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ORIGINAL ARTICLE

An Evaluation of Shade Differences Between Natural Anterior Teeth in Different Age Groups and Gender Using Commercially Available Shade Guides

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Abstract Shade selection with the help of shade guides and color matching the restorations to the natural dentition continues to be one of the most perplexing and frustrating problems in fixed prosthodontics. The purpose of the study was to evaluate the shade differences of the natural anterior teeth in different age groups and gender, within the cross sectional Bangalore, Karnataka population, using commercially available shade guides. The shade of a cross section of the population comprising of 400 subjects of both the sexes (800 incisors; 400 maxillary central incisors; 400 mandibular central incisors) visiting the outpatient Department of Government Dental College was selected randomly and evaluated visually by a single observer using three commonly used shade guides i.e. Vita Lumin, Chromascop and the Vita 3D Master. The incidence of the most common shades in the different age groups and gender using these shade guides was obtained and this data was subjected to the χ^2 test ($p < 0.05$—significant). The most common shade for the maxillary and mandibular incisors in the younger age group is A2/2R1.5/140 and A1/1M2/120 for the males and females using Vita Lumin, Vita 3D Master and Chromascop shade guides respectively. In the advanced age group the most common shade for the maxillary and mandibular incisors is A2/2R2.5/140 using the same order of shade guides. However the results showed no statistical significance in shade variation in males and females in different age groups using different shade guides. Although the incidence of males with darker teeth as compared to females was higher; the study showed no statistical significant correlation between shade differences in both the sexes. It is also observed that there is a significant darkening of teeth as the age advances.

Keywords Shade · Color · Anterior teeth

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Introduction

Shade selection with the help of shade guides and color matching the restorations to the natural dentition continues to be one of the most perplexing and frustrating problems in fixed prosthodontics. A correct color match is just one of the essentials in creating an aesthetic restoration. Outline form, surface anatomy, real and or apparent translucency, texture, function, alignment and other factors share in the total effect. And just as the total aesthetic effect is composed of many elements, a correct color match is also a compound phenomenon. Visual response of an individual, quality and quantity of the viewing lights, metamerism, color of the surroundings and past experiences are among those elements that enter into the color matching [1–6]. Shade selection requires knowledge of physics, physiology and psychology of color and therefore it is both an art and science requiring in depth knowledge, accurate clinical judgment and perception on the part of the dentist [3]. Advances in technology have made shade selection easier, because of the availability of a wide range of commercially available shade guides. However most of the commercial shade guides do not completely represent the color variation present in the natural dentition [2, 7–10]. Early shade guides were derived from tooth colors that were considered pleasing, rather than from the distribution of shades found

in the general population. In 1931, Clark [7, 11] recognizing the need for a more systematic approach, introduced a custom shade guide based on visual assessment of human teeth, recorded in Munsell: Hue, Value, and Chroma. While this was a good attempt at organized shade management, the guide was cumbersome to use. In the early 1970s, Sproull [2] suggested that an ideal shade guide should consist of shade (color) tabs that are well distributed and logically arranged in color space. He recommended such a shade guide be based on the Munsell Color Order system. Lemire and Burk [12] investigated the distribution and frequency of natural tooth color space in 1974 using a spectrophotometer and concluded that the color space occupied by natural teeth was larger than that measured by the shade guides.

In addition to coverage error, Preston [8] identified several problems associated with popular shade guides. He described the influence of the gingival tissue during shade assessment, and addressed the material differences between shade tabs and restorative ceramics. Quality control issues regarding color mismatches of shade tab and porcelain batches from the same manufacturer could be as problematic as mismatches among manufacturers. Preston related that quality control of color in dental manufacturing was generally inconsistent, primarily because it was accomplished visually. Goodkind and Loupe [13] surveyed dental educators and reported that the respondents suggested that a full range of natural tooth colors should be included in the shade guides. Further, Schwabacher and Goodkind [9] in 1990 reiterated that shade guides did not match well with the color space of human teeth. Miller [14] also acknowledged that the material of the shade guide should be the same as the restoration and the thickness of the shade guides should not be more than the average porcelain veneer. The limitations of shade guides are significant factors that compromise shade matching procedures in dentistry and contribute to the dissatisfaction of clinicians, technicians, and patients.

