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Intraoral characterization of monolithic ceramics: The "Triple R" protocol

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ABSTRACT

A successful life like dental ceramic restoration should be able to blend harmoniously with the adjacent natural teeth. This could be achieved by mimicking and duplicating the natural teeth color, translucency, as well as the surface characterization of natural teeth. Shade matching is an important and a difficult task in mimicking natural teeth that usually leads to unreliable and inconsistent results. Still, a small percent of human teeth shade cannot be matched by available commercial shade guides. The presence of a chair side CAD/CAM system in the dental office eliminates the presence of laboratory steps and hence saving time and cost, but at the same time it deprives the dental office from gaining benefit of the laboratory technician skills and expertise. Thus the clinician has to gain more knowledge and acquire more skills about how to finish, characterize and stain ceramic restorations. Clinicians are also required to develop methodologies that remain practical and enable them to deliver to their patients a successful life like ceramic restoration that blends harmoniously with the adjacent natural teeth. The "Triple R" protocol suggested by the author consists of three steps 1) Recognize 2) Record and 3) Replicate. This protocol identifies the most common color shapes and provides the clinician with guidelines that increase his ability to customize ceramic restorations intraorally. It also highlights the importance of extending the replication of tooth shade beyond the limitations of the present commercial shade guides.

1. Introduction

A successful life like dental ceramic restoration should be able to blend harmoniously with the adjacent natural teeth. This could be achieved by mimicking and duplicating the natural teeth color, translucency, as well as the surface characterization of natural teeth [1–4]. Shade matching is an important and a difficult task in mimicking natural teeth that usually leads to unreliable and inconsistent results [5–7]. One of the difficulties that dentists have to face is that various light sources do not produce consistent results [1]. The recommended intensity for the main light source in dental operating room is between 2000 and 3200 lux. The ambient and direct lightning used in the operating room will be reflected from surfaces before reaching the teeth and restoration. It has been recommended that the walls as well as the operator cloths should be of colors that have a chroma of 4 Munsell units or less. Those colors are the pastel or neutral gray tones [8–10].

Another difficulty is that the available shade guides do not duplicate the shades of some teeth, i.e. they do not cover the entire color space of natural dentition. Moreover, various shade guides do not produce consistent results. As a practical way to extend the range of available shade guides, using two or more guides has been recommended [1,10–18]. Additionally, the color of the prepared tooth has an influence on the final ceramic restoration shade. In order to help the dental laboratory technician reproduce the exact shade of the teeth adjacent to the restoration a specially colored die material has been introduced to the market (IPS Empress, Ivoclar Vivadent) that has a special dentin shade guide [19–23].

Still, a small percent of human teeth shade cannot be matched by available commercial shade guides. In a trial to match the shade of such teeth, extensive use of stains and surface characterization had been recommended, yet this might have an adverse effect as it increases light reflection preventing light transmittance through the ceramic [24]. Extending the concept of the commercial guide by fabricating a custom made shade guide by using different porcelain powder combinations in various distributions resulting in an infinite number of shades is considered very time consuming and requires specialty skills that the dentist cannot provide [25]. Another approach that was proposed by (GC America) is light cured porcelain staining system that is used in-office to custom stain the closest matching shade tab. The tab is sent to the dental lab to duplicate the customized shade [10,26].

Chairside color modification has been proposed. The technique involves staining the restoration till the required effect is created, then

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taking note of which stain was used and where. The restoration is then removed out the mouth and washed. The characterization is then re-created and the restoration is glazed. The disadvantage of this technique is that the color is produced through surface stains thus a lifelike restoration may not be the result. Loss of fluorescence and increase in metameric effect may result due to excessive surface stains. A restoration rougher than autoglazed one may be produced and the stains may wear away by tooth brushing [27–31]. A practical approach is the shade distribution chart. The tooth is divided into three thirds; incisal, middle and cervical. Independent shade selection is performed for each third. Also a chart for surface characteristics may be helpful, where details as fine as hairline fractures and hypocalcifications are marked on the chart and sent to the lab together with a digital image. The image should show the selected shade tab beside the adjacent teeth to help the dental technician to properly calibrate the shade [32].

