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## Clinical and Laboratory Protocol for Porcelain Laminate Restorations on Anterior Teeth

Alan V. Sulikowski, DMD, Od\*/Aki Yoshida\*\*

**A**s we enter the 21st century, the fabrication of esthetic, functional, and biocompatible dental restorations has become the objective of restorative dentistry. This phenomenon has created a paradigm shift in which function and esthetics are no longer two separate or antagonistic elements. However, creating esthetic restorations that are indistinguishable from the natural teeth can be a challenge.<sup>1</sup>

To meet this challenge, all members of the dental team must take a myriad of factors into consideration. They must have a very precise ap-

proach and an in-depth understanding of tooth anatomy, dental structures, dental materials, and light behavior.

Contemporary materials allow the manipulation of light to mimic the natural dentition. However, a protocol should be established to predictably achieve the desired results. This article will present a rationale based on color for the diagnosis, tooth preparation, and laboratory protocol for the restoration of anterior porcelain veneers.

### DIAGNOSIS

A correct diagnosis, to recognize all the factors that will play a role in the final outcome, is one of the key steps in providing an adequate treatment plan. Due to the quantity of factors that have to be determined,<sup>2</sup> this article will focus on the color evaluation of problem teeth that require porcelain restorations.

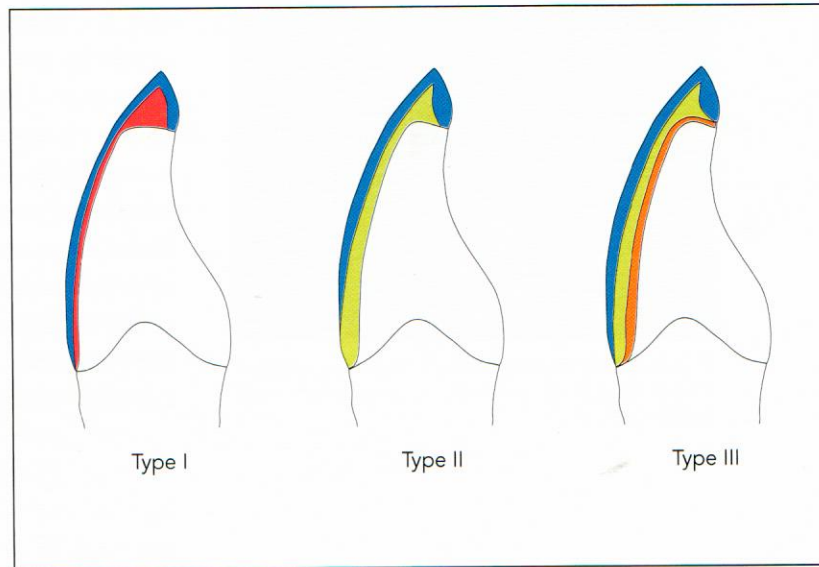
The existing color of the tooth will influence the technique used to achieve the final result. Oftentimes, the tooth to be restored is not the same

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\*Clinical Instructor, Postgraduate Prosthodontics, Harvard School of Dental Medicine; Private Practice, Cambridge, Massachusetts.

\*\*Technical Instructor, Department of Postgraduate Prosthodontics, Tufts University, Boston; Technical Instructor, Noritake Dental Supply Company; Dental Technician, Gnathos Dental Laboratory, Weston, Massachusetts.

Reprint requests: Dr Alan V. Sulikowski, 181 Concord Avenue, Cambridge, MA 02138.



**Fig 1** Diagram of three types of preparations based on the color of the tooth to be restored. Type I shows a space requirement of 0.3 mm, type II a space requirement of 0.6 mm, and type III a space requirement of 0.9 mm.

color as the adjacent teeth. Three types of preparations are proposed to better diagnose and prepare a treatment plan for individual clinical cases (Fig 1).

- **Type I Preparation:** *The shade of the tooth/teeth to be restored is similar to the shade of the final restoration; there is usually no more than a shade of difference.* In this situation, tooth preparation will provide a minimal reduction of about 0.3 mm from the proposed contours. The margin location will be supragingival. The restoration will take advantage of the background color to achieve a natural look.
- **Type II Preparation:** *The shade of the tooth/teeth to be restored differs up to two shades when compared to the proposed restoration.* In this situation, the final restoration will play an important role in modifying the background shade to bring it to the desired level. The space requirements for tooth preparation will be about 0.6 mm from the proposed contours. Margin location will be at the gingival crest. The resulting shade will be a combination of the background and the desired shade of the porcelain restoration. For example, if the de-

sired shade is A2 and the background color is A3.5, the technician will utilize an A1 shade to create the desired result.

- **Type III Preparation:** *There are three shades or more of difference between the proposed restoration and the color of the tooth/teeth.* In this case, a masking effect is necessary to obtain the desired color. The porcelain restoration will mask the unwanted discoloration and will provide the desired color. A space requirement of 0.9 mm is needed for tooth reduction. The margin location will frequently be subgingival.

