Incisal Translucency of Vital Natural Unrestored Teeth: A Clinical Study

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ABSTRACT

Introduction: Understanding the distribution of incisal translucency will provide clinicians a guide to use this knowledge to improve the esthetic replication of anterior restorations. The aim of this study is to investigate the distribution of incisal translucency of unrestored vital natural maxillary central, lateral, and canine vital teeth from a stratified population in different age, gender, and race.

Materials and Methods: A total of 120 subjects were recruited for this study. Six subjects with equal gender balance from four racial/ethnic groups (White, Black, Asian, and others) were recruited from each of the following age groups: 18 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, and 60 to 85 years. Potential subjects were clinically screened to determine if three specific anterior teeth (maxillary central incisor, lateral incisor, and canine) were non-restored, natural permanent teeth free from external staining or bleaching. A digital imaging and shade analysis device was used to measure tooth translucency.

Results: Statistically significant interaction ($p < 0.001$) was found for the groups. The interaction between race and gender was not statistically significant ($p = 0.485$). However, the interaction between race and age ($p = 0.03$), age and gender ($p = 0.015$), and among age, race, and gender ($p < 0.001$) was found statistically significant according to the analysis of variance test results. The interaction between race and gender was not statistically significant ($p = 0.485$).

CLINICAL SIGNIFICANCE

Understanding the distribution and types of incisal translucency will provide clinicians a guide to use this knowledge to improve the esthetic replication of anterior restorations.

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INTRODUCTION

A smile has been known to be one of the most important interactive communication skills of a person.[1] The ultimate objective of esthetics in dentistry is to create a beautiful smile, with teeth of pleasing inherent proportions to one another, and a pleasing tooth arrangement in harmony with the gingiva, lips, and face of the patient.[2] In addition to value, hue, and chroma, other more subtle secondary optical properties of the tooth exist which can affect the overall appearance of the tooth. During the fabrication of a restoration, the parameters of surface form, color, and translucency need to be replicated to ensure an esthetic anterior crown.[2–4]

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These have been reported to include translucency, opacity, iridescence, surface gloss, and fluorescence.[5] Translucency and opacity have been viewed as the most important of these secondary properties, because these are indicators of the quality and quantity of light reflection.[6] The cervical regions have been shown to have the lowest translucency.[7] Iridescence produces a rainbow effect within the object being viewed. Varying degrees of iridescence can be observed depending on the direction, location, and illumination of an object and are dependent on the wavelengths of dispersion, diffraction, and interference of light. Surface gloss affects the appearance and vitality of teeth.[5] Light reflected from tertiary anatomy on the labial surface of anterior teeth adds to vitality, whereas less vitality is evident when this anatomy is worn with age. The tooth surface morphology affects the amount and type of reflection—a rough or coarse surface allows more diffuse reflection, whereas a flat, smooth surface allows more specular reflection. For example, the amount of light reflection at tooth enamel surfaces in vivo following toothbrushing has been shown to significantly increase.[8]

Obtaining proper incisal translucency is important to ensure esthetic replication of anterior restorations. The incisal translucency of a tooth is determined by observing the incisal area of the anterior tooth to which the anterior crown is to be replicated. It has been reported[9] that incisal translucent layers have various patterns in Japanese population. The maxillary central incisors of 213 males and females in various age groups were illuminated under natural and artificial lights, and the patterns of translucent layers were sketched by way of visual observation. The patterns were classified into three main categories. Type A included teeth which had no clear distribution pattern of the translucent layer or showed translucency evenly over entire surface. Type B included teeth which had a translucent layer only in the incisal portion, subdivided into seven subgroups. Type C included teeth which had translucent layers at both proximal and incisal portions, subdivided into eight subgroups.[9]

Translucency can be evaluated by both visual observation and digital devices which use color-matching procedures. Currently, there are several electronic shade-matching instruments available for clinical use. These devices can be classified as spectrophotometers, colorimeters, digital color analyzers, or combinations of these. ShadeScan (Cynovad, Montreal, Canada) is one of the measuring devices for this purpose. This device is the first product introduced that combines digital color image technology with colorimetric analysis to aid in dental shade specification. The device is handheld and has a color liquid crystal diode (LCD) screen that controls the image location and focus. The device supplies its own bright halogen light source, which is carried to the image surface through a fiber-optic cable and continuously monitored and adjusted to maintain a constant intensity through a feedback loop. The device is self-calibrated against standards that include not just gray, but several colors that are located on the inside of the light shutter. The multiple color calibration ensures that the color reproduction is consistent over time. The measuring geometry is 45/0, and the illuminance level is high enough to overwhelm any stray ambient light; therefore, it can be used under any lighting conditions. The digital information may be downloaded to a computer, where the included software performs simple shade and translucency mapping.[10]