Various color measuring devices are available for clinical use. The reliability of these devices is 90%, and accuracy is from 60 to 90%, yet some of them when clinically tested show clinical results similar to visual matching [33–37]. Image analysis using computer software is another digital approach where the image is taken by a digital camera and then calibrated by mathematically adjusting known references in the image thus unknown image components are discovered and marked on the tooth. This method includes not only recognition of shade but also translucency and value [10,38].

Despite of the availability of the previous techniques yet they have difficulties and still not 100% accurate. It is always difficult to duplicate and mimic the patient tooth without the patient being present. The "Triple R" protocol discussed in this article might be considered as guidelines through which the dentists could be able to intraorally reproduce the challenging and difficult natural tooth shades and surface characterizations thus delivering restorations that mimic the adjacent natural teeth.

2. Materials and methods

The "Triple R" protocol consists of three steps "Recognize, Record, and Replicate".

2.1. Recognize

When matching a ceramic restoration to a tooth, the color shapes and its location play an important role in the success of the restoration to mimic the natural tooth appearance than is the selected tooth shade. These color shapes are a result of the interaction between light and the tooth surface texture and composition (enamel and dentin). Our first step will be to recognize the color shapes present in the tooth/teeth to be mimicked. If we take the upper central incisor as an example to describe what is meant by color shapes (Fig. 1), the following color shapes may be described in an inciso-cervical direction into;

2.1.1. The incisal halo

A halo is a prismatic illusion that marks the incisal edge. It results from convergent angle incisal edge enamel that is unsupported by dentin. It has a white and/or vanilla hue that extends from tooth contact point to contact point, with various thicknesses.

2.1.2. Translucent zone

Cervical to the incisal halo, the unsupported enamel of the buccal and lingual surfaces is nearly parallel, thus allowing light transmission through them. It has a blue or gray hue of different shape. It extends proximally from contact to contact and cervicaly in between the developmental grooves.

2.1.3. Mamelons

The mamelons are the most incisal aspect of the developmental lobes that offers the first incisal enamel support. They extend incisaly into the translucent zone. They may have the same shade as the body of the tooth or may have a different shade of orange, vanilla, or salmon. Sometimes each mamelon may have a different color and its projections may be "tipped" with white.

2.1.4. Interproximal enamel

It appears as a translucent wash of blue and/or gray that is present proximal to the developmental lobes and extends in a cervical direction. It may be considered as a prismatic illusion seen from an oblique view.

2.1.5. The tooth body

It is the shade of the tooth body and cervical areas that may be simplified as being white, yellow, or orange [39].

2.1.6. The tooth neck

This is the area of dentin close to root and is covered with minimal or no enamel. It varies in hue from ochre, copper, orange, khaki, to sunset yellow.

2.2. Record

The second step after recognizing the color shapes of the natural teeth to be mimicked is to record these shapes extension and hue and determine which stains to be used for replicating them by both of the following steps;

a) Selecting a basic shade using commercial shade guides.
b) Color Mapping

Draw the outline of the tooth to be mimicked (Fig. 2) and determine the following;

- Incisal halo presence, thickness and color (white and/or Vanilla).
- Translucent zone shape, extension and color (blue or gray).
- Mamelons visibility, shape and color (orange, vanilla, salmon, or the basic shade).
- Interproximal enamel shape, extension and color (blue or gray).
- Tooth body shape and value.
- Cervical area at the tooth neck shape and color (copper, orange, yellow).