## SHADE TAKING

When taking a shade, we must pay careful attention to several points. The first and most important point is to control the quantity and quality of light in the room. The light must be daylight, temperature must lie between 5000°K and 5500°K, and the intensity of the light should be 175 to 200 foot-candles (ft-c), especially in the zone around the patient's face (Fig 2). Sometimes it is necessary to use bulbs of various temperatures to achieve this result. If there is a window in the



**Fig 2** Color temperature meter is used to check the lighting conditions around the patient's face.

room, the daily fluctuations of the sky conditions will introduce unpredictable influences in the process; closing the curtains and/or blinds is always recommended. If possible, the ceiling, walls, and furniture should be neutral gray. Intense colors throughout the operatory and dental laboratory should especially be avoided.<sup>3</sup> Because patients' teeth dehydrate during any examination, shade taking is the first step in the process. If white calcification occurs due to dehydration, it will take at least 2 hours for the shade to return to normal.<sup>4</sup> If the cheek retractor is on for more than a minute before the photographs are taken, the teeth should be artificially moisturized.

When taking a shade, it is always necessary to develop a strategy for matching a shade that is cognizant of the multiple layers of various porcelain involved in a build-up. The hue and chroma will be determined by the dentin porcelain powder. The overlay of enamel and translucent powders primarily determines value, but custom characterization also influences value, as well as color and intensity. In the procedure used for this report, the order of steps is to (1) choose the hue, (2) choose the chroma, (3) choose the value, and (4) assess the translucency (an often overlooked step). While making a restoration, careful attention must be paid to the translucency. Because there is no commonly accepted translucency guide, notes are made comparing the translucency of the teeth and

various shade tabs. Separate assessments are made for the dentin and the enamel. Sometimes only one of the two will have a different translucency than the shade tab, but sometimes they both will. One might be more translucent than the tab and the other less than the tab. If only the enamel layer has a different translucency than the tab, then only the outer surface has to be adjusted with translucent powders. If the dentin has a different translucency than the tab, the dentin porcelain powder must be adjusted. If there is enough space, further control of the translucency is possible by adjusting the thickness of the layers of dentin enamel and translucent powders.<sup>5</sup> This method of shade taking, which involves the unique order described and a crucial concept of developing a build-up strategy during shade taking, makes it easier for the ceramist to accurately recreate the shade of the natural teeth.

The chosen shade tab should be included in the photograph. The absolute shade of a slide will depend on the camera, the film, the flash system, etc, but if the tab is included, differences between the tab and the teeth are accurately recorded. The differences recorded on the slide are then used to adjust the color. The tab should be edge to edge and in the same plane as the teeth. If the shade tab is held up against the labial surface of the preparation or an adjacent tooth, it will not be in the same plane and will look relatively higher in value.<sup>6</sup> Depending on the case, it may be best to include more than one shade tab. Also, be sure that the tab labels are clearly visible.

If the camera is held perpendicular to the labial surface when photographing the mamelons, there will be too much reflected light. Therefore, the camera should be held high and the photograph taken downward at an angle of 30 degrees. To best record the translucency in the incisal edge, separate photographs should be taken to show the patient's teeth both clenched and open. If the photographs are taken from a 30-degree side angle, the thickness of the enamel layer as well as any crack lines will be revealed.

Professional-grade color slide film should be used and developed as soon after shade-taking as

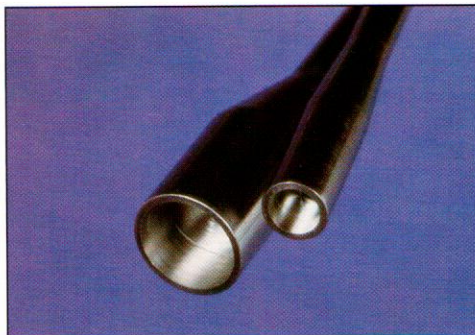
possible. Before the build-up, a sketch of the porcelain layering strategy is made. The powders that will be needed during build-up may be mixed if necessary (Fig 3). An accurate, written record of the powder ratios should be kept in the event it becomes necessary to reproduce the result or communicate to someone else how to achieve that particular shade. The need to remake one unit of a multi-unit case a few years later is not unusual. If the shade needs to be adjusted after the oral try-in, a written record of the layering technique and the mixing ratios will ease the process.

### RESTORATIVE CONTOURS

Restorative contours are evaluated by means of computer-aided analysis and conventional wax-up techniques. As a rule, emergence profiles and contours found in natural teeth are often created. However, depending on the case, some characteristics may be accentuated to create a better outcome. This is often true when there is some misalignment in a buccolabial or mesiodistal direction of the teeth to be restored. Tooth length is determined by esthetics and function. It is not uncommon to change the length for a more esthetic result. At this stage, tooth proportion is evaluated for each tooth, and as a whole, for form, function, and relation to the lips. The proposed contours will then be confirmed with the temporary restorations.

### TOOTH PREPARATION

With the evolution of dental materials, the principles of tooth preparation have changed tremendously. The tooth preparation guidelines for partial-coverage porcelain restorations are determined by the removal of diseased dental structures, quantity and quality of remaining tooth structure, and adequate space requirements for the proposed restoration to provide form and function.