Shade selection can be accomplished through either visual assessment or instrumental color analysis. Visual shade selection is the most common method of color determination in dentistry [15], but color duplication via this process is plagued by unreliable and inconsistent results [1, 16].

Instrumental color analysis offers a potential advantage over visual color determination: instrumental readings are objective, quantifiable, and more rapidly obtainable. Although the extensive use of computerized colorimeters and spectrophotometers has been reported in dental research [16–25] most devices currently are unsuitable for routine clinical dental use given their limited ability to measure the color of translucent objects [1, 26] (such as teeth) and their prohibitive cost/size [23–25].

Shade matching, whether by visual or instrumental methods, requires an understanding of color harmony and tolerance—namely, what actual color difference (ΔE) would be perceptible to the human eye. The CIELAB-based color difference formula, introduced in 1976 and recommended by the International Commission on Illumination [27], defines a color space (L*a*b*) in which L* represents lightness, a* represents the chromaticity coordinate for red-green (+a* is the red direction and −a* is the green direction), and b* represents the chromaticity coordinate for yellow-blue (+b* is the yellow direction and −b* is the blue direction). Color difference, or ΔE, is defined by the following equation [28]:

$$\Delta E = \sqrt{(L_f^* - L_i^*)^2 + (a_f^* - -a_i^*)^2 + (b_f^* - -b_i^*)^2}$$

where the initial (*i*) and final (*f*) are color descriptors. This formula has been used extensively in dental research. Instruments designed to measure tooth shade in CIE L*a*b* values help to assess color differences using an objective approach [29]. These instruments include spectrophotometers and colorimeters. Although visual determination of shade selection is unreliable, inconsistent and a continuing problem in dentistry, it remains the method of choice until technology can provide not only an accurate but also practical instrument.

Shade guides have been developed to address deficiencies in visual assessment. Egger [30] conducted a worldwide clinical study in which the tooth shades of more than 3,500 patients were recorded and analyzed spectrophotometrically. The NCC color indicator was derived from these data, which served as the basis for the dental color space. The NCC system consists of 208 color blends based on 38 basic shades. Shofu offered the Natural Color Concept [30] (NCC) (Shofu Inc, Kyoto, Japan), while Vita in addition to the Vita Lumin introduced a 3-dimensional shade guide [31] system (Vita 3D-Master; Vita Zahnfabrik, Bad Sackingen, Germany).

The Vita Lumin Vacuum Shade guide affords accuracy and simplicity through its logical system of shade grouping. It is arranged in four shade groups (A, B, C and D) and then degree of saturation and the brightness of color (1–4). The Chromascop shade guide (Ivoclar, Vivadent UK) has different hues which are chromatically arranged. The Vita 3D-Master shade guide [31] features a systematic colorimetric distribution of 26 shade tabs within the tooth color space. According to the manufacturer this shade guide demonstrates an equidistant distribution in the color space. The shade guide is organized into 5 primary value levels, with a secondary distribution based on chroma and hue. These value groups are arranged from lightest (value level 1) to darkest (value level 5), left to right. Intermediate shades can be achieved

based on mixing formulas. The manufacturer advocates a 3-step process: value is determined first in making a shade determination, then the proper chroma and hue are determined. The selection process is simplified because the number of choices decreases throughout the 3-step procedure.

It is a proven fact that teeth darken with age and hence a need was felt to correlate the shade differences of the natural anterior teeth in different age groups and gender using these commercially available shade guides. Keeping this view in mind, a study is planned to evaluate the shade differences of the natural anterior teeth in different age groups and gender using the Vita Lumin, Chromascop and the Vita 3D commercially available shade guides.

