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The 3D-Master Shade-Matching System and the Skeleton Buildup Technique: Science Meets Art and Intuition

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Shade selection and communication in dentistry has been mere guesswork due in large part to inadequate shade-matching systems available to date.[1-3] Evaluation of natural tooth color compared to existing shade guides clearly demonstrates that the shade guides do not adequately cover natural tooth shades. Sproull[4] concluded that: *(1)* existing shade guides lacked adequate coverage of natural tooth color space; *(2)* there was no logical or systematic arrangement of the shade tabs; and *(3)* clustering and duplication of colors existed in some areas of color space and voids in other regions. Color space is described in 3 dimensions—just as an object can be described in the 3 dimensions of length, width, and depth. The dimensions of color as described in the Munsell color system[4,5] are termed hue, chroma, and value. There have been several detailed descriptions published covering the Munsell color system and its application in dentistry.[4,5]

Patient desires for esthetic, naturally appearing restorations have increased dramatically in recent years.[6] The request for "white teeth" that maintain a semblance of naturalness is a daunting challenge for the dentist/ceramist team. Because of the inadequacies of existing shade systems, techniques for fabricating porcelain crowns that match natural dentition in both shape and shade require extensive experience and artistic ability.

A plethora of new materials and techniques recently have been developed to facilitate this process[7-9]; however, sophisticated techniques are still required for the ceramist to build these various materials.[10-16] To the beginning or average ceramist, these techniques and the results achieved seem unrealistic and relegated to the truly artistic. Results are achieved because of the exquisite artistic ability of the ceramist, and in most cases the patient is present with the ceramist during the fabrication process. Usually it is not possible or practical to have the patient present during the fabrication process, thus problems with the communication of the many nuances of shade and shape continue to plague dentistry.

Our ultimate goal should be to develop materials and techniques that allow the average dentist/ceramist team to create what I

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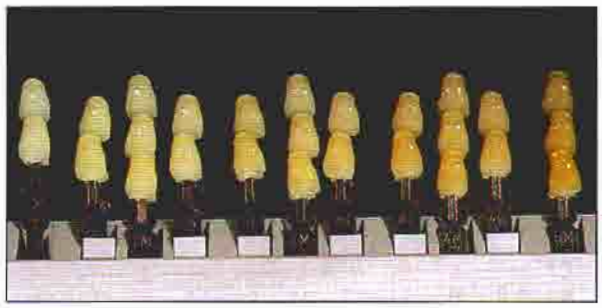

Fig 1 The 3D-Master shade guide system.

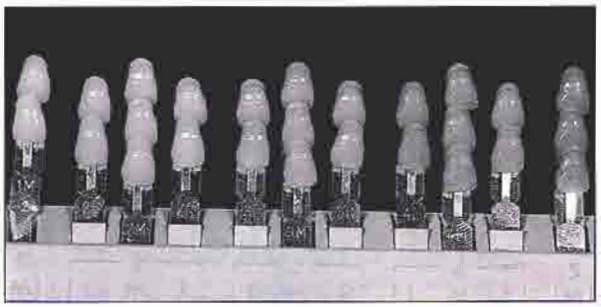

Fig 2 The shade guide photographed in black and white demonstrates the 5 value levels.

like to call "conversational esthetics"—restorations that are believable viewed at a conversational distance. To this end, what was needed was a shade-taking system that relies on color science, adequately covers natural tooth color space, is simple to use, facilitates transfer of information to the ceramist, and offers simplified porcelain building techniques for duplication of the desired shade.

This article presents a systematic technique for the three-dimensional control of shade and shape of porcelain restorations from shade taking—using a new shade-matching system, the 3D-Master (Vita Zahnfabrik)—all the way through the porcelain fabrication process. A simplified, easily teachable technique for building porcelain, called the "Skeleton Buildup Technique,"[10] is reviewed in conjunction with the use of the new shade system.

■ The 3D-Master Shade-Selection System

Until recently, the taking and communicating of existing tooth shades has been fraught with problems. The foremost problem was that existing shade guides didn't adequately cover the color space of natural teeth.[1-3,17] Just as important, there was no systematic arrangement or logical spacing within the color space.[1-3,17] Clearly there was a need for the application of color science to the process of shade matching and the development of shade-taking systems and matching porcelains. Recently, the Vita company introduced the 3D-Master shade-taking system, which has greatly facilitated the shade taking and communication process (Fig 1). The system was developed to take into account the full range of natural tooth shades within the 3 dimensions of color space: hue, chroma, and value.