**Fig 3** A measuring scoop set from the Gnathos shade set (Belle de St. Claire/Kerr, Orange, CA). The relative volumes are 50, 25, 5, and 1. These scoops are used for mixing custom powders.

In addition to the factors mentioned above, the tooth preparation will be directly affected by the proposed contours of the final restorations. Enamel is preserved whenever possible. Geometric principles of tooth preparation for porcelain veneers are followed to maximize strength.<sup>7</sup>

Adequate three-dimensional tooth preparation is confirmed with a silicone index, made of the diagnostic wax-up, which is transferred to the patient's mouth.<sup>8</sup> Although space requirements for porcelain veneers vary from 0.3 to 0.9 mm, that does not necessarily mean there will be the same reduction of dental structures. Final tooth contours are designed to maximize tooth enamel preservation. Tooth position may vary the amount of reduction needed. For example, if a tooth is lingually misplaced in the arch and the final restoration will correct such misalignment, the space requirements will be met with minimal to no preparation of the tooth structures.

Incisal reduction of about 1.5 to 2 mm of proposed contours is designed following current research.<sup>9</sup> A final impression is then made and temporary restorations are fabricated following the diagnostic wax-up. Esthetics, phonetics, and functional aspects are evaluated on the temporary restorations.<sup>10</sup> With all the information gathered, the final restorations are fabricated and delivered to the patient.

## CLINICAL CASES

### *Type I Preparation: Single Laminate Case*

In this patient, the maxillary left central incisor will be restored with a porcelain laminate veneer (Fig 4). The shade, anatomy, and surface texture must all be copied exactly. Obviously, reproducing the white calcification in the middle third will be a crucial determinant of success in this case. Because there is no discoloration, a type I preparation will be used to take advantage of the existing conditions (Figs 5 to 7). The hue of the teeth is on the orange side of Vita Lumin A shade. The chroma matches A1. The value is lower than A1. The translucency of the right central incisor is about 25% less than the A1 tab (Fig 8). To recreate this tooth, a layering technique illustrated by the sketch in Fig 9 was used. Orange-colored dentin modifier was mixed with dentin porcelain to shift the hue toward orange. If enough modifiers were added to match the desired orange hue, the resulting chroma would be higher than A1, even if B1 body porcelain was used. Therefore, B0 body porcelain from the Noritake New Color Kit (Darby Dental, Westbury, New York, USA) was used (Fig 10). Also, some opacous dentin had to be mixed to reduce the translucency. Surprisingly, even though the laminate is very thin and highly translucent, the final result is quite sensitive to the mixing ratio. This is especially crucial with single-tooth restorations (Figs 11 to 13).

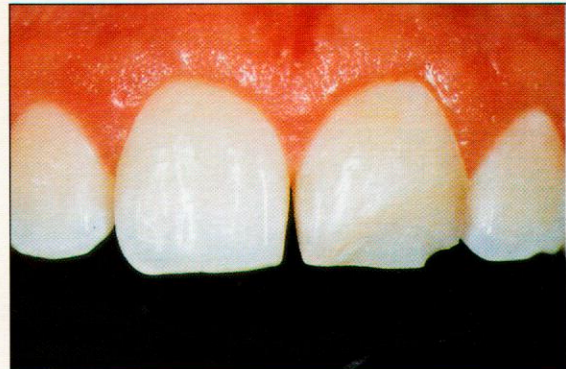
After some porcelain has been built up and fired, it is difficult to increase the value. It is much easier to decrease the value. Therefore, the enamel for a standard A1 was chosen. After the first build-up was fired, the value was carefully decreased using the Internal Live Stain Technique.<sup>11</sup> The mamelons, the white calcification, the color,

the intensity, and the positioning of the patient's other individual characteristics were carefully studied and reproduced using the slides (Figs 14 to 17). Cervical translucency is an important aspect of success in porcelain laminate veneers. Normally, orange and pink modifiers are added to the dentin porcelain to adjust the color, and then translucent powder is added to increase the translucency of the cervical area. The ratio is chosen on a case-by-case basis. The mixing ratio in the cervical area must be chosen carefully (especially if the margin is supragingival) and always measured accurately and documented.

When working with porcelain veneers, the layering of porcelain and space control is critical. To measure the thickness of the porcelain on the refractory die, the following method is used. Four points are marked on the facial surface of the refractory die with a refractory pencil before final degassing. On the lingual side, four small indentations are made directly opposite of the four pencil marks (Figs 18 and 19). Then the thickness of the refractory die is measured between each of the four pencil mark/indentation pairs before any porcelain is built up and written records are made (Fig 20). The pencil marks will still be visible after the porcelain is fired. Note that the pencil marks will not be visible in type III cases where masking porcelain is used; however, the thickness can still be approximated by using the small indentations as a reference (Fig 21). Using this method, the thickness of porcelain laminate veneers can be controlled before the veneer is divested to help create better control of shade, hue, chroma, value, and translucency. Glazing temperature should not control detail of surface texture. For best results, the texture should be controlled by judicious choice of burs, wheels, and polishing materials during mechanical polishing (Figs 22 to 25).

