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Art and Science of Shade Matching

Abstract: Shade selection is an important step in restorative procedures. The objective of this step is to provide aesthetically pleasing restorations which blend in with the existing dentition of the patient. This article highlights clinical difficulties which may hinder proper shade selection and a number of factors causing these difficulties. For ease of understanding, these factors have been divided into four categories. These are factors related to the dentist, the shade matching environment, the material used for shade selection and the patient. Because shade selection is an important step, it is recommended that this step should be given sufficient time. A checklist and a form for shade selection have also been devised to avoid any oversights during shade selection. This will help improve dentist laboratory communication which can result in an improved and aesthetically pleasing restoration.

CPD/Clinical Relevance: Shade selection is a crucial step in the process of fabricating an aesthetically pleasing restoration.

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Restorative dentistry is a blend of science and art. For a restoration to be successful, it should fulfil mechanical, functional and aesthetic considerations. Today, growing demand for aesthetic restorations has produced many challenges for dentists. Shade selection is a demanding task even for the most experienced clinician.¹ Failure to select a shade accurately can result in frustration for the dentist and dissatisfaction for the patient. Shade selection is an art which can be learned by having knowledge of colour science.²

This article will review the problems experienced in shade selection and offer guidance to improve techniques regarding shade selection and communication with the laboratory.

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Shade selection

Clinical difficulties in shade selection can be broadly divided into four categories.

1. Factors related to the dentist;
2. Factors related to the shade matching environment;
3. Factors related to the materials used for shade selection;
4. Factors related to the patient.

Factors related to the dentist

These factors can be further subdivided into two groups.

1. Factors not under the control of the dentist;
2. Factors under the control of the dentist.

Factors not under control of a dentist

Subjective faults in colour perception by the dentist: Colour matching becomes more complicated because of differences in perception of colour by clinicians. A review of different studies has shown that there are differences among dentists when shade selection was carried out for the same tooth.³ Some people may have a colour deficiency, which means that they need the assistance of someone at

the time of shade selection. According to a study, 6.5% of individuals have colour vision defects.⁴ Accordingly, dentists, dental students and dental technicians should undergo tests to check if they are colour deficient.⁵

Factors under control of the dentist

Knowledge about colour science: It is essential for every dentist to have knowledge of colour science and he/she should know the art of its application in clinical practice.⁶ Today, as patients are more concerned about aesthetics, the need for training to achieve more life-like results is growing. Prior to shade selection, the dentist should understand the differences in physical composition between a natural tooth and dental porcelain. Transparency and translucency are both found in a vital tooth. Reflection and refraction of light occur because of transparency of enamel rods. On the other hand, porcelain is a heterogeneous material. It has transparent properties but also has metallic oxides that act as opacifiers. Thus, light is modified by absorption, transmission and reflection by porcelain.⁷



Figure 1. The operator and dentist should be at the same level during shade matching procedure.



Figure 2. Holding the shade tab incisal edge to incisal edge.

Timing of shade selection

Shade selection should be carried out at the beginning of the appointment. At the end of a dental procedure (especially under rubber dam isolation), the tooth gets dry and its colour appears lighter and less saturated.⁸

Time taken by dentist to select shade

When a colour is observed for more than 5 seconds, the observed colour becomes less saturated and the chroma of complementary colours increases.⁹

The receptors become less sensitive to further stimulation after being stimulated for a period of time. When an individual stares at red colour for some time, red receptors will be exhausted relative to blue and green receptors.¹⁰ After that, when he/she sees an object, the red receptors will produce a weakened response and he/she will see a green-blue after image. The after image will always be a complementary colour to the colour at which the individual had been glaring.¹¹ Neutral grey colour is an ideal background for shade selection as it has no

