Clinical threshold of the translucency parameter of maxillary central incisors

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The aim of this in vivo study is to describe the clinical threshold and relative factors associated with the translucency of maxillary central incisors. Bilateral maxillary central incisors were measured in 106 individuals using a digital colorimeter against black and white backings. The translucency parameters (TP) of incisors and the difference in TP (ΔTP) between the left and right maxillary central incisors of the same individual was calculated. The mean TP value of the maxillary incisors was 8.22. There was a significant effect of age on the translucency of the maxillary central incisors (p<0.05). The TP of females was higher than that of males (p<0.05). The absolute mean value of ΔTP was 1.33. The ΔTP of the two maxillary central incisors in the same individual can be used as a reference for the threshold value of translucency.

Keywords: Translucency, Clinical threshold, Esthetics, Human incisors

INTRODUCTION

The visual appearance of a prosthesis is of great importance in the field of esthetic dentistry. However, in clinical practice, it is sometimes difficult for a dental prosthesis to simulate the appearance of natural teeth. The complex optical properties of natural teeth might be the main reason for the disharmony of the appearance of the prosthesis. In addition to hue, value and saturation, there are many subtle secondary optical properties of natural human teeth, such as translucency, opacity, iridescence, surface gloss and fluorescence. A growing number of researchers have recognized that the translucency of a prosthesis is extremely important to its esthetic performance. Some scholars have proposed that an emphasis on translucency should be added to the three-dimensional color system to form a new four-dimensional system.

Translucency is the relative amount of light propagating through a turbid medium or the relative amount of light diffusing over the surface of a substrate through a turbid medium. At present, there are three kinds of translucency parameters commonly used in the field of esthetic prosthodontics, including the transmittance (T), contrast ratio (CR), and translucency parameter (TP). Among these three indicators, the TP value is calculated using the CIEDE2000 color difference formula and is generally considered to be more applicable for visual evaluations of translucency. TP refers to the color difference in the translucent material before the black and white backings. Its calculation formula is:

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TP_{\text{CIEDE2000}} = \left( \frac{\Delta L_{\text{B-W}}}{K_{LcS_c}} \right)^2 + \left( \frac{\Delta C_{\text{B-W}}}{K_{CcS_c}} \right)^2 + \left( \frac{\Delta H_{\text{B-W}}}{K_{HcS_c}} \right)^2 + \left( \frac{\Delta L_{\text{B-W}}}{K_{LcS_c}} \right)^2 \\
R^T \left( \frac{\Delta C_{\text{B-W}}}{K_{CcS_c}} \right) \left( \frac{\Delta H_{\text{B-W}}}{K_{HcS_c}} \right)^{1/2},
\]

The TP value of maxillary incisors was measured in the mouth by Hasegawa. The results showed that the range of TP values was 6–15, which was different from that of the VITA shade guide. The TP of 2 mm dentin slices was 5.5 for anterior teeth and 22.1 for molars. The TP of the enamel and dentin slices was 18.7 and 16.4, respectively, when the slice thickness was 1 mm. Clinically, ceramic materials are commonly used in esthetic restorations to simulate the translucent appearance of natural teeth. There are abundant studies concerning dental ceramic translucency. However, due to the lack of sufficient data on the translucency of natural teeth, no study has been conducted to compare the translucency of dental ceramics to that of natural teeth. Therefore, it is necessary to enrich the research data on the translucency of natural teeth.

When comparing the color of ceramic restorations with natural teeth, the threshold for color difference (ΔE) is used to identify whether the difference in the color is noticeable. The main purpose of a color difference threshold is to achieve the greatest agreement between the resulting shade from the smallest color difference and the visual judgments of average observers. Due to the lack of a corresponding aberration standard, it cannot be determined whether a prosthesis has successfully simulated the translucency of natural teeth. Liu et al. reported that the average threshold of CR was ΔCR=0.07. Xiong et al. discovered in their study that the resolution threshold of transmittance (ΔT) ranges between 1% and 3%. However, there is currently no related research on the clinical threshold of the TP.
value.

Therefore, the aim of this study was to identify an acceptability threshold for differences in translucency and to describe the distribution and relative factors associated with the translucency of vital human maxillary incisors.

MATERIALS AND METHODS

A total of 106 human subjects over the age of 18 years were recruited. The subjects were distributed into three age groups: young (18-39 years), middle-aged (40-60 years), and senior (>60 years), with a nearly balanced gender distribution. The final division is shown in Table 1. The inclusion criteria included generally healthy subjects over 18 years of age and the presence of both central incisors (vital and nonrestored). The exclusion criteria included subjects with restorations of any type, bleaching, extrinsic or intrinsic staining (tetracycline stains or fluorosis), severe attrition resulting in incisal enamel wear, nonvital teeth, and spontaneous gingival bleeding. The study was approved by the Institutional Review Board of the college (WCHSIRB-D-2017-025).

Measurements of teeth were made with a VITA Easyshade Advanced 4.0 (VITA Zahnfabrik H. Rauter, Bad Säckingen, Germany) according to the manufacturer’s directions. Easyshade is a spectrophotometer consisting of a probe, a signal conditioner and software and is a spot measuring instrument. Easyshade can be used under any lighting condition because the incident light conducted by the optical fiber is bright enough to be unaffected by the environment.

The teeth were cleaned before the test by using a handpiece and silicone polishing tips (SHOFU, Kyoto, Japan) for 1 min. After adjusting the white balance according to the manufacturer’s direction, the Easyshade probe was placed on the labial surface of the right central incisor. To ensure the repeatability of the measurement, the location of the probe was determined as follows: A measuring stop made by transparent acrylic resin was attached to the probe as shown in Fig. 1. The width of the incisor edge was measured, and the central point was marked. During measurement, the probe contacted the labial surface of the incisor with the measuring stop contacting the central point of the edge (Fig. 1). This ensured that the margin of the probe was 0.5 mm from the edge of the incisor.

CIELab color space of the incisor crowns were measured against white and black paper backings. Three coordinates $