along with sufficient space to allow excursive movements (Fig 72).

The preparation margin of the all-ceramic abutments was located slightly subgingivally. Before insertion of the definitive restoration, the peri-implant soft tissue situation was again evaluated. The individualized abutments were fixed on the implants. The ideally formed soft tissue architecture and implant emergence profile angle show the importance of a step-wise treatment plan (Figs 73a and 73b).⁹ The screw cavity should then be covered with gutta-percha or self-curing acrylic resin.

The gingiva at the two pontics was reshaped concavely to achieve a natural-looking pontic design. Once the gingiva healed, the pseudopapillae and egg-shaped site for the ovate pontic were recognizable. Thanks to the newly developed gingival architecture, the pontic resembled a natural tooth.

At this stage, the patient was invited to the laboratory for shape correction, glazing, and finishing (Fig 74). The authors prefer to evaluate the patient's restoration in an unglazed bisque bake. Long contact surfaces were fabricated to prevent open interdental spaces. Any additional shaping and contouring can be done at this time to ensure the support of the gingiva. The ovate pontics can be fine-tuned directly in the patient's mouth. The crown margin should be designed to mirror that of a natural tooth (Fig 75). Any final characterization necessary to match the adjacent teeth should be performed at this stage as well.

A biologically natural tension will arise within a restoration when the width-to-length ratio of the teeth is in harmony. Studies have shown that the width of central incisors is approximately 80% of their optimum length.³ In this case, the soft tissue reacted positively to the restoration, and tissue regeneration was observed. The margin of the crown



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76a

Fig 74 Cementation of the definitive restorations. Adequate pressure should be applied to the incisal edge.

Fig 75 The crown margin was designed to mirror the emergence profile of a natural tooth.

Figs 76a to 76d Final result.



76b



76c



76d

should be no more than 0.5 to 1.0 mm subgingivally to allow for removal of any excess cement.

The final result is shown in Figs 76a to 76d. The gingival tissue was healthy, and optimal gingival support was evident. The success of this restoration was the combined result of perfect periodontal pre-

treatment and appropriate technical execution. Due to the sizable change in shape, the patient's oral appearance was radically improved compared to the initial situation. It was impossible to distinguish the implants and ovate pontics from natural teeth—exactly what the treatment aimed to achieve.

CONCLUSIONS

This article demonstrated the advantages of zirconium dioxide and the Procera system using three complicated patient cases. Zirconium dioxide is biocompatible and can be easily integrated into the periodontal and gingival structures. Further, its stability has been proven as a base for ceramic veneering materials.

Mother Nature is extremely complex, and it takes flexibility and virtuosity from the treatment team to produce a successful restoration. Solid treatment planning, a healthy dental and periodontal baseline situation, functional occlusion, and harmonious integration of the restoration in the patient's mouth are fundamental issues for a successful treatment outcome.

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