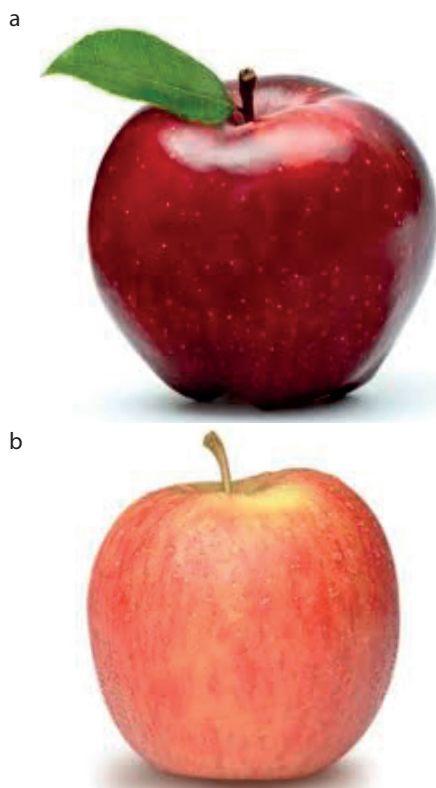


Figure 3. (a) Shiny smooth apple. (b) Apple with rough surface texture.

complementary colour and is soothing to the cones.¹²

Position of patient and operator

The patient should be in an upright position and his/her level should be the same as that of the operator (Figure 1) because the part of the retina which will be used in this way is the one that is most colour sensitive.¹²

Choice of shade guide

The dentist should use a shade guide in accordance with the laboratory to which he/she is consulting or sending casts for fabrication of prosthesis. Choosing a shade from one shade guide and constructing a prosthesis from another manufacturer's material will not produce the desired shade originally selected.³

Method of holding the shade tab

Shade tabs should not be placed



Figure 4. (a) Rough surface texture. (b) Shiny surface texture.

adjacent to the tooth to be matched, as the colours of both will reflect on each other and will make shade selection difficult. Dentists should hold the shade tab incisal edge to incisal edge (Figure 2).

To do list at the time of shade selection

The word 'shade selection' is not mere selection of a colour, but it also includes recording other morphological details. The Glossary of Prosthodontic terms defines Shade Selection as '*determination of colour and other attributes of appearance of an artificial tooth or set of teeth for a given individual*'.¹³

Shade matching is not as simple as picking up a shade tab. The procedure of shade selection includes many details to be recorded. For example, if an individual wants to make an artificial apple simulating the apple in Figure 3a, he/she will not be able to simulate it unless its surface texture (shiny and smooth) is matched. So, in addition to 'hue', 'chroma' and 'value', 'surface texture' is an important aspect which should be observed and noted. If hue, chroma and value are appropriately matched to fabricate the artificial apple shown in Figure 3b, it will not be a good match unless surface texture is copied too.

Surface texture of teeth at eruption is the roughest and, as age increases, these surface features gradually wear and, as wear continues, the tooth appears shiny and smooth with a highly reflective glossy surface (Figure 4).

Translucency is another aspect which is important in fabricating a restoration which looks more like a natural



Figure 5. Translucency of teeth should be examined and noted in the shade selection form.



Figure 6. Selecting stump shade.



Figure 7. A patient with porcelain fused to metal ceramic crowns on incisors, canines and first premolar (patient has gum recession on right central incisor and canine): (a) captured in daylight; (b) captured in fluorescent light; (c) captured with ringflash.

may both have the same hue, chroma and value but they do not look the same. This is because of the difference in translucency¹² (Figure 5).

The appearance of teeth is also determined by surface topography of a tooth. The way light interacts with a curved surface is different from that of a flat surface. The shape of the labial or buccal surface is one of the most important aspects of shade matching because it determines how most of the light will be reflected.¹²

Stump shade (a term referring to a tooth's dentine shade¹³) should be selected if all-ceramic restorations (except for zirconia) have to be fabricated for a patient. If not recorded, and a restoration is fabricated after selecting the shade just of the adjacent tooth, it will become a different shade when placed in the mouth¹⁰ (Figure 6).

For proper shade selection, a clinician should give time to this step, so that all necessary details can be recorded which are important for shade selection and consequently for fabrication of an aesthetically successful prosthesis.

Dentists should have a step-by-step to-do list and should have printed forms available so that all information can be recorded and sent to the laboratory without missing any details.