**CASE 1** (Figs 4 to 25)

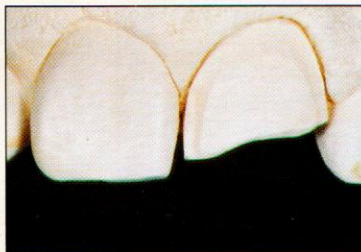
**Fig 4** Pretreatment: Patient with chipped composite on the maxillary left central incisor was seeking esthetic treatment.



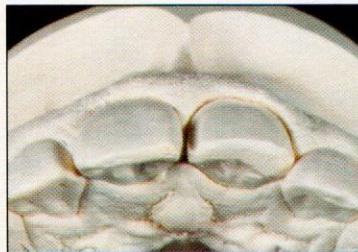
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**Figs 5 and 6** The master cast. Tooth preparation was designed as type I to achieve the best results.

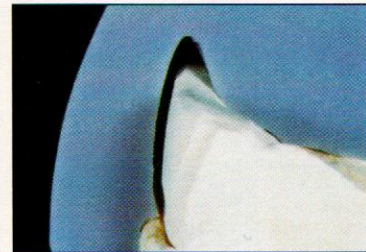
**Fig 7** Cross section of a silicone index impression of the diagnostic wax-up placed over the cast to show the tooth preparation and the build-up space.



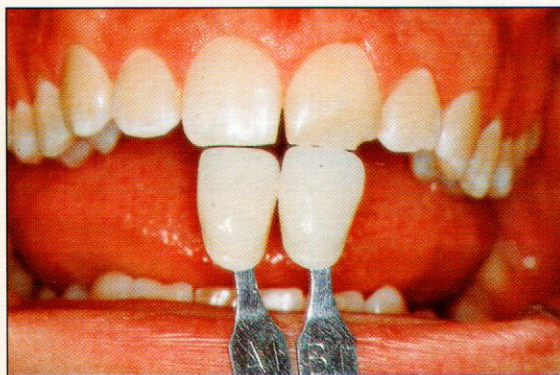
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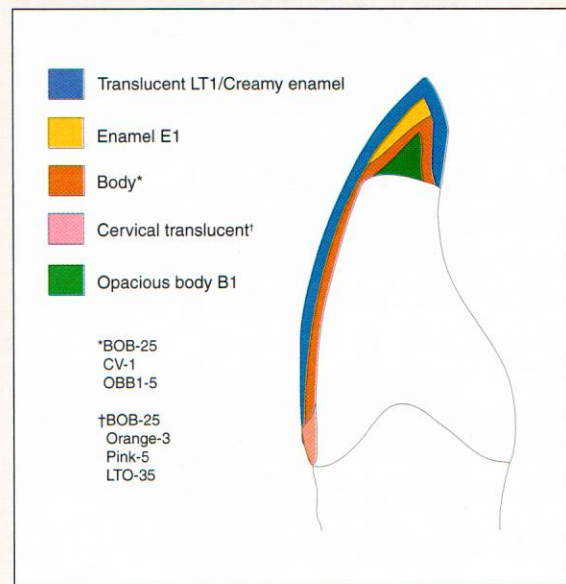


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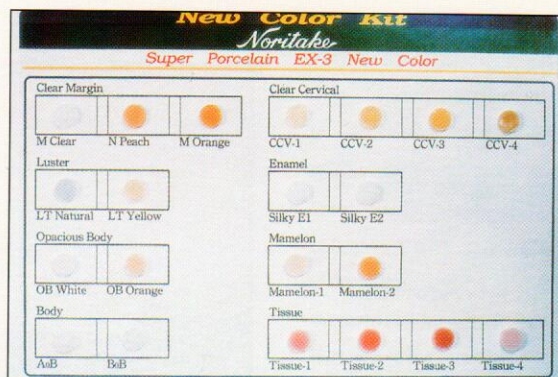


**Fig 8** Shade taking with A1 and B1 tabs.

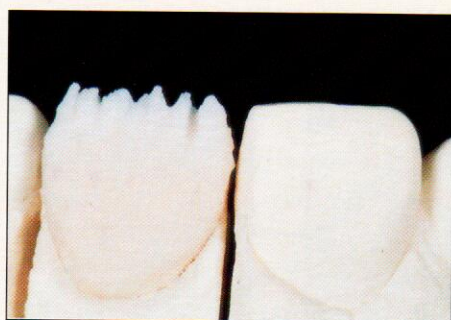
**Fig 9** Diagram of the build-up strategy. Note especially the custom mixture of body and cervical translucent porcelains.



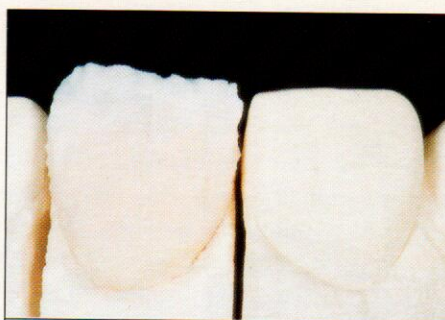
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Fig 10 Noritake New Color Kit.