Aims and Objectives

1. To determine the most suitable shade for the maxillary central incisor from the shade guides, for the different age groups (Tables 1, 2, 3; Figs. 1, 2, 3).
2. To determine the most suitable shade for the mandibular central incisors from the shade guides, for the different age groups (Tables 4, 5, 6; Figs. 4, 5, 6).
3. To assess the shade variation between the maxillary and mandibular central incisors.
4. To analyze shade variation with age and gender.
5. To evaluate the reliability of the commercially available shade guides used in the study, for the selection of the shade in the local population.

Table 1 Incidence of the most common shade for the maxillary central incisor in different age groups and gender using the Vita Lumin

	15–25 years		25–35 years		35–45 years		45 years and above	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
A1	14	38	6	8	0	4	2	6
A2	52	42	10	30	12	12	4	6
A3	6	2	36	34	40	38	38	32
A3,5	0	0	6	2	16	14	22	28
A4	0	0	0	0	0	0	8	6
B1	4	2	2	2	0	4	0	0
B2	14	10	26	18	10	14	0	6
B3	4	0	8	4	16	10	20	14
B4	0	0	0	0	0	0	4	2
C1	6	6	0	0	0	2	0	0
C2	0	0	6	2	6	2	2	0

Table 2 Incidence of the most common shade for the maxillary central incisor in different age groups and gender using the Vita 3D Master

	15–25 years		25–35 years		35–45 years		45 years and above	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
1M1	2	0	0	0	0	2	0	0
1M2	14	40	10	10	2	6	2	4
1L1.5	4	2	0	0	0	2	0	0
2L1.5	14	14	34	16	12	16	2	6
2R1.5	62	42	8	32	14	6	2	6
2R2.5	0	2	40	38	48	42	38	34
2L1.5	0	0	0	0	0	0	0	0
2L2.5	2	0	0	2	0	2	20	14
3L2.5	0	0	2	0	8	16	20	28
3R1.5	0	0	0	0	0	0	6	0
3R2.5	0	0	0	0	0	0	2	0
3L2.5	0	0	0	0	0	0	4	2
4R2.5	0	0	0	0	0	0	0	8

Table 3 Incidence of the most common shade for the maxillary central incisor in different age groups and gender using the Chromascop

	15–25 years		25–35 years		35–45 years		45 years and above	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
110	12	8	2	2	4	4	2	0
120	14	38	10	10	0	6	2	4
130	18	10	26	18	10	16	2	6
140	48	42	12	30	14	12	4	6
210	2	2	0	4	0	0	0	2
220	6	0	26	34	42	38	36	30
230	0	0	0	0	0	0	0	0
310	0	0	8	0	12	10	20	12
320	0	0	16	2	18	14	26	34
340	0	0	0	0	0	0	8	6

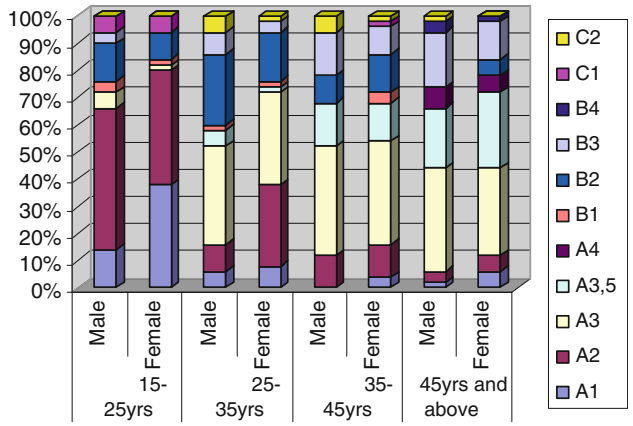

Fig. 1 Incidence of the most common shades of maxillary central incisor in different age groups and gender using the Vita-Lumin