The to-do list at a shade selection visit should include the following details:

1. Selection of surface texture;
2. Determining value, hue and chroma;
3. Identifying where the tooth is translucent;
4. Determining contours of labial/buccal surface;
5. Documenting the stump shade;
6. Determining the tooth morphology characteristics;
7. Taking a photograph of the prepared and adjacent teeth;
8. Shade mapping;
9. Suggesting your selected/preferred restorative material.¹⁴

Factors related to the shade matching environment

Although shade selection is a necessary step in the overall restorative procedure, in the authors' opinion, it is usually not

given the importance which it actually deserves. Many clinicians' dental clinics are not adequately built for shade matching.¹⁵

The factors affecting shade selection are as follows:

1. Quality of the light source;
2. Quantity of the light source;
3. Metamerism;
4. Contrast and glare;
5. Colour of the ceiling;
6. Colour of the walls of the dental operatory;
7. Colour of the furniture;
8. Patient's clothes;
9. Patient's make-up.

1. Quality of the light source:

During visual shade matching, a light source of appropriate quality should be used. Colour temperature close to 5500 degrees Kelvin is ideal for colour matching. Most dental clinics have incandescent (3800 K) and fluorescent light (3000 to 4200 K) whose colour temperature is not ideal in terms of colour matching.¹¹

For shade matching, a Colour Rendering Index (CRI) greater than 90 is recommended. The CRI is a number from 1 to 100 given to a light source to indicate its relative equivalence to pure white light, which has a colour rendering index of 100. The closer the number is to 100, the more it resembles pure white light (GPT-9).¹³

An ordinary incandescent light emits a high concentration of yellow light waves, whereas fluorescent light gives off a high concentration of blue waves. Colour corrected fluorescent lighting is ideal for shade matching which contains a balance of the entire visible spectrum.¹⁶ Fortunately, white energy saver lamps are cheaper and easily available and can be used to meet this standard.¹

2. Quantity of light source:

Light intensity of 18–28 lux* is recommended for dental operatory and 28 lux* for dental laboratories.¹⁷ Appropriate intensity of lighting is necessary in dental operatory in terms of contrast but it should not be so strong as to wash out the colour and mask the differences.¹⁶

For visual shade matching, lighting environment of most of the dental operatories is not ideal in terms of quality and quantity. Auxiliary light sources are recommended to solve this problem.¹⁸

3. Metamerism: It is the characteristic of a restoration where it will

tooth. Shade matching is incomplete unless the areas which are translucent are noted and copied. Pieces of snow or frosted glass





Prosthodontics





Figure 8. (a) Patient wearing red lipstick: teeth look whiter in shade. **(b)** Same patient without lipstick: teeth look yellowish.

match its adjacent teeth in one light but show a different colour in other lighting conditions. The use of surface stains should be performed with caution as metamerism increases with their use.¹⁹

Perception of the colour of an object is because of the spectral distribution of a light source and the reflectance spectrum of an object. For example, when an object is viewed under one light source, some of the wave lengths which are present in that light source will not be present when the same object is viewed under different light sources. The viewer will therefore see a different colour as the wavelength reflecting from an object and reaching the patient's eyes are now different²⁰ (Figure 7).

4. **Contrast and glare:** Difference between the brightness of an object and its background is 'contrast'. A certain level of contrast is helpful for shade selection but excessive contrast causes 'glare'. Lighting of teeth should not be considerably greater than the ambient environment and the ambient light ratio should not exceed 3:1.¹

5–9. Colour of surroundings

The colours of the walls of dental clinics, clothes of dentist, dental assistants and patient and colour of dental curtains/blinds may influence the perceived colour of a patient's teeth and shade guide.

Recommendations about the shade matching environment are as follows:

- Walls, staff clothing, dental curtains/blinds and the shade matching

environment have a chroma of 4 Munsell units or less (pastel or ideal neutral grey tones).

- The patient should not be wearing bright clothes or make-up. The dentist can cover the patient's clothes with a neutral grey apron and should ask the patient to remove any bright lipstick¹⁷ (Figure 8).