2.3. Replicate

Color shape replication and final shade modifications are done using low fusing ceramic pastes (shades and stains). These are 3-dimensional ceramic stains developed to bring color deepness and life like translucency to ceramics. They are based on fine ceramic particles, enabling a thicker application compared to conventional stains. They have a fine thixotropic property for easy and precise applications. Many kits are available in the market e.g. **CERABIEN ZR FC Paste Stain (Kuraray, Noritake, Japan), Ivoclar IPS e. max Ceram Shade and IPS Ivocolor (Ivoclar Vivadent AG, Liechtenstein) GC initial IQ luster paste NF (GC America, USA).**

Replicating tooth surface characterization is the art of reproducing natural defects. Since copying the exact characterization will allow the ceramic restoration to blend with the adjacent teeth, thus, replicating the natural surface characterization intra-orally will insure best results (Figs. 3–5). Dehydration of the adjacent tooth will result in increasing its value so to prevent dehydration a thin layer of the shade/stain liquid may be applied to form a protective coat, preventing dehydration till the characterization procedure is completed.

The following are just guidelines for replication of the most common color shapes. Clinicians are advised to try different stains and shade hue and not to be afraid to make their own mix of hues with different proportions.

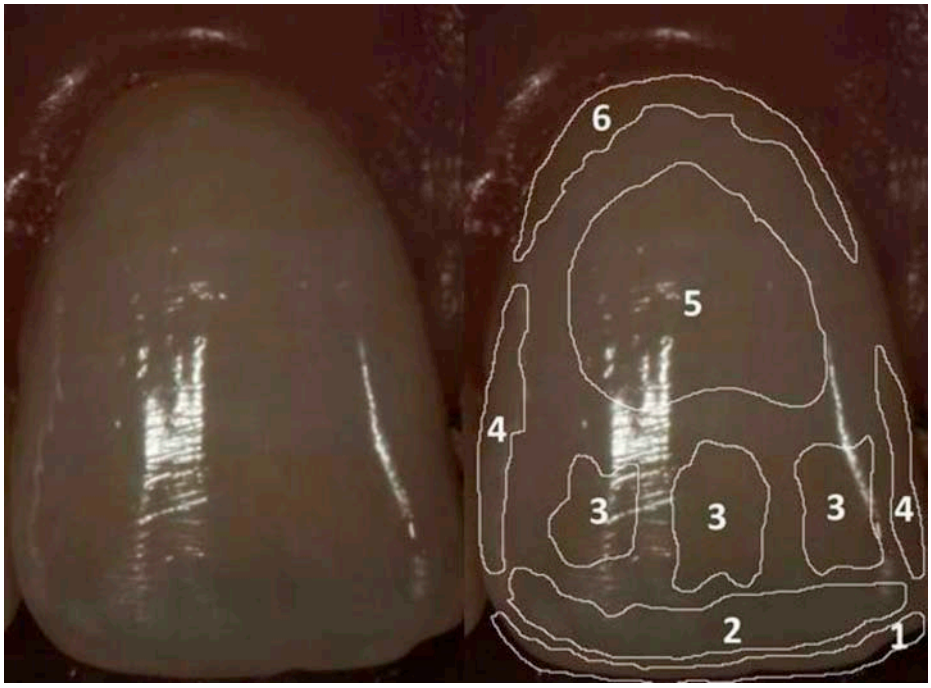

Fig. 1. Color shapes; 1) The Incisal Halo 2) Translucent zone 3) Mamelons 4) Interproximal enamel 5) The tooth body 6) The tooth neck.