Value Selection

The system is arranged first around choosing the value, which is the most important optical parameter (Fig 2). Crowns with an incorrect value are rarely accepted, while even moderate inaccuracies in chroma and hue may go unnoticed. There are 5 value levels that are equally spaced 5 ΔEs apart within the color space. (ΔE is a mathematical measurement of the distance between 2 points in color space; the human eye can only differentiate points that are greater than 2 ΔEs apart.) The procedure of choosing the value is best done by a process of elimination; the closest value is chosen and recorded on a specially devised prescription pad (Fig 3). If it is determined that the tooth to be matched is between 2 value levels (eg, between value level 2 and 3), this would be recorded as value 2.5. The ceramist would then mix equal amounts of value level 2 and 3 porcelains, which would give a result halfway between value 2 and 3 in the final restoration.

Chroma Selection

The next step is to determine the level of chroma, of which there are 5 (Fig 4). Again, it

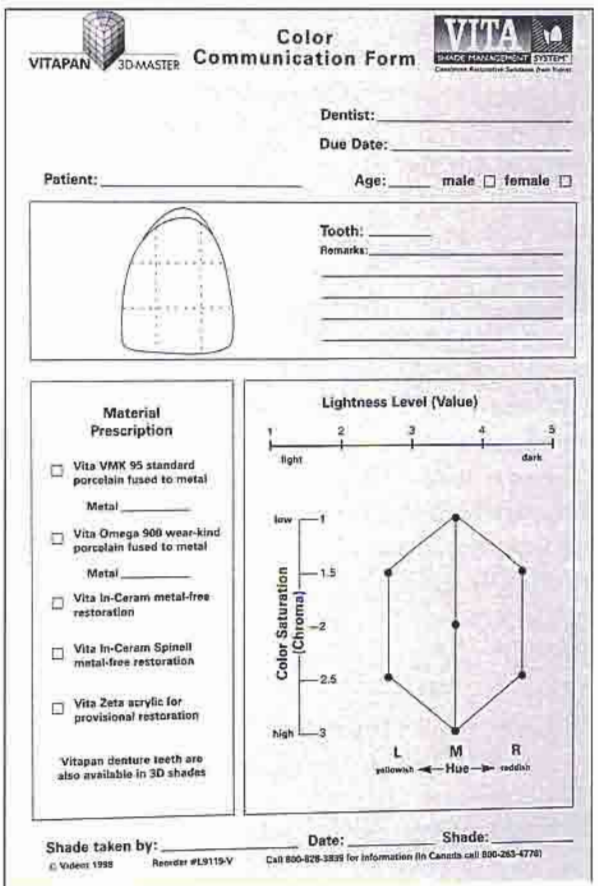

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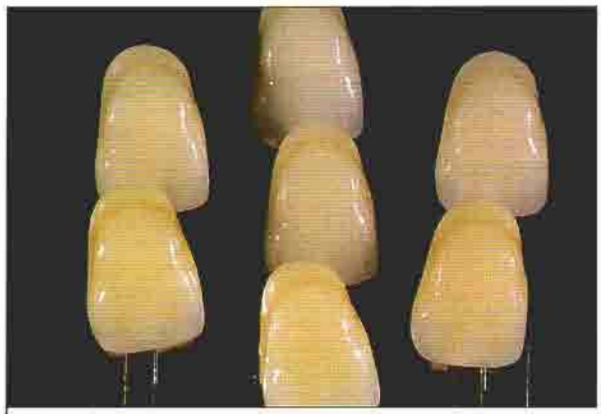
Fig 3 Specially formatted prescription pad.

Fig 4 Five different chroma levels and 3 different hues within value level 3. The middle column includes the average hue measured for natural teeth; the right column includes redder shades and the left column yellower shades.

Fig 5a Value level 3 in black and white demonstrates that the different chroma levels and hues all have the same value.

Fig 5b Shade guide in situ photographed in black and white to ascertain the correct value.