Fig 11 Mamelon construction at the body and enamel stage.

Fig 12 Translucent is added to the incisal edge before the first firing.

Fig 13 The incisal edge is shifted slightly to the lingual to compensate for the firing shrinkage toward the labial that is characteristic of laminate cases.

Fig 14 After the first bake, smoothing by grinding is needed before application of internal stain.

Fig 15 Noritake Internal Live Stain Kit.

Fig 16 After application of internal stain.

Fig 17 Fired internal stain.

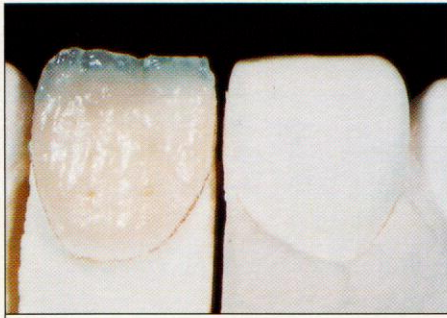
Fig 18 Refractory pencil marks on the dies are used to check the porcelain thickness of undivested restorations.

Fig 19 The indentations on the lingual side are used in conjunction with the pencil dots.

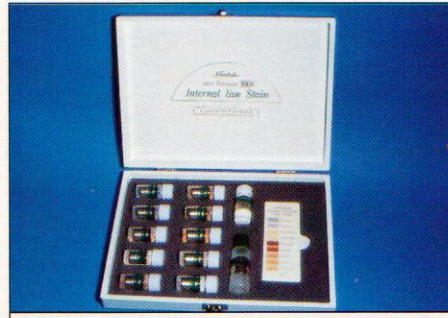
Fig 20 The thickness of the refractory die is measured between a dot and an indentation die before any build-up. This method will guarantee that the different layers of porcelain will remain identical after finishing the veneer.

Fig 21 Total thickness after firing. The porcelain thickness is calculated by subtracting the cast thickness from the total thickness.





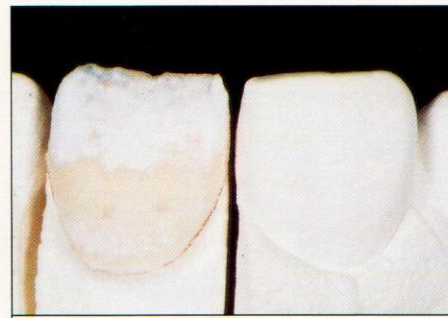
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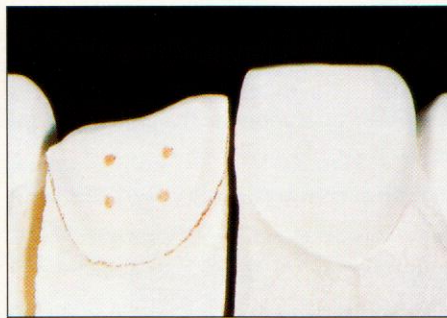
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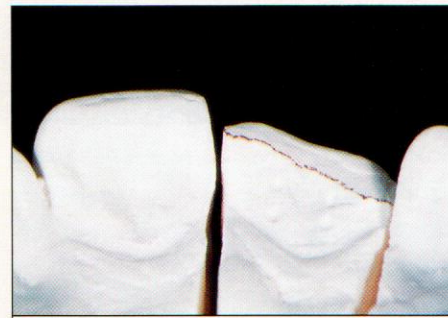
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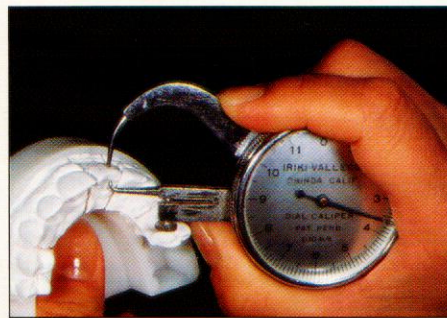
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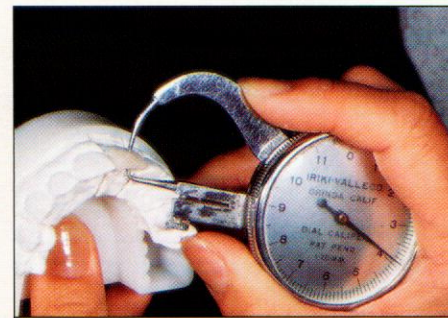
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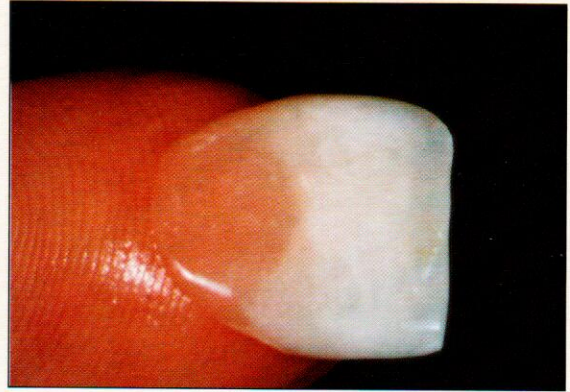
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**Fig 22** Finished laminate on the master cast.