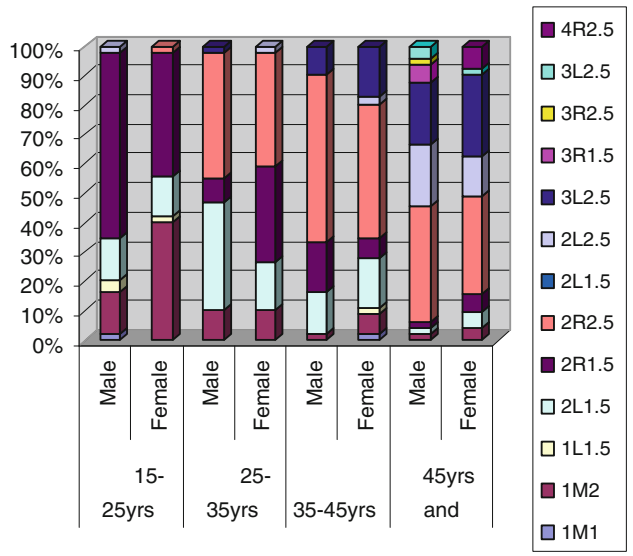

Fig. 2 Incidence of the most common shades of maxillary central incisor in different age groups and gender using the Vita-3D

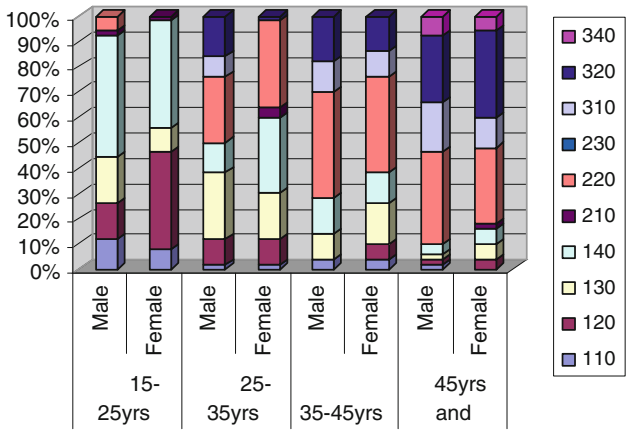

Fig. 3 Incidence of the most common shades of maxillary central incisor in different age groups and gender using the Chromascop

Materials and Methods

A cross section of the population comprising of 400 subjects of both the sexes visiting the outpatient Department of Government Dental College were recruited randomly for the study. Informed consent was obtained under a protocol reviewed and approved by the Institutional Review Board.

The commonly used shade guides i.e. Vita Lumin (Vita Zahnfabrik, Bad Sackingen, Germany), Chromascop (Ivoclar, Vivadent, UK) including the Vita 3D Master (Vita Zahnfabrik, Bad Sackingen, Germany) was used for the study.

The observer was checked for negative color blindness using the Ishihara test.

Criteria for Selection of the Subjects

1. Male and female subjects are categorized in four age groups: 15–25, 25–35, 35–45 and 45 years above.

Table 4 Incidence of the most common shade for the mandibular central incisor in different age groups and gender using the Vita-Lumin

	15–25 years		25–35 years		35–45 years		45 years and above	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
A1	66	78	14	38	10	12	2	12
A2	6	4	44	36	58	50	62	58
A3	0	0	0	0	0	6	10	6
A3,5	0	0	0	0	0	0	0	2
A4	0	0	0	0	0	0	0	0
B1	18	12	20	20	8	16	0	6
B2	4	0	16	4	18	12	20	14
B3	0	0	0	0	0	0	4	2
B4	0	0	0	0	0	0	0	0
C1	4	6	6	2	6	4	2	0
C2	0	0	0	0	0	0	0	0

Table 5 Incidence of the most common shade for the mandibular central incisor in different age groups and gender using the Vita 3D

	15–25 years		25–35 years		35–45 years		45 years and above	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
1M1	20	16	20	18	8	6	2	6
1M2	66	76	18	42	20	18	2	8
1L1.5	6	4	0	0	0	0	0	0
2L1.5	4	2	18	4	16	16	16	14
2R1.5	4	2	44	36	56	50	62	62
2R2.5	0	0	0	0	0	10	10	8
2L1.5	0	0	0	0	0	0	2	2
2L2.5	0	0	0	0	0	0	0	0
3L2.5	0	0	0	0	0	0	4	0
3R1.5	0	0	0	0	0	0	0	0
3R2.5	0	0	0	0	0	0	0	0
3L1.5	0	0	0	0	0	0	2	0
3L2.5	0	0	0	0	0	0	0	0
4R2.5	0	0	0	0	0	0	0	0