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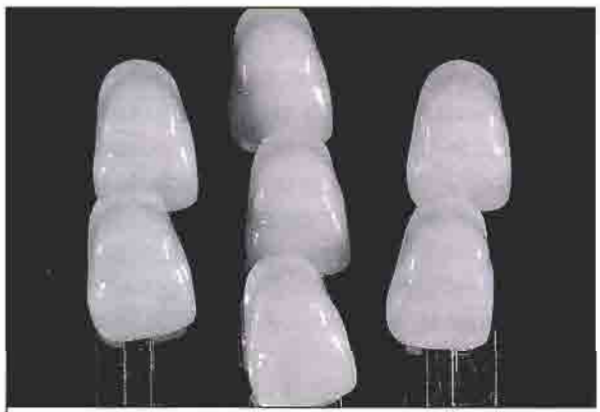


5a

5b

is best accomplished by a process of elimination, recording the closest match or noting if it is between 2 chroma levels. The chroma levels are all equal distances from each other within the color space. Changing the levels of chroma historically have created a problem with altering the value. Because this system has 5 different chroma levels and 3 different hues within the value groups 2, 3, and 4 (Fig 4), we can increase or decrease chroma and change the hue without changing the value (Fig 5). This feature alone significantly aids in matching restorations to teeth.

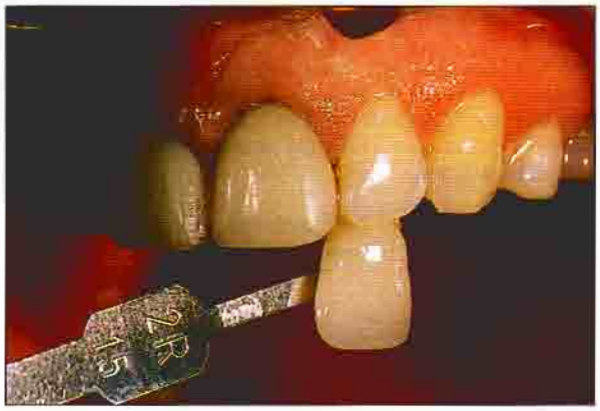


Fig 6 Shade guide with the redder shade compared to the natural tooth.

Fig 7a Preoperative photograph.

Fig 7b Cemented all-ceramic Spinell crowns fabricated for the maxillary central incisors using the new shade system.

Hue Selection

The last step is to choose the specific hue (Fig 4). Spectrophotometric analysis has shown that natural teeth exist in a very small hue range.[3] There are 3 specific hues: the middle hue (orangish), which corresponds to the middle range of natural teeth; a yellower hue; and a redder hue equidistant in color space from the middle hue (Fig 6). The observer would evaluate the middle (M) hue relative to the tooth, decide if it matches or if its redder or yellower, and then record the chosen hue. Thus, the shade-matching process becomes very systematic and based on color science. Specific characteristics (ie, crack lines or decalcifications) can be recorded by a drawing or high-quality photography. Figures 7a and 7b show restorations prepared using the first attempt at shade matching with the 3D-Master system.

■ Communicating Shade and Shape

Once the desired shade is chosen, it is paramount to get acceptance from the patient; often the patient's perceptions are quite different than ours. One of the most important tools for communicating, both from the patient/dentist and the dentist/ceramist perspective, is the provisional restoration. While the provisional restoration has been sparingly used to communicate form, the communication of color is a mostly overlooked benefit of properly constructed provisionals.

Provisional materials that closely approximate the shade guide and accompanying porcelain systems would help solve many of the shade problems we encounter. If we could place a provisional restoration of the desired shade on the prepared tooth, the dentist and patient could truly see if the chosen shade adequately matches the existing dentition. Many times the patient has a perception of a desired shade, only to find that in fact the shade doesn't blend with the existing dentition when the restoration is placed in situ. It would be ideal to find this out at the provisionalization phase.

A recently introduced provisional material, Zeta cold cure (Vita), matches the 3D-Master shade system and its corresponding porcelains. The material is a cold-cure methylmethacrylate, which can be used for both direct and indirect techniques. Provisional restorations are fabricated in the preferred manner and then placed on the prepared teeth. At this stage the dentist and patient can evaluate the shade and form of the provisional. Should alterations be necessary, they can be done at the provisional stage, minimizing the need for costly remakes (Figs 8 and 9).