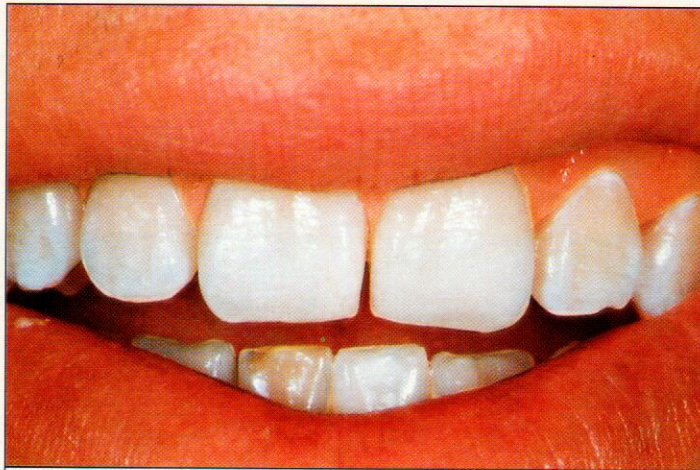


**Fig 23** The translucency of the laminate is illustrated by wetting it with stain liquid and setting it on a fingertip.



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**Figs 24 and 25** Restoration cemented in the patient's mouth. The diastema was left open at the patient's request.



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### **Type II Preparation: Laminate and All-Ceramic Crown Combination Case**

This patient will receive a maxillary canine-to-canine six-unit anterior restoration in which the left central incisor is a full crown and the others are porcelain laminate veneers (Fig 26). Because all six maxillary anterior teeth are being restored, we have the freedom to choose appealing anatomy and shade. The patient, a young female whose esthetic priority was a natural appearance, wanted the restored teeth to harmonize with the other teeth. We tried to follow her desire as much as possible.

If we use more than one kind of restoration in a combination case, it is difficult to match the shade—especially if a different material is chosen for only one central. Therefore, a porcelain jacket crown, rather than a porcelain-fused-to-metal (PFM) crown or alternative all-ceramic system, was selected for the left central. Since only one material is being used, all the units can be made at the same time. Noritake EX-3 porcelain has high flexural strength (111 MPa), which is almost as high as that of the Optec all-ceramic system (Jeneric Pentron, Wallingford, CT, USA) (117 MPa). This type of restoration is much stronger since the advent of high bond strength resin cements.

In this case, no shade adjustment was deemed desirable (Fig 27). It was prepared as type II, with a porcelain thickness of 0.6 mm to create enough opacity control to match the translucency of the veneers and the jacket crown (Figs 28 to 30). From lateral to lateral, the shade is A1. The canines are A2. Because natural appearance was the priority, moderate incisal area characterization and matching surface texture were the crucial factors for success in this case (Fig 31). During the porcelain build-up in a six-unit anterior case, careful attention must be paid to the differences in the degree of dentin cutback among the central incisors, lateral incisors, and canines to create appropriate differences in the value and chroma across the arch. The largest degree of dentin cutback is on the lateral, followed by the central, with the least

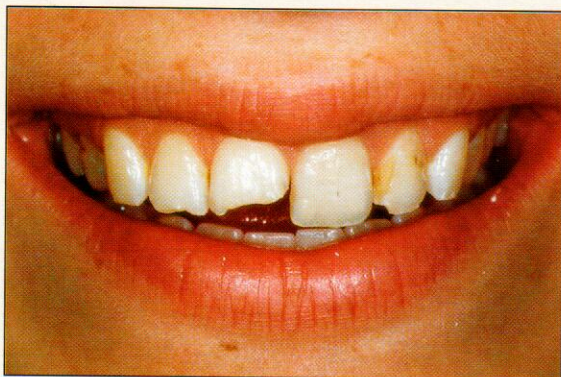
cutback on the canine. There are important differences in lateral and central mamelons. Also, there are no mamelons in the canine (Fig 32). The entire surfaces were covered with Noritake luster porcelain with natural opalescence and fluorescence to beautifully harmonize with the natural dentition (Figs 33 to 36).

### **Type III Preparation: Four-Unit Porcelain Laminate Veneer Case**

This patient presented with an esthetic problem in the maxillary anterior area. An accident had caused the fracture of both central incisors, one a horizontal fracture and the other an oblique fracture. Root canal therapy was performed in the left central incisor. Several attempts were made in the past to correct the dark color of the central incisors using resin composite. This resulted in overcontoured restorations with an opaque and monotone appearance that caused esthetic and periodontal problems such as gingivitis and recession.

Both central incisors have discolored preparations, but the laterals do not (Figs 37 and 38). To match the centrals and the laterals, it was necessary to use masking porcelain on the centrals and to prepare the teeth as type III (Figs 39 to 41). To make suitable masking porcelain, Noritake creamy white luster porcelain and opacious body porcelain were mixed. A greater amount of creamy white is used when more masking power is needed. The particle size of luster porcelain is much smaller than that of conventional porcelain. The small particle size diffuses the light that reflects off of the discolored preparation so that the discoloration is not visible (Fig 42).<sup>12,13</sup> Thus, the color is masked while some translucency is maintained. Masking porcelain was built up to extend the short preparation to make the opacity of the core uniform (Fig 43). The patient's teeth had been bleached. To match the incisal edge, straight creamy enamel was used (Figs 44 to 46).