Restorations must be reproduced carefully, as they result in the most remarkably observed variations in shade or patterns of translucent layers in natural teeth.[11] Therefore, knowledge of human tooth translucency and its distribution is critical to replicating an esthetically pleasing anterior restoration.

To date, the use of appropriate color measuring instrumentation to measure distribution of incisal translucency of vital natural teeth in different age, gender, and racial groups has not been published. Therefore, the purpose of this descriptive study was to investigate the translucency of vital teeth in a convenience sample of a population that was stratified into five age groups and four racial categories.

MATERIAL AND METHODS

Human subject approval was obtained from The Ohio State University Institutional Review Board

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(#2003H0001 as of 19 June 2003). A total of 120 human subjects over the age of 18 years were recruited through notices posted around the University's Health Science Campus. Six subjects with equal gender balance (three men and three women) from four ethnic groups (White, Black, Mongol/Pacific Islander, and others, which included Middle Eastern/Indian and American Indian/Alaskan Native) were recruited into each of the following five age groups: 18 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, and 60 to 85 years. Potential subjects responded to the advertisements posted near The Ohio State University Medical Center by calling the clinical research laboratory and were screened using a telephone screening form. This screening process ensured that potential subjects satisfied the inclusion and exclusion criteria for this study. The inclusion criteria included generally healthy subjects between the ages of 18 and 85 years of age, presence of at least one maxillary central incisor, maxillary lateral incisor, and maxillary canine, willingness to brush their teeth for 3 minutes prior to color measurement and to spend approximately 1 hour for this study, sign informed consent and Health Insurance Portability & Accountability Act (HIPAA) forms. The exclusion criteria included subjects with restorations of any type, bleaching (eliminating possibility of any change in tooth color and translucency), extrinsic or intrinsic staining (tetracycline stains or fluorosis), severe attrition resulting in incisal enamel wear, non-vital teeth, spontaneous gingival bleeding, pregnant subjects (eliminating the possibility of any misunderstanding that color measurement instrument may cause any harm to the unborn child), psychiatric, cognitive, or social conditions (alcoholism or drug abuse) that would interfere with giving consent and cooperation.

Subjects that qualified for the study were provided with a toothbrush (Butler GUM, 411 Soft, Sunstar Americas, Inc., Chicago, IL, USA) and toothpaste (Crest, Proctor and Gamble, Cincinnati, OH, USA) and were requested to brush their teeth for 3 minutes.

Measurements of teeth were made with a digital imaging and shade analysis device (ShadeScan) according to the manufacturer's directions. ShadeScan

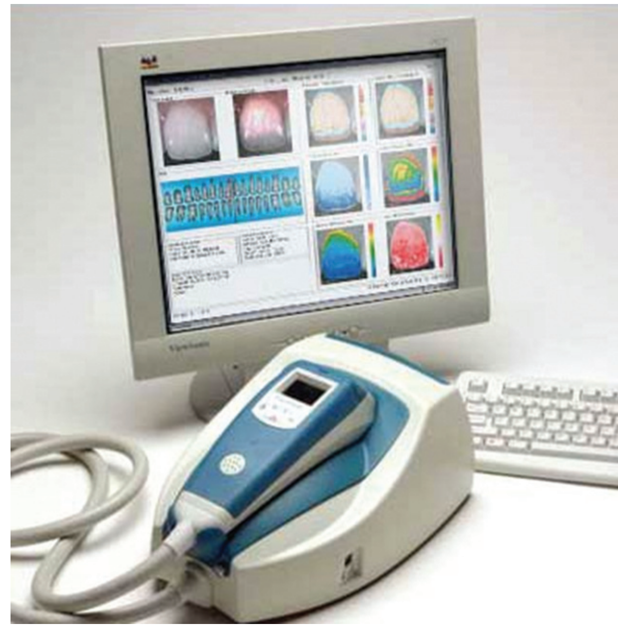

FIGURE 1. ShadeScan (Cynovad, Montreal, Canada) display.