For a ceramist, it is most frustrating to complete a beautiful multilayered restoration and have it returned by the dentist after try-in significantly altered in form. The lack of communication of form creates this problem; use of the provisional could reduce the incidence of this problem considerably. The provisional ideally should be contoured within 0.2 mm of the desired final restoration. Once the provisional is placed in the mouth, the patient can give final acceptance of both the form and color. This information can be transferred to the ceramist via a study cast of the provisionals.

I have found a way to significantly improve this technique. For almost all cases I will fabricate 2 provisionals; both will be of the same contour and shade. Both will receive acceptance from the patient. One will be cemented, and one will go with the case to facilitate the fabrication of the final restorations. The ceramist now has a three-dimensional model of the desired final restoration that can be placed on the working dies. The ceramist can use the provisional to recreate the desired form, length, labial contours, and embrasure form (Fig 10).

■ Simplified Porcelain Building: The Skeleton Buildup Technique

Many different techniques are espoused for layering dental porcelain. Most of these involve sophisticated placement of the various powders, which are built to full contour and

Fig 8 Provisional restoration of the desired form and value.

Fig 9 Completed all-ceramic crowns on the maxillary central and lateral incisors.

Fig 10 A duplicate provisional, which has been tried in the mouth, is used during the porcelain building process.

Fig 11 Captek metal coping displays the ideal cutback.

then fired. Mastery of these techniques will result in an exquisite final result. In these techniques, meticulous placement of each layer is critical, and extensive experience with the material is required to know exactly how much it will shrink on firing. If shrinkage isn't precisely controlled, the desired color effects cannot be achieved. It is also easy to unintentionally mix the individual layers while building; furthermore, the individual layering cannot be viewed until firing.

The Skeleton Buildup Technique is a compilation of many techniques broken down further into distinct manageable and easily correctable steps. It is so named to create an image of a structure that is built from the skeleton outward, one layer at a time. The layers are individually completed prior to veneering the skin (enamel surface), thus allowing maximum control of both shape and shade. Just as our human form is distinctly different from that of other primates due to the different morphology of our skeletal systems, the three-dimensional expression of shade and shape in a porcelain crown requires the exact placement of the internal dentin layers (skeleton) to support the surface enamel layer (skin). Thus, for maximum control it is best to build each individual layer and then fire it prior to adding the subsequent layers. Each layer can then be adjusted as necessary by grinding or adding more of that specific layer prior to proceeding.

■ Metal vs All-Ceramic Substructure Considerations

For metal-ceramic anterior crowns, vertical reduction of the metal framework labially and interproximally up the axial wall 2 mm is highly recommended.[18] With correct margin design, this will not affect the strength of the cemented crown.[19] This amount of metal cutback allows for more translucent porcelains to be used in the marginal area, which improves optics in this region (Fig 11).

Framework design should allow for maximum thickness of porcelain, within the accepted limits, to minimize susceptibility to fracture. Frameworks for single teeth in esthetic areas without an increased potential for ceramic fracture can be safely thinned after casting to 0.15 mm.[20] This would be catastrophic for all-ceramic restoration frameworks. Margin design can be a conventional metal margin (collar), but this creates a shadowing effect in the gingival third of the crown and in the marginal gingiva. This can be overcome somewhat by using other alloy systems that contain high levels of gold[21] and maintain a granular surface finish to give a warm diffuse, rather than a specular, reflection (Captek, Precious Chemicals).[22,23]

Of the many different all-ceramic systems on the market, only In-Ceram and Spinell from Vita match the 3D-Master system. The In-Ceram system will be discussed here in relation to core design and use of the corresponding 3D porcelains. The recommended core dimensions for In-Ceram and Spinell is 0.5 mm due to the high reported flexural strength of these core materials.[24,25] For anterior teeth, core dimensions can be trimmed to 0.3 mm on the facial aspect, which is a low-stress area, as long as the interproximal,

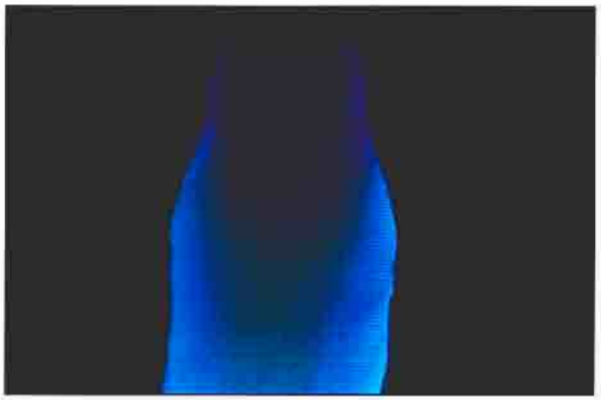


Fig 12a Fluorescent lighting shows similar fluorescence of the Luminaries to natural dentin.