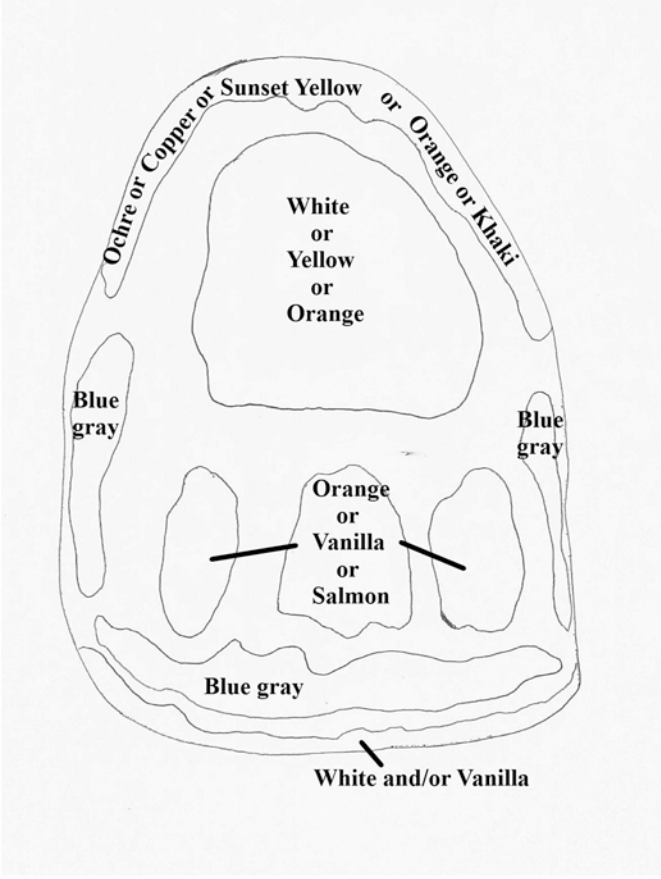

Fig. 2. Color map.

2.3.1. Chroma adjustment

To increase chroma; for basic yellow shades add yellow, while for yellow-red shades add orange. To decrease chroma; for yellow shades add purple-blue, while for orange shades add blue or blue-green.

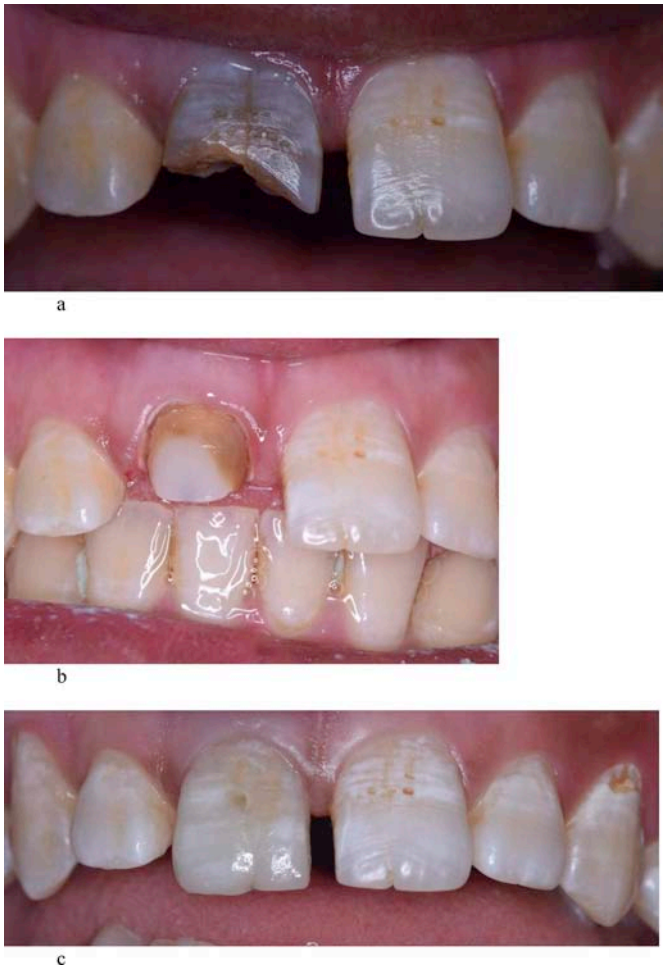

Fig. 3. a) Fractured, discolored and endodontically treated upper right central incisor b) Crown preparation c) Intraoral staining d) Post-operative.