Table 6 Incidence of the most common shade for the mandibular central incisor in different age groups and gender using the Chromascop

	15–25 years		25–35 years		35–45 years		45 years and above	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
110	24	18	24	22	14	18	0	0
120	66	80	14	38	12	12	0	0
130	4	0	18	4	18	14	0	0
140	6	2	44	36	56	50	0	0
210	0	0	0	0	0	0	0	0
220	0	0	0	0	0	6	8	6
230	0	0	0	0	0	0	0	0
310	0	0	0	0	0	0	4	4
320	0	0	0	0	0	0	0	2
340	0	0	0	0	0	0	0	0

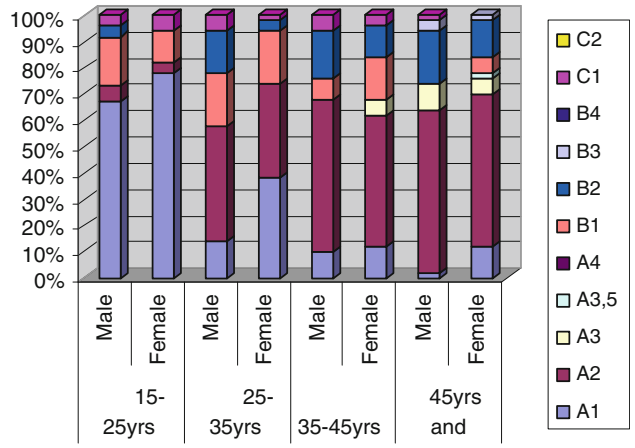

Fig. 4 Incidence of the most common shades of mandibular central incisor in different age groups and gender using the Vita-Lumin

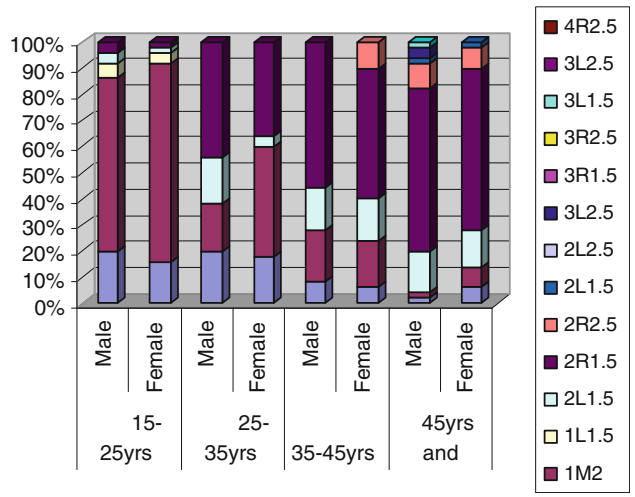

Fig. 5 Incidence of the most common shades of the mandibular central incisor in different age groups and gender using the Vita 3D shade guide

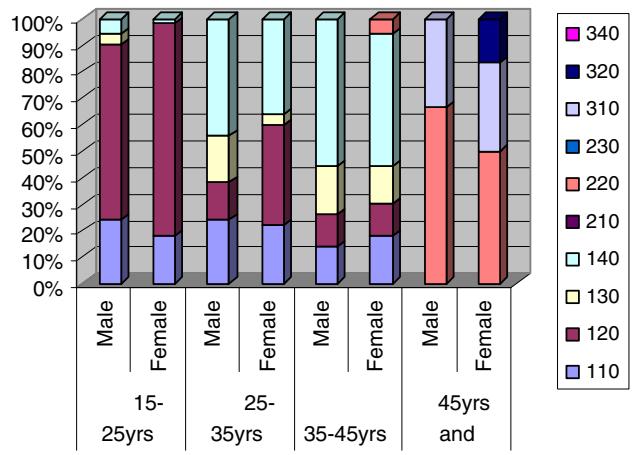

Fig. 6 Incidence of the most common shades of mandibular central incisor in different age groups and gender using the Chromascop