Fig 12b Fluorescent powders are used as a shoulder material with all-ceramic techniques.

palatal, and incisal edge thickness remains at 0.7 mm and there is a 1-mm-thick collar of the lingual.[26] One of the unique benefits of the In-Ceram system is that the translucency of the core can be altered depending on the processing technique.[26] This is beneficial in clinical situations where discolored teeth or teeth with posts need to be restored; it is discussed in great detail elsewhere.[26]

Opaque Layer, Metal-Ceramics

The first layer of opaque porcelain should be applied very thinly and fired 20 to 30 degrees higher than recommended. This allows better wetting of the metal surface, which creates a bonding layer. The second layer of opaque is completed in the usual manner, with opaque porcelains corresponding to the shade chosen.

Bonding Layer, All-Ceramics

With all-ceramic restorations I have found it is best to create a bonding layer to the core, as is done with the first opaque layer in metal-ceramic restorations. This is accomplished by placing opacious dentin of the desired shade into an opaque gun and spraying a thin layer on the surface of the ceramic core. This is then fired 40 degrees higher than the recommended firing temperature for opacious dentins to ensure good wetting (bonding) of porcelain onto the core surface.

Shoulder/Cervical Area

After opaqueing, fluorescent shoulder porcelain materials are built up and fired (Figs 12a and 12b) for both metal-ceramic and all-ceramic techniques. Special-effect powders (Luminaries, Vita) are used in this region, the only difference being that with the metal-ceramic porcelain it will take at least 2 bakes to close the margin because of the vertically reduced metal framework. These Luminary powders can be placed as a thin wash over the surface of a ceramic or metal core and fired, which creates an increased luminescent effect. The powders increase the fluorescence of the finished restoration, which increase the quantity of light reflected back at the viewer. This is especially beneficial in high-value shades, or to block out any discolorations, as it can raise value without negatively affecting translucency.

Fig 13a Opacious dentin built up.

Fig 13b Fired opacious dentins.

Fig 14a Dentin buildup.

Fig 14b Fired dentin buildup.

Opacious Dentins

For metal-ceramic and In-Ceram/Spinell techniques, the remaining steps are the same. Opacious dentins of the desired shade are built up and fired; slight overbuilding is preferred, as it is a simple matter to adjust back the fired material (Figs 13a and 13b). Stains or dentin modifiers can be mixed in to create high-chroma effects as necessary.

Dentins

Dentin powders are built up using the base shade dentin in the middle third, with a higher-chroma dentin in the gingival third and a higher-value dentin in the incisal third. This creates subtle contrasts, which is what is seen in natural teeth. Again, it is best to slightly overbuild the dentins, which can be adjusted after firing (Figs 14a and 14b).

Incisal Framing

With the internal structure (skeleton) of the opacious dentins and dentins fired, it is easier to control the position and dimensions of the enamel materials. The lingual wall of the incisal edge (incisal frame) is built up with the appropriate enamels and translucent porcelains, and then fired. Because of the small volume of porcelain, firing shrinkage is minimal, thus affording maximum positional con-

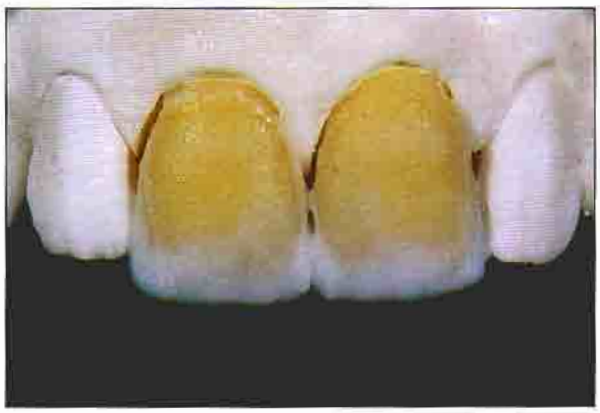


Fig 15a Incisal frame built up.