(Figure 1) consists of a handpiece with an LCD screen that seat in a base unit allowing auto-calibration. It contains a halogen light source and utilizes 45/0 measuring geometry. ShadeScan can be used under any lighting condition because the halogen light is bright enough to be unaffected by ambient light.[11,12] The LCD screen was used to align and focus the image of the tooth properly before the image was captured. The digital information was downloaded to a computer, where the included software performs simple shade and translucency mapping, and translucency patterns were classified according to Figure 2.

Statistical evaluation of findings was performed with univariate analysis of variance (ANOVA) and Chi-square test by using SPSS 11.0 software program (SPSS 11.0; SPSS Inc., Chicago, IL, USA). Univariate ANOVA was applied to determine whether there were statistically significant differences.

RESULTS

Unrestored vital maxillary central incisor, lateral incisor, and canine were evaluated three times on each subject. A total of 1,080 measurements were made on

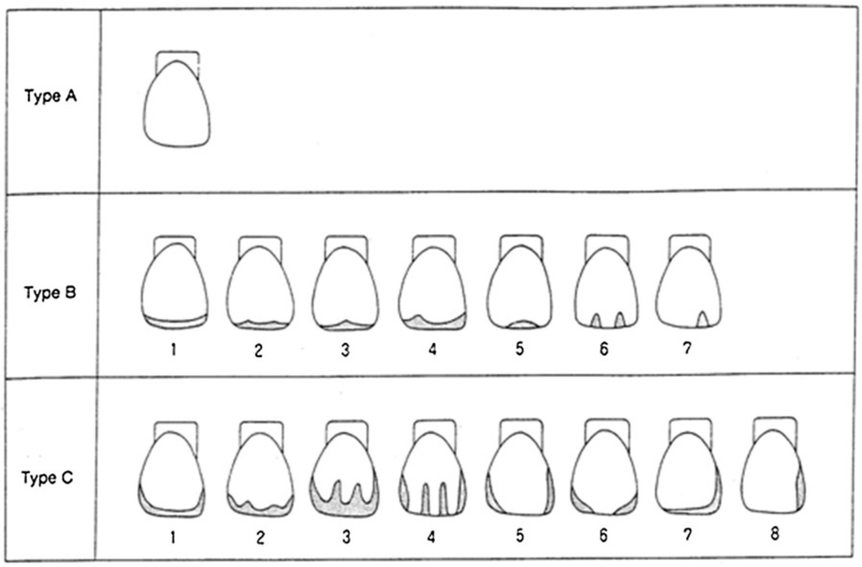

FIGURE 2. Classification of various patterns of translucent layers. Type A: teeth in which distribution of translucent layer is indeterminable and teeth with translucent layer over the entire coronal surface. Type B: teeth having translucent layer only at the incisal portion. Type C: teeth having translucent layer at both proximal and incisal portions.

each of the 120 subjects (Table 1). Results of ANOVA (Table 2) indicated that statistically significant interaction ($p < 0.001$) was found for the groups. The interaction between race and gender was not statistically significant ($p = 0.485$). However, the interaction between race and age ($p = 0.03$), age and gender ($p = 0.015$), and among age, race, and gender ($p < 0.001$) was found statistically significant according to the ANOVA test results (Table 2). Overall, the most common translucency pattern observed was Type C (87%), followed by Type B (10.3%), and Type A (2.7%). The most common translucency subgroup was Type C2 (26.1%), followed by Type C6 (13.9%), and Type C5 (13.7%).

The most common translucency pattern for female subjects was Type C2 (30%), followed by Type C5 (14.5%), and Type C6 (13.4%). For male subjects, the most common translucency pattern was Type C2 (22.2%), followed by Types C6 and C8 (13.3%), and Type C5 (11.6%) (Table 3; Figures 3 and 4).

For subjects aged 18 to 29, Type C2 (7.3%) was the most common translucency pattern. For subjects aged 60 to 85, Types C6 (3.7%) and C8 (3.6%) were the most common translucency patterns, followed by Type C5 (2.7%).

Type A (1.6%) was rarely observed, and Types B4 and C4 were not observed (Table 4). For subjects aged 18 to 29, Type C2 was found in higher percentage compared with other age groups. Types C6 and C8 were associated with an average age of more than 60 years (Table 4; Figure 5).