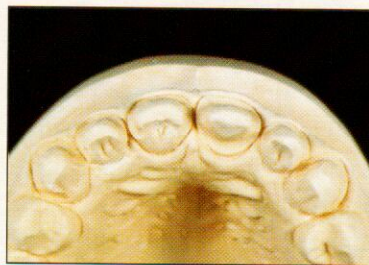
**CASE 2** (Figs 26 to 36)



**Fig 26** Pretreatment. The incisal edge of this patient's maxillary right central incisor was broken in an automobile accident. The patient wanted function restored and esthetics enhanced.



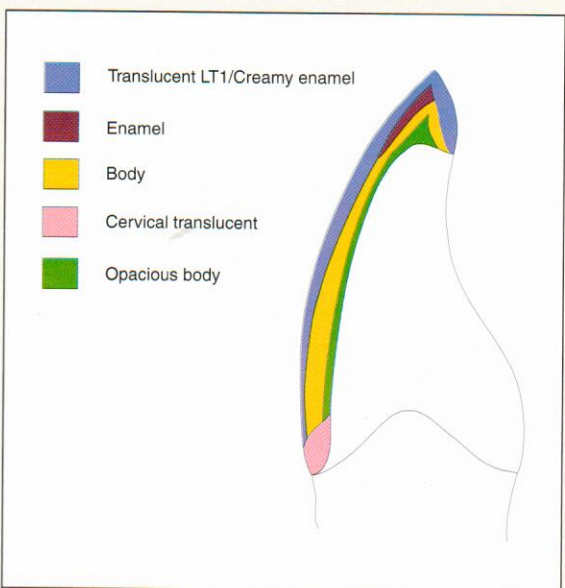
**Fig 27** Shade is taken with an A1 tab.



**Figs 28 and 29** The master cast. A type II preparation was used. Interproximal caries was addressed by the design of the preparation.



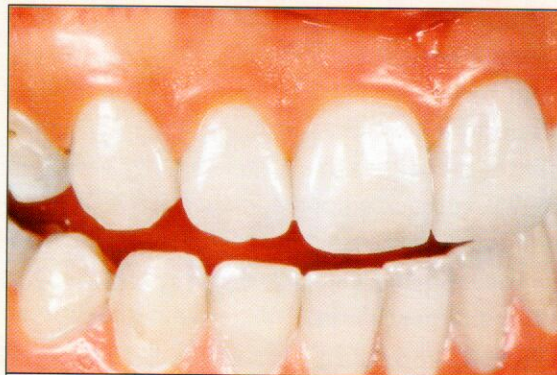
**Fig 30** Cross section of a silicon index impression of the diagnostic wax-up placed over the cast to illustrate the tooth preparation and build-up space.



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**Fig 31** Diagram of the build-up strategy.

**Fig 32** Note the difference in the mamelons between the centrals and the laterals and the absence of mamelons in the canine.



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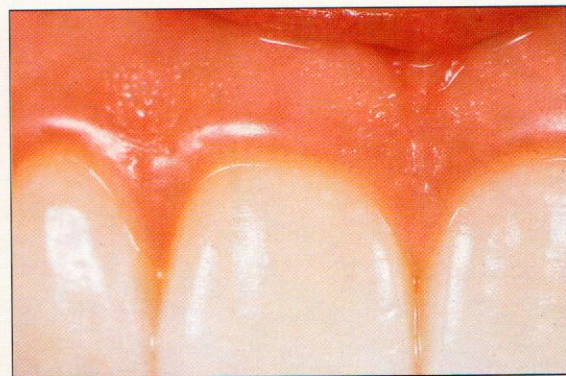
**Figs 33 and 34** The finished restorations. A porcelain jacket crown was constructed on the maxillary left central incisor.



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**Fig 35** Noritake luster porcelain. Note the opalescent effect with reflected light.



**Fig 36** Note the periodontal tissue response to the atraumatic intervention.

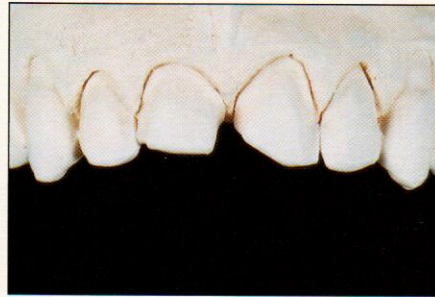
**CASE 3** (Figs 37 to 46)



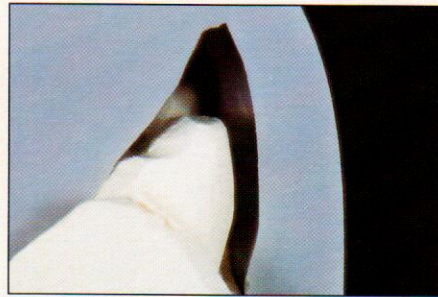
**Fig 37** Pretreatment (type III). Note the gingival inflammation and recession caused by the overcontoured existing restorations.