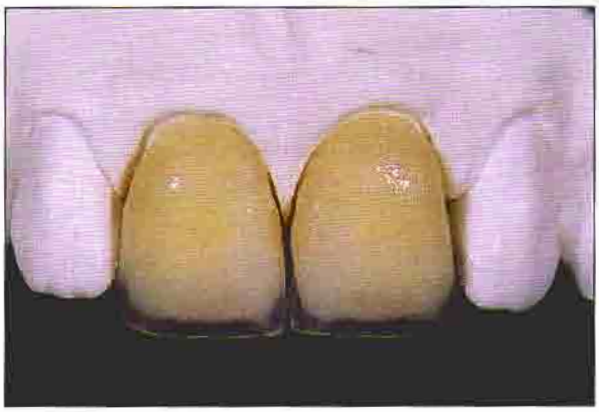


Fig 15b Incisal frame fired.

Fig 16a Incisal effects fired. Note the chalky appearance because of the low firing.

Fig 16b Incisal effects are wet with glycerin to show the completely sintered color effects.

trol of the incisal edge. Slight overbuilding can be adjusted after firing, and slight underbuilding can be corrected by adding more porcelain and refiring prior to going to the next layer (Figs 15a and 15b).

Internal Effects

Mamelon or other internal effects are created at this point. Special high-chroma porcelains called Intensives (Vita) or fluorescent stains (Internos, Vita) are layered on top of the fired dentin to create mamelon effects. Other effects are created in the same manner. These are then air fired to only 800°C to set them on the surface. Firing to 800°C will not affect the internal microstructure of the fired dentins and enamels, thus minimizing the devitrifying effect of multiple firings. After firing, the applied effect powders will appear chalky because they are incompletely sintered at this point (Figs 16a and 16b). Wetting the surface with a glycerin-type liquid will alter the refractive index to allow viewing of the fired effects (Fig 16b). This step can be repeated as many times as necessary until the desired effects are obtained. If the effects are excessive, it is a simple matter to remove them prior to proceeding to the next layer. With a full-contour buildup technique, effects cannot be viewed until after complete sintering. If undesired effects are created, complete stripping of the crown may become necessary.

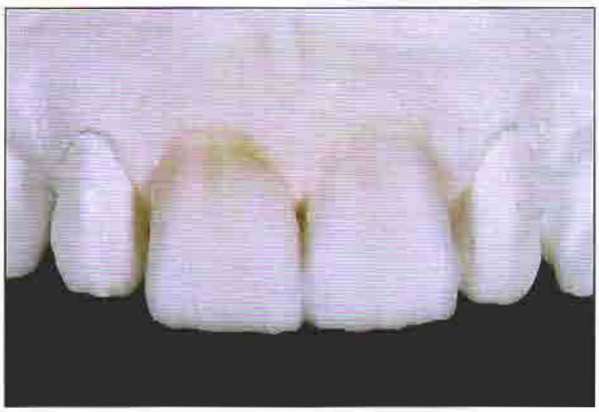


Fig 17a Enamel skin built up.

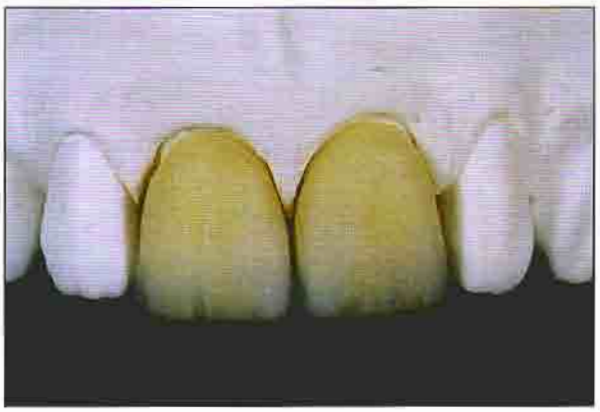


Fig 17b Enamel layer fired.