In terms of race, the most common translucency pattern for Mongol/Pacific Islander subjects was Type C2 (8.6%), followed by Type C3 (4.7%), and Type C5 (3.6%). For Black subjects, the most common translucency pattern was Type C2 (6.2%), followed by Type C5 (3.6%), and Type C6 (2.7%). For White subjects, the most common translucency pattern was Type C2 (5.2%), followed by Type C8 (4.5%), and Type C6 (3.6%). For subjects grouped as others, the most common translucency pattern was Type C2 (6.2%), followed by Type C5 (4.2%), and Type C6 (3.8%) (Table 5; Figure 6).

DISCUSSION

An important consideration is the ability of color measuring instruments to measure tooth color reliably and accurately. Reliability refers to the consistency of the device in matching the same specimen. Accuracy refers to the ability of the device to provide a correct match for a given specimen. Several studies have evaluated various electronic shade-matching devices and compared color-matching accuracy of the devices with that of human observers.[13] Natural teeth have

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TABLE 1. Number of subjects of translucent layer pattern by gender, race, and age

Gender	Translucency category	Race				Total
		Asian	Black	Others	White	
Female	A	—	—	6	15	21
	B1	3	9	—	—	12
	B2	—	3	6	3	12
	B5	—	—	3	6	9
	B6	3	3	3	—	9
	B7	3	—	3	—	6
	C1	—	—	9	9	18
	C2	57	39	33	33	162
	C3	24	27	—	—	51
	C5	15	21	33	9	78
	C6	24	15	15	21	75
	C7	3	12	12	15	42
	C8	3	6	12	24	45
		135	135	135	135	540
Male	A	3	3	—	3	9
	B1	—	3	3	6	12
	B2	—	—	3	9	12
	B3	—	—	—	3	3
	B5	3	—	6	3	12
	B6	—	6	—	—	6
	B7	3	6	3	9	21
	C1	6	—	9	12	27
	C2	36	27	33	24	120
	C3	27	27	3	—	57
	C5	24	18	12	9	63
	C6	12	15	27	18	72
	C7	3	12	24	15	54
	C8	18	18	12	24	72
		135	135	135	135	540

TABLE 2. Analysis of variance results for the groups

Source	Sum of squares	df	Mean square	F-value	Sig.
Corrected model	1,234.79	39	31.661	2.51	0.000
Intercept	138,380.21	1	138,380.208	10,985.91	0.000
Race	48.63	3	16.208	1.29	0.278
Age	94.92	4	23.729	1.88	0.111
Gender	44.41	1	44.408	3.53	0.061
Race * Age	375.08	12	31.257	2.48	0.003
Race * Gender	30.83	3	10.275	0.82	0.485
Age * Gender	156.38	4	39.096	3.10	0.015
Race * Age * Gender	484.55	12	40.379	3.21	0.000
Error	13,100.00	1,040	12.596	—	—
Total	152,715.00	1,080	—	—	—
Corrected Total	14,334.79	1,079	—	—	—

df = degree of freedom; Sig. = significance.

variable surface texture and anatomic variations that may influence shade measurement. The layering effect of enamel over dentin and the varying degrees of translucency of natural teeth likely create more of a challenge. The reliability and accuracy data are useful in comparing these devices in vitro and may predict their performance in a clinical setting. Kim-Pusateri and colleagues[14] tested four shade-matching devices: SpectroShade (MHT Optic Research AG, Niederhasli, Switzerland), ShadeVision (X-Rite America, Inc., Grand Rapids, MI, USA), Vita Easyshade (Vident, Brea, CA, USA), and ShadeScan. Color measurements were made of three commercial shade guides (Vitapan Classical, Vitapan 3D-Master, and Chromascop). Shade tabs were placed in the middle of a gingival matrix (Shofu Gummy, Shofu Dental Corp., Kyoto, Japan) with shade tabs of the same nominal shade from additional shade guides placed on both sides. Measurements were made of the central region of the shade tab positioned inside a black box. For the reliability assessment, each shade tab from each of the three

TABLE 3. Incidence of translucent layer pattern by gender (%)

Translucency category	A	B1	B2	B3	B5	B6	B7	C1	C2	C3	C5	C6	C7	C8
Female	3.9	2.3	2.3	—	1.7	1.7	1.2	3.4	30	9.5	14.5	13.4	7.8	8.3
Male	1.7	2.3	2.3	0.5	2.3	1.2	3.8	5	22.2	10.5	11.6	13.3	10	13.3

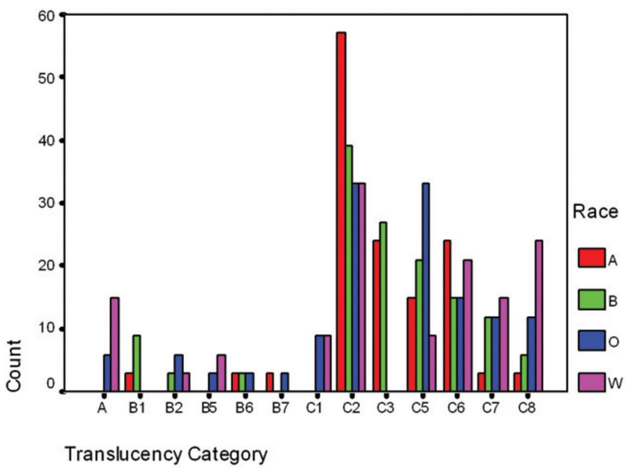

FIGURE 3. Incidence of translucent layer pattern by gender: female. A = Asian; B = Black; O = others; W = White.

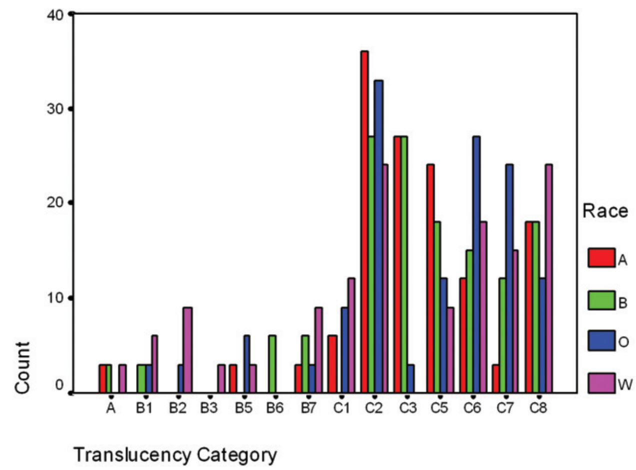

FIGURE 4. Incidence of translucent layer pattern by gender: male. A = Asian; B = Black; O = others; W = White.

TABLE 4. Incidence of translucent layer pattern by age (%)

Translucency category	Age					Total
	18–29	30–39	40–49	50–59	60–85	
A	0.3	—	0.6	0.4	1.6	2.9
B1	—	0.3	1.6	0.3	—	2.2
B2	0.3	1.2	0.2	—	0.6	2.3
B3	—	—	—	0.2	—	0.2
B5	—	—	—	0.8	1.1	1.9
B6	—	—	—	0.8	0.5	1.3
B7	—	0.2	0.3	—	1.9	2.4
C1	1.6	—	1.1	0.2	1.1	4
C2	7.3	6.9	5.4	5.5	1.1	26.2
C3	3.8	3.6	1.6	0.9	—	9.9
C5	1.9	3.4	2.7	2.3	2.7	13
C6	2.3	1.7	2.6	2.8	3.7	13.1
C7	1.4	1.2	2.3	2.5	1.9	9.3
C8	1.2	1.7	1.8	3	3.6	11.3

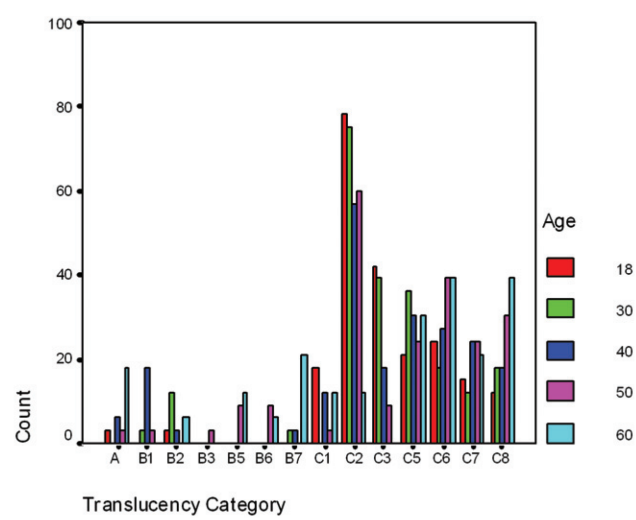

FIGURE 5. Incidence of translucent layer pattern by age.

shade guide types was measured 10 times. For the accuracy assessment, each shade tab from 10 guides of each of the three types evaluated was measured once. Most devices had similar high reliability (over 96%), indicating predictable shade values from repeated measurements. However, there was more variability in

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TABLE 5. Incidence of translucent layer pattern by race (%)

Translucency category	Race				Total
	Asian	Black	Other	White	
A	0.3	0.3	0.5	1.7	2.8
B1	0.3	1.1	0.3	0.6	2.3
B2	—	0.3	0.8	1.1	2.2
B3	—	—	—	0.3	0.3
B5	0.3	—	0.8	0.9	2
B6	0.3	0.8	0.3	—	1.4
B7	0.6	0.6	0.6	0.8	2.6
C1	0.5	—	1.8	1.9	4.2
C2	8.6	6.2	6.2	5.2	26.2
C3	4.7	5	0.2	—	9.9
C5	3.6	3.6	4.2	1.6	13
C6	3.4	2.7	3.8	3.6	13.5
C7	0.5	2.2	3.3	2.7	8.7
C8	1.9	2.2	2.3	4.5	10.9

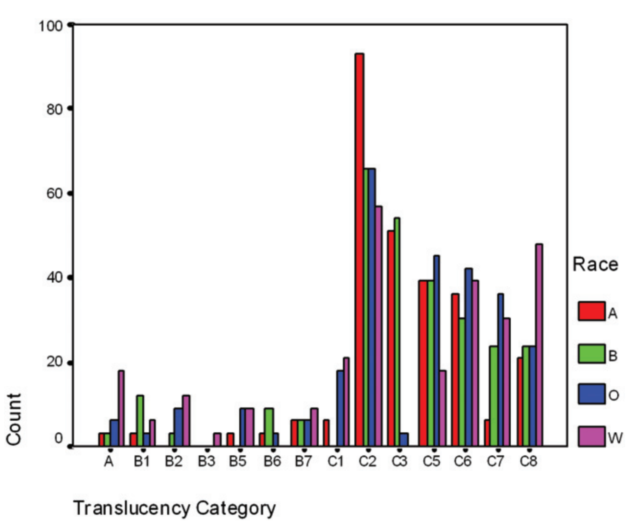

FIGURE 6. Incidence of translucent layer pattern by race. A = Asian; B = Black; O = others; W = White.

accuracy among devices (67–93%), and differences in accuracy were seen with most device comparisons. It was reported that the reliability of the ShadeScan was 87.4% and the accuracy of devices was found to be 66.8%.

This study showed that Type C2 was the most commonly observed translucency pattern for subjects aged 18 to 59 years and Type C6 was the most commonly observed translucency pattern for subjects aged 60 to 85 years. Older subjects were more likely to have teeth with lower translucency. Several studies have shown that the aging process has a profound effect on the shade of teeth, in that teeth became darker and less translucent with age.[15,16] The translucency of natural teeth has been shown to decrease from the incisal toward the central region.[7]

Changes in color or translucent pattern of the natural teeth with aging are generally attributed to an increase in translucency of the enamel layer, change in the dentin layer, staining, and discoloration. As the enamel becomes more calcified with aging, these structures gradually fill with crystals, resulting in a nonstructural substance. In younger people, the incident light contacting the enamel surface is diffused and strongly scattered by hydroxyapatite and other structures, such as enamel rods, cuticles, and stromata, with different refractive indices. As a result, teeth seem relatively less translucent and whiter. When the enamel layer becomes more translucent, the shade of the underlying layers, such as the dentinoenamel junction and dentin, is more easily reflected to the surface of a tooth. This is the main reason why color in the natural teeth changes with aging.[9]

If the natural teeth are to be reproduced in ceramo-metallic or all ceramic systems, differences between age groups, quadrants, sex, teeth, and locations, in terms of shade and pattern of translucent layer, should be taken into consideration to obtain an esthetically pleasing matching anterior crown. The change in the translucent pattern probably occurs based on the extension of translucent layer in the enamel. Calcification in the superficial layer of the enamel generally is most remarkable at the incisal edge and cusps. Therefore, these areas are often highly translucent. The translucency pattern for Type B1, which has a translucent layer only at the incisal edge, may be due to thin tooth structure in this region. Type C has a translucent layer extending to the proximal surface that increases with aging. It has been

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reported that an increase in the incidence of Type A may be due to attrition of enamel in the incisal region and loss of the translucent layer over the entire structure. Type C5 which has a highly translucent layer in the proximal surface and the other groups of the Type C which have translucent layers both at the proximal and incisal portions may be the result of attrition of the enamel structure in the incisal region, as well as abrasion of the enamel surface on the labial surface. The thin enamel layer resulting from abrasion will make the form of the dentin more transparent and give us a perception as if the translucency at the proximal region increased. In addition, attrition at the incisal edge will change the incisal dentin into a more translucent, harder dentin structure. Types C2 and C3 will result if attrition is insignificant and enamel structure become more translucent. It has been previously reported that Type A was commonly seen in subjects in their 40s, with a relatively high incidence in other age groups as well. Type B decreased with aging, from 40% in children and teenagers, 34% in subjects in their 20s, 21.1% in subjects in their 30s, and 10% in subjects in their 40s. In contrast, Type C increased with aging, from 40% in children and teenagers, 36% in subjects in their 20s, 50% in subjects in their 30s, and 57.9% in subjects in their 40s. It was indicated that translucency increases in the proximal portion with aging.[9]

The present study demonstrated that the overall incidence of translucency in Type C2 was 26.1%, followed by 13.9% in Type C6, and 13.7% in Type C5. The sum of these three types is 87% in Type C, 10.3% in Type B, and 2.7% in Type A. The most commonly observed translucency pattern were in Type C2 for all races, 8.6% for Mongol/Pacific Islander, 6.2% for Black people, 5.2% for White people, and 6.1% for the others. In addition, Type C2 (7.3%) was the most commonly observed translucency pattern in subjects aged 18 to 29 years and Type C6 (3.7%) was the most commonly observed translucency pattern in subjects aged 60 to 85 years, followed by Type C8 (3.6%). This study demonstrates that the aging process has a profound effect on the translucency of teeth, in that teeth become less translucent with age. Calcification proceeds with aging in the dentin and increased translucency. This, together with an increase in translucency of the enamel, increases the transmission of light through the entire tooth. This is responsible for the low value of the teeth in older people.

In dental ceramics, it is important that ceramists imitate the appearance of the tooth as a sum of its entire visual dimension. Human teeth are characterized by varying degrees of translucency, which can be defined as a gradient between transparent and opaque. Generally, increasing translucency of a crown lowers its value. With increased translucency, light is able to pass the surface and is scattered within the body of porcelain. The translucency of enamel varies with the angle of incidence, surface luster, wavelength, and level of dehydration. With a translucent enamel layer, the ceramist achieves color depth and the illusion of a natural tooth.[17] Further evaluation of translucency of teeth in different human populations may provide useful information and a comparison can be made with the result of the present study.

CONCLUSION

Within the limitation of this study, the following conclusions can be drawn:

1. Overall percentage incidence was 26.1% in Type C2, followed by 13.9% in Type C6, and 13.7% in Type C5.
2. Type C2 (7.3%) was the most commonly observed translucency pattern in subjects aged 18 to 29 years and Type C6 (3.7%) was the most commonly observed translucency pattern in subjects aged 60 to 85 years, followed by Type C8 (3.6%).
3. The most commonly observed translucency patterns for females: Type C2 (30%), Type C5 (14.5%), and Type C6 (13.4%); for males: Type C2 (22.2%), Types C6 and C8 (13.3%), and Type C5 (11.6%).
4. The most commonly observed translucency pattern was Type C2 for all races, 8.6% for Mongol/ Pacific Islander, 6.2% for Black people, 5.2% for White people, and 6.1% for the others.
5. The sum of these three types is 87% Type C, 10.3% Type B, and 2.7% Type A.

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6 Aging process has a profound effect on the shade of teeth, in that teeth become less translucent with age. It can be explained as the result of attrition of the enamel structure at the incisal area, as well as abrasion of the enamel surface in the labial aspect.

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