2. The subject included in the investigation should meet the following criteria
   - Must have a full complement of natural upper and lower anterior teeth.
   - The anterior teeth should be free from restorations, caries, stains, decalcifications, fluorosis, hypoplasia, nonvitality and any other effect that are likely to affect the color of the teeth.
   - Female patients are asked not to use any lipstick or bright makeup before shade selection.
   - To decide the shade the observations are made in the following three positions;
     i. Outside the mouth along the side of the nose.
     ii. Under the lips, with only incisal edges exposed.
     iii. Under the lips with the cervical end covered and the mouth open.
3. If an exact shade is not possible a shade of lower chroma and higher value is selected.
4. A swift shade selection is done for no more than 5 s to avoid fatigue to the cones in the retina.
5. Gazing at a blue card or towel in between each shade evaluation is followed by the observer to avoid fatigue.

Results and Discussion

The results indicated that the most common shade for the maxillary and mandibular central incisors for males and females in the age group of 15–25 years using the three shade guides Vita Lumin, Vita 3D Master, and Chromascop respectively are A2/2R1.5/140 and A1/1M2/120.

The most common shade for the maxillary central incisors using the same order of shade guides, in the age group 25–35 years are A3/2R2.5/220 respectively. The most common shade for the females is A3/2R2.5/140 respectively. The most frequently seen shades for mandibular incisors, in males in the same age group A2/2R1.5/140 respectively and for the females are A1/1M2/120 respectively.

The most common shade for the maxillary and mandibular central incisors, for males and females, in the age group 35–45 years, using the same order of shade guides are A3/2R2.5/220 and A2/2R1.5/140 respectively (Tables 7, 8, 9, 10, 11, 12).

The most common shade for the maxillary and mandibular central incisors for males and females, in the age group 45 years and above, using the same order of shade guides are A3/2R2.5/220 and A2/2R1.5/140 respectively.

The findings in all the above age groups are similar to the findings carried out in a study by Smith and Wilson [32]. The variation in results can be explained by the fact

Table 7 The most common shade for the maxillary incisors in males

	15–25 years	25–35 years	35–45 years	45 years and above
Vita Lumin	A2 (56 %)	A3 (36 %)	A3 (40 %)	A3 (38 %)
Vita 3D	2R1.5 (62 %)	2R2.5 (40 %)	2R2.5 (48 %)	2R2.5 (38 %)
Chromascop	140 (48 %)	220 (26 %)	220 (42 %)	220 (36 %)

Table 8 The most common shade for the maxillary incisors in females

	15–25 years	25–35 years	35–45 years	45 years and above
Vita Lumin	A2 (42 %)	A3 (34 %)	A3 (38 %)	A3 (32 %)
Vita 3D	2R1.5 (42 %)	2R2.5 (38 %)	2R2.5 (42 %)	2R2.5 (34 %)
Chromascop	140 (42 %)	140 (30 %)	220 (38 %)	220 (30 %)

Table 9 The percentage of shade variation in maxillary and mandibular teeth in males

	15–25 years	25–35 years	35–45 years	45 years and above
Vita Lumin	78 %lighter 82 % lighter	90 % lighter 10 % same	88 % lighter	100 % lighter
Vita 3D	82 %lighter 86 % lighter	92 % lighter 8 % same	86 % lighter	100 %lighter
Chromascop	78 %lighter 84 % lighter	92 % lighter 8 % same	88 % lighter	100 % lighter

Table 10 The percentage of shade variation in maxillary and mandibular teeth in females

	15–25 years	25–35 years	35–45 years	45 years and above
Vita Lumin	74 %lighter	90 % lighter	90 % lighter	100 % lighter
Vita 3D	78 %lighter	92 % lighter	92 % lighter	100 %lighter
Chromascop	76 %lighter	92 % lighter	90 % lighter	100 % lighter

Table 11 Statistical significance of shade variation in different age groups using the different shade guides