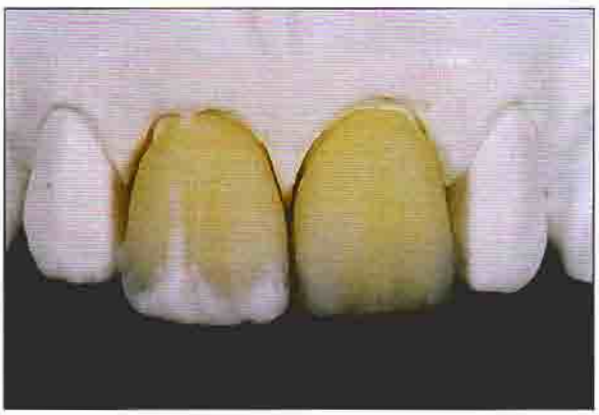


Fig 18a An "incisal halo" effect can be created in the correcting bake.

Fig 18b After firing.

Enamel Skin

The last step in the process is to place the enamel/translucent layer. Because of the exact control of the internal layers (skeleton), the precise control of the enamel/translucent layer (skin) is fairly easy. At this point different translucent powders can be built up incrementally, as in the lateral segmental technique (Figs 17a and 17b).[16] Overbuilding is preferred, as this will allow slight contouring of the porcelain after firing rather than a second addition of translucent porcelains to complete contour.

Keeping the translucent porcelain firing cycles to an absolute minimum is critical to prevent devitrification. Dentin porcelains do not devitrify as readily as translucent porcelains on multiple firings. Devitrification is caused by crystal growth within the porcelain on multiple firings, which makes it appear cloudy. Materials added to translucent porcelains to create the opalescent effect act as nucleating agents mediating this process. Dentin powders typically do not have opalescent agents added to the material; thus devitrification on multiple firings is not as problematic.

An incisal halo effect, if desired, is created by placing a thin bead of a mixture of dentin and enamel porcelain at the incisal edge of the facial translucent layer. Also, any slight corrections of form can be completed by the addition of small amounts of translucent porcelains. This is then fired to complete the buildup (Figs 18a and 18b). Thus, other than the glaze firing, the enamel/translucent layer is fired a maximum of 2 times.

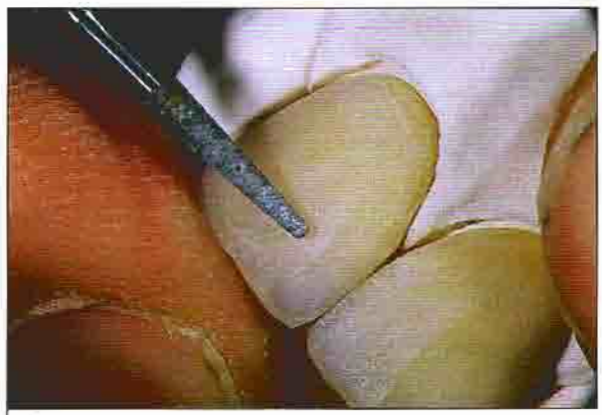
19a

19b

Fig 19a Large-diameter bur is used for contouring.

Fig 19b Contouring in same area with smaller-diameter bur.

Fig 19c Contouring in the same groove but with the bur turned 90 degrees.



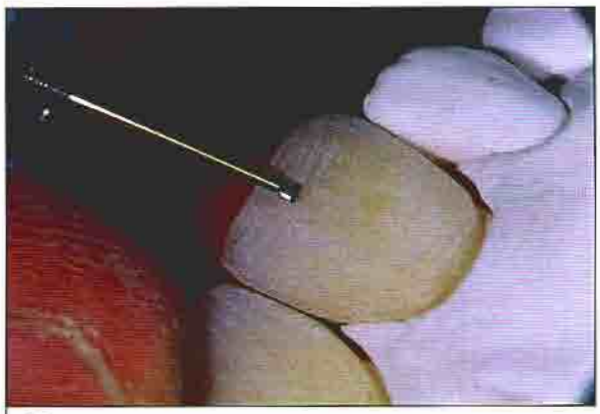
19c

Contouring and Glazing

It is important to note that natural teeth, even very old teeth, have some surface texture. Proper contour and texture are a prerequisite for natural-looking restorations. Failure to replicate the surface texture of the adjacent natural teeth will result in different surface reflection; this will suggest artificiality, despite correct color and contour matching.[27]