Factors related to materials used for shade selection

Shade selection can be done by two methods:

1. Visual shade matching; and
2. Instrumental shade matching.

Visual shade matching

This technique involves the use of shade guides for matching shade. Though this is the most common method of shade selection, there are many inaccuracies with the use of these commercial shade guides. Problems that may arise include the following:

1. The shade guide with which the shade selection is done does not match the porcelain available for that shade in the laboratory;
2. Shade variations occur between different batches of porcelain manufactured by the same company;
3. The thickness of the shade guide tabs are 4–5 mm, whereas porcelain used for the restoration is approximately 1.5 mm;
4. Fluorescent porcelain is not always used to fabricate the shade guide, which causes discrepancies in colour matching;
5. It is tough to foresee the final shade after the layering of opaque, dentine and enamel;
6. Guide tabs have no metal backing unlike metal ceramic restorations;²¹
7. The procedure of condensing porcelain on shade tabs is different from the way it is condensed on metal coping for metal ceramic crowns.¹⁷

Shade analysis using instruments

This technique involves use of colorimeters, spectrophotometer and digital imaging devices. Whenever possible, shade matching should be done using both visual and instrumental methods.²² Like other devices, they also have limitations along with benefits. These limitations are because teeth are semi-translucent and small in

size, the tooth surface is uneven and the surrounding components of teeth are complex. These devices measure limited areas of the tooth, so multiple areas should be evaluated for shade matching to produce the same shade. Besides this, due to the translucent nature of teeth, small-window tooth colour measurement may cause edge loss of the light.²³ This article is focused on visual shade analysis, which is why explanation of instrumental shade analysis is limited.

Factors related to the patient

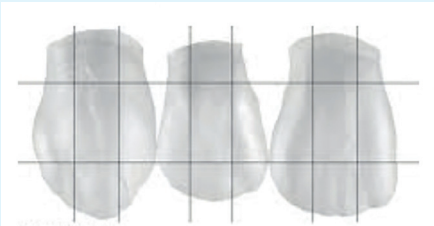
Some patients prefer whiter teeth rather than teeth being matched to their own remaining teeth. In such cases, proper shade selection can be difficult as the best shade may not be considered best by the patient. Patient education and counselling is required and if he/she still insists, then a temporary prosthesis can be given with the shade selected by the patient. This will help him/her and people in his/her surroundings to judge the shade of the prosthesis. In the authors' opinion, the patient should be given a week to assess the shade of the prosthesis. (During this time, he/she will get a chance to go through the routine of a weekly schedule, meeting his/her colleagues in weekdays and with friends/family in holidays.) The comments of people may have an affect on the acceptance or rejection of a prosthesis by a patient. After a week, the patient might be convinced or otherwise that a compromise will be made between the shade selected by the clinician and the shade chosen by the patient, in order to consider the patient's autonomy.

Conclusion

There are a number of clinical difficulties in the shade selection process. The first, and most important step, is to identify these difficulties and, if possible, to eliminate them. The problem can only be solved once there is knowledge of its existence. This article has tried to identify and describe all clinical difficulties that may arise during shade selection to enable clinicians/dentists to evaluate their own practice, clinical setting and material they are using for shade selection. A form for shade selection

Prosthodontics

Patient's name: _____
 OPD No: _____
 Age: _____ Gender: _____
 Tooth Number: _____
 Surface texture of tooth: Coarse Shiny Dull
 Contour of labial/buccal surface: Flat Convex Concave
 Name of the Shade guide used: _____
 Lightening condition: _____
 (If natural light is used also mention time and weather on that day)
 Shade selected:
 Incisal third _____
 Middle third _____
 Cervical third _____
 Identify translucent or transparent areas: Incisal third Middle third Cervical third
 Stump shade: _____
 Tooth morphology characteristics:
 Craze lines (if present, also mention their location)
 Cracks
 Stains
 Incisal halos
 Mamelons
 Cupping of teeth
 Attrited incisal edges
 Vertical grooves
 Horizontal grooves
 Clinician's selected/preferred restorative material:
 Metal ceramic
 Collarless metal ceramic
 All-ceramic: Leucite-based all-ceramic
 Lithium disilicate-based ceramic
 Zirconia-based ceramic
 Others: _____
 Shade mapping:



Other special features (eg fluorosis, tetracycline staining): _____

Photograph of prepared tooth: _____

Photograph of adjacent teeth: _____

Figure 9. Suggested form for shade selection

is provided for assistance (Figure 9). Elimination of the factors causing these difficulties should be the objective of every restorative dentist because, if these clinical difficulties are not identified, and shade selection is made in haste, a restoration will look like a restoration but not a natural tooth.

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Informed Consent: Informed consent was obtained from all individual participants included in the article.

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