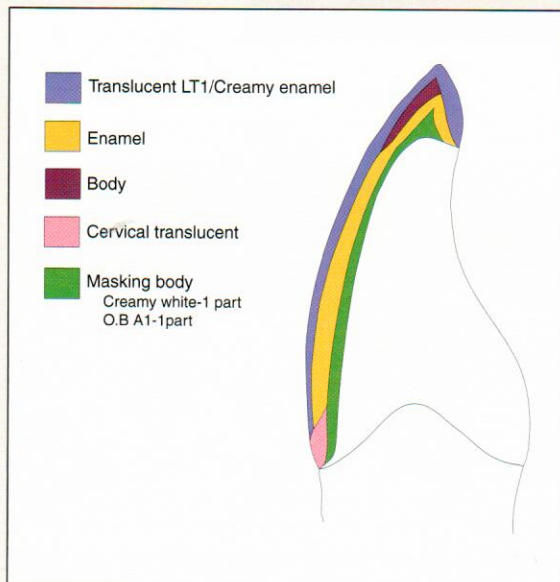
**Fig 38** The teeth had been bleached and both central incisors were significantly more discolored than the adjacent teeth.



**Fig 39** The master cast.



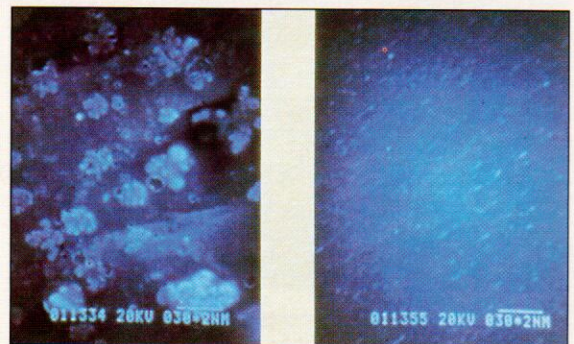
**Fig 40** Cross section of a silicone index impression of the diagnostic wax-up placed over the cast to illustrate the tooth preparation and the build-up space. This required a type III preparation of approximately 0.9 mm on the facial surface. Incisal reduction was guided by the remaining tooth structure under the composite restorations.



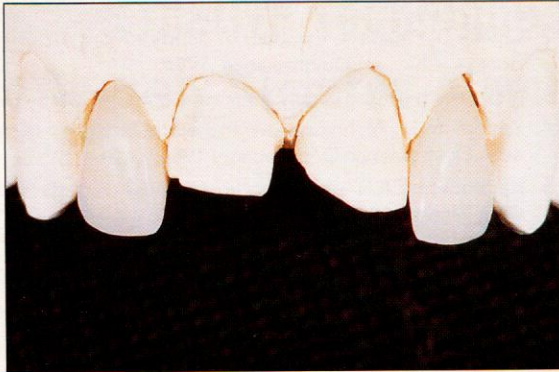
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**Fig 41** Diagram of the build-up strategy.

**Fig 42** Scanning electron micrograph of conventional porcelain (left) and luster porcelain (right) at 5,000 $\times$  magnification.



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**Fig 43** Restorations of the two lateral incisors were placed on the cast to illustrate how short the two central incisors are.



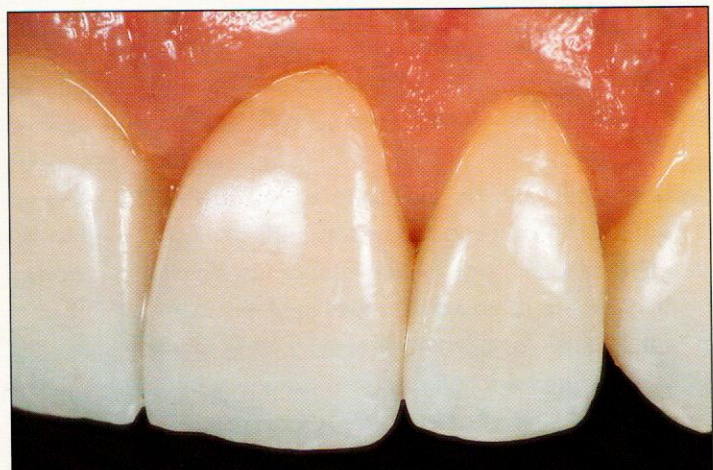
**Fig 44** The cemented veneers. Note the blocking effect of the restorations compared to the high chroma of the preparations.



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**Fig 45** Right lateral view of the finished case. Note the similar color translucency and depth between the central and lateral incisors. Masking porcelain was only used in the centrals.

**Fig 46** Left lateral view of the finished case. The correct contours have been restored. Note the improvement of periodontal health.



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## CONCLUSION

This article discussed a new approach to treatment planning and treatment execution for the restoration of the anterior dentition. A new protocol is established based on color to facilitate the achievement of the desired outcome. Clinicians should use their own judgment as they apply these concepts to a specific situation to produce accurate results.

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