To create surface texture, diamonds and stones are used. Upon careful inspection of natural teeth under magnification and different light sources, grooves appear to follow a general pattern. The larger developmental grooves that run incisogingivally appear to have several different radii as they follow their course. There is an unevenness to the pattern, but all hills and valleys gently flow together. This can be recreated by using at least 2 burs of different diameter to sculpt the groove by gently bouncing over the surface of the crown while constantly changing the angulation of the bur slightly (Figs 19a to 19c). Horizontal grooves are generally much finer and closer together, but they are never straight or overlapped. These grooves need to be placed so close together that visually they cannot be differentiated; once glazed they will roll slightly toward each other, giving a natural appearance.

Placing the grooves is best accomplished under a microscope using a new 35 inverted cone bur in a low-speed handpiece (Fig 20). If the grooves are placed visually, they generally end up too far apart. Upon glazing and



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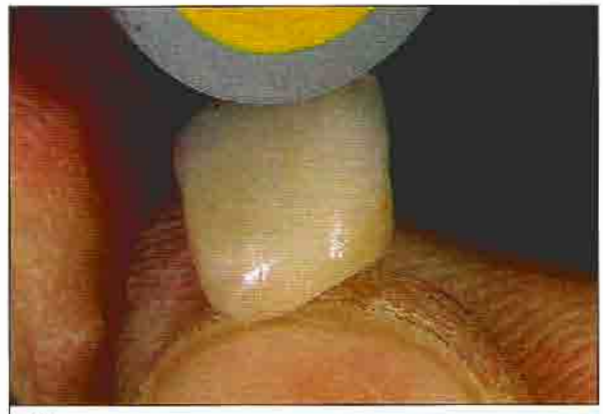

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Fig 20 A 35 inverted cone is used to create the fine horizontal lines.

Fig 21 Special porcelain polishers (Brasseler) are used after glazing.

Fig 22 A high shine is placed with diamond-impregnated felt wheels.

polishing it will appear as though there are flat areas separated by notches. The horizontal grooves of natural teeth have an appearance of a peak next to a valley with no intervening flat area. Ultimately the surface finish should match the adjacent natural teeth or, if multiple teeth are treated, create an effect *that is age-specific for that patient.*

There is a controversy as to whether to autoglaze or overglaze the restoration.[28] It is believed that autoglazed porcelain and polishing will result in a more natural-looking final result. Overglazed restorations exhibit significantly higher flexural strengths than autoglazed porcelain due to development of a compressive layer on the overglazed surface. From a material science perspective, it is best to overglaze the porcelain. Overglazed porcelain can then be polished, and to the onlooker's eye it would be difficult to tell which technique was used. Polishing is accomplished with a specially designed porcelain polishing kit called Dialite (Brasseler) (Fig 21). Generally only the pink and then the gray wheel are necessary. To put a highly reflective surface on the restoration, a diamond-impregnated felt wheel is used (Cerebril, Metalor) (Fig 22). The clinical case in Figs 23a to 23d depicts all the elements discussed in this article.

■ Discussion and Summary

Shade communication historically has been problematic and really nothing more than guesswork. This was in large part due to poor matching of existing shade guides to the color ranges of natural teeth. A new shade-matching system, the 3D-Master, has

23a

23b

Fig 23a Preoperative photograph of case presented in this article.

Figs 23b to 23d Postoperative views of the case presentation.

23c

23d

been developed and presented here based on extensive study of natural teeth. The system uses color science to create a logical arrangement and spacing within the color space of natural teeth. This greatly facilitates the shade-matching and communication process. There are many other important factors related to matching the shade of natural teeth, such as illumination, room setup, and patient preparation. The reader is referred to several excellent and detailed articles on these related factors.[1-3,17,27]

The Skeleton Buildup Technique presented here allows systematic control of the shade and shape of metal-ceramic and all-ceramic restorations. This technique might seem rather time intensive, but actually the time spent building porcelain is the same as in other techniques. The only difference is the oven time; if the ceramist has other work to do while the restoration is baking, there is no actual increase in labor time. The benefit of this technique is complete control of each buildup step with the ability to view each fired layer and adjust it as necessary prior to proceeding.

■ Acknowledgments

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