	15–25 years	25–35 years	35–45 years	45 years and above
Vita Lumin	$p = 0.13617$	$p = 0.17167$	$p = 0.52396$	$p = 0.27372$
Vita 3D	$p = 0.08483$	$p = 0.03621$ (significant)	$p = 0.22763$	$p = 0.55387$
Chromascop	$p = 0.06765$	$p = 0.02045$ (significant)	$p = 0.64826$	$p = 0.483$

Table 12 Percentage of the most commonly selected shades for the maxillary central incisor by Dentists in Karnataka

Shades	(%)
A1	13
A2	27
A3	25
A3,5	17
B1	5
B2	5
B3	5
C1	1
C2	2

Results taken from a commercial laboratory in Bangalore using the Vita Lumin shade guide on a sample of 400 subject selected randomly

that color perception is an individual phenomenon and it varies with the quality and quantity of light, color of the surroundings, observer and the object.

A parallel study was conducted to assess the most common shades and shade guides used in commercial laboratories in Bangalore. Out of 1,000 samples, 400 were randomly selected and the shades studied. The results were in conformity with those obtained in the study. However the commercial laboratory used only the Vita Lumin shade guide, and the other shade guides were not used.

The results also indicate that teeth darken as age advances with A2/2R1.5/140 being the most frequently seen shades for males and females in the age group 15–25 years whereas A3/2R2.5/220 being the most commonly seen shade for males and females in the age group 45 years and above. These findings are in confirmation with previous studies carried out by Young et al. [33].

The results also suggest that mandibular teeth are lighter as compared to the maxillary teeth. With the Vita Lumin shade guide 87.75 % of the subjects had lighter mandibular

incisors as compared with the upper, 89.50 % had lighter mandibular incisors with Vita 3D Master and 87 % had lighter mandibular incisors with the Chromascop shade guide.

Although generally males had darker teeth as compared to females, the study did not show any statistically significant correlation between shade differences in both the sexes, therefore gender as a basis for shade selection is not suggested. These findings are in confirmation with previous studies carried out by Young et al. [33].

Among the three shade guides the Vita 3D was found to be the most reliable, since it had a wide range and uniformly arranged shade tabs. However its reliability could not be confirmed clinically, because the Vita 3D Master was not the standard shade guide in commercial laboratories in Bangalore at the time of the study. Further investigations regarding the standardization of the study needs to be carried out, as color perception by an individual observer can be both tricky and elusive, especially if the ocular apparatus of the observer has not been checked for color vision deficiencies.

Emphasis has to be laid on the light source while handling color matching problems. Metamerism is the "monster" in color matching that caused a seemingly accurate color match to disappear when the conditions under which the original match was observed are changed. Therefore color matching under different light sources needs to be recommended. All visual assessment of shades needs to be confirmed spectrophotometrically if a more closer and accurate color match is to be affected. Further investigations pertaining to this discipline of Prosthodontics needs to be conducted so as to constantly challenge ambiguity regarding current concepts.

Summary and Conclusion

Color is a complex interaction of light source, object and observer, and therefore is not an exact science. Fine color discrimination is required in shade selection and there is a necessity for color correlation between the dentist and the dental laboratory for accurate prosthetic reproduction.

A study was undertaken to evaluate the most suitable shade for the maxillary and mandibular incisors from the shade guides for the different age groups and gender. An attempt was also made to assess the shade variations between the maxillary and mandibular incisors.

The conclusions that were drawn from the study were that the most common shade for the maxillary and mandibular incisors in the younger age group is A2/2R1.5/140 and A1/1M2/120 for the males and females using Vita Lumin, Vita 3D Master and Chromascop shade guides respectively. In the advanced age group the most common shade for the maxillary and mandibular incisors is A2/2R2.5/140 using the same order of shade guides. Although generally males had darker teeth as compared to females the study showed no statistical significant correlation between shade differences in both the sexes. It is also observed that there is a significant darkening of teeth as the age advances. The study found that the Vita 3D Master had the greatest variety of shades with the variations between subsequent shade tabs being very subtle.

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