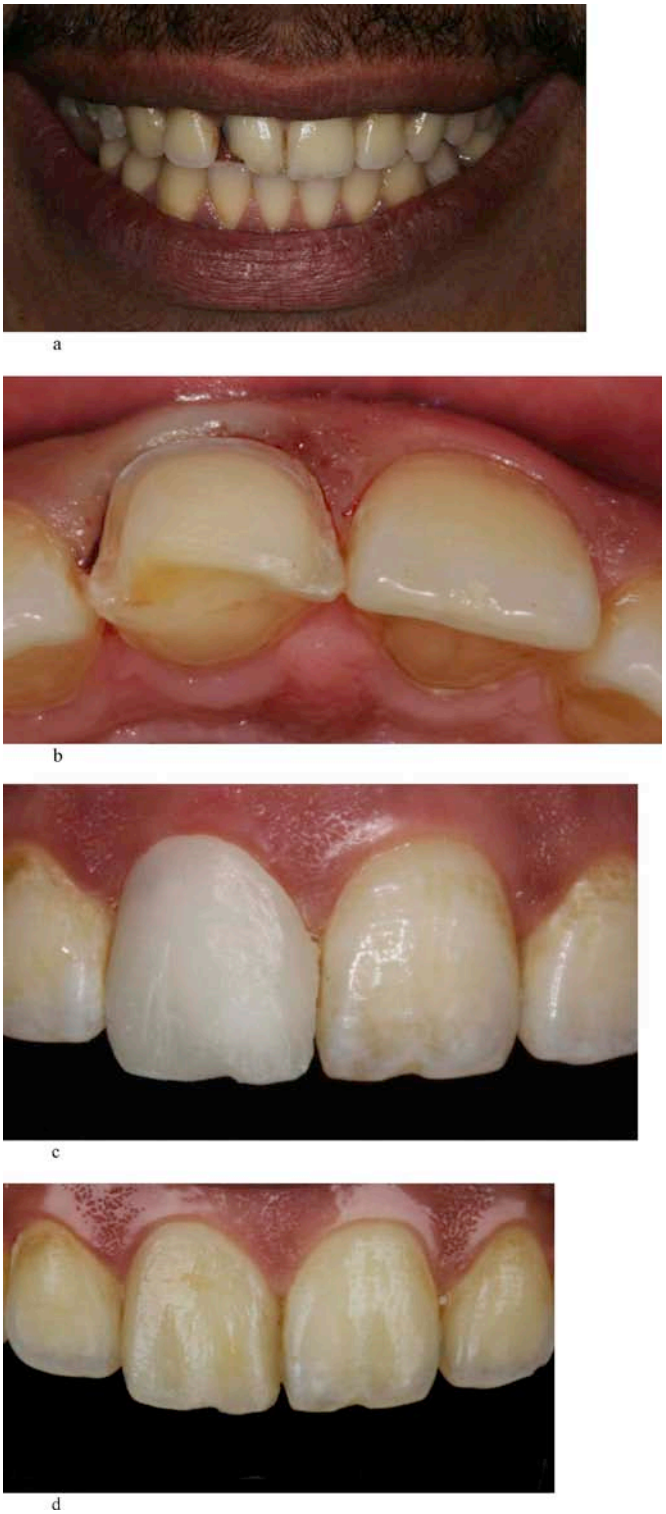

Fig. 4. a) Carious upper right central incisor b) Preparation c) Laminate Veneer d) Post-operative.

Taking in consideration that altering chroma by shades lowers the value.

2.3.2. Hue adjustment

To alter hue, pink-purple moves yellow shades towards yellow-red while adding yellow reduces the red content in yellow-red shades.

Fig. 5. a) Preparation of upper left canine b) Post-operative cantilever bridge to replace missing upper left lateral incisor.

2.3.3. Value adjustment

Adding complementary colors decreases value. Violet decreases the value of yellow restorations but increases apparent translucency. Sometimes gray shade decreases the value as well as translucency but too much gray will result in a cloudy appearance.

2.3.4. Hypocalcified areas

Use a white shade to replicate same outline at same position of the tooth to be mimicked.

2.3.5. Proximal coloration

To produce the effect of proximal depth for single units and the illusion of separation for several fused units, use brown and/or orange shades. The shades are applied very lightly in the proximal area. Sometimes it may be useful to extend the shades slightly on the buccal surface cervical to the contact.

2.3.6. Enamel cracks

We first make a dot at the place where the crack line starts using brown-orange shade. Then, use a clean brush to drag the dot into a line extending on the surface in the desired pattern. The highlight of the crack is done using a white shade on one or both sides. To create an illusion of depth, gray shade is used on one side to produce a shadow effect.

2.3.7. Exposed dentine islands

Dentine facets resulting from enamel wear should first be simulated by a round diamond stone then an orange shade surrounded by light

brown border line will replicate the shape. Sometimes white or gray may be applied around the facet to give more natural appearance.

2.3.8. Incisal halo

To produce an opaque incisal edge, a white and yellow shade (4:1) is placed on the inciso-palatal area extending to demarcate the inciso-labial line angle of the incisal edge.

2.3.9. Translucent area

A mix of gray and blue shade is used to produce the illusion of the translucent area. If these shades are used in a 1:1 ratio a cloudy dark effect might result giving an artificial appearance. Thus, after mixing them this ratio, mix the result with neutral shade paste in a ratio of 20% gray/blue to 80% neutral paste [10].

3. Discussion

In the last 25 years there has been a significant advance in digital technologies and the use of CAD/CAM technology has become more popular in the dental field. The presence of a chair side CAD/CAM system in the dental office eliminates the presence of laboratory steps and hence saving time and cost, but at the same time it deprives the dental office from gaining benefit of the laboratory technician skills and expertise. Thus the clinician has to gain more knowledge and acquire more skills about how to finish, characterize and stain ceramic restorations. Clinicians are also required to develop methodologies that remain practical and enable them to deliver to their patients a successful life like ceramic restoration that blends harmoniously with the adjacent natural teeth.

The "Triple R" protocol suggested by the author consists of three steps 1) Recognize 2) Record and 3) Replicate. The first step is to "Recognize" color shapes and be able to understand how these shapes affects the final outcome of the shade. The second step is to "Record" the present color shapes in the patient dentition by selecting a basic shade using commercial shade guides then drawing a color map for the color shapes extension and hue and determine which stains to be used for replicating them. The third step is to "Replicate" the recorded color shapes intraorally guided by the adjacent natural teeth using luster paste stain kits that are available in the market. Then the restoration is removed from the patient's mouth and placed in a porcelain furnace.

This protocol identifies the most common color shapes and provides the clinician with guidelines that increase his ability to customize ceramic restorations intraorally. It also highlights the importance of extending the replication of tooth shade beyond the limitations of the present commercial shade guides.

Although the Chairside color modification technique involves staining the restoration intraorally same as that proposed by the "Triple R" technique, yet The "Triple R" technique overcomes all of the Chairside color modification technique. In the Chairside color modification technique the clinician takes note of which stain was used and where then the restoration is removed out of the mouth and washed. All data are sent to the lab where the characterization is then recreated and the restoration is glazed. Definitely laboratory replication of the different effects will not be as accurate as direct intraoral mimicking. Another disadvantage of the chairside technique is that the color is produced through surface stains thus a lifelike restoration may not be the result. Loss of fluorescence and increase in metameric effect may result due to excessive surface stains [27–31]. While in the "Triple R" protocol the color shapes are reproduced by using luster pastes. These pastes are low fusing ceramic pastes. Thus, a more natural fluorescence can be produced. Chairside color modification technique use surface stains that are applied as a final layer. This result in a restoration rougher than an autoglazed one and also the stains may wear away by tooth brushing. On the contrary, in the "Triple R" protocol, the shades and stains are applied as a step prior to the final surface glazing step. Thus the restoration final surface is smooth and the stains are protected by the glaze layer preventing their wear by tooth brushing.

4. Recommendations

Although the "Triple R" protocol provides a strong workflow, still natural dentition is rich of colors that represent an everyday challenge for the clinician. Tooth surface texture has a very important role affecting the final shade of the restoration and since the "Triple R" protocol describes a workflow for color replication therefor surface texture replication steps are recommended to be included. The "Triple R" protocol relies on the ability, knowledge and skill of the clinician to visually recognize, record and replicate different color shapes. The use of digital photography as a tool to identify and record color shapes might be very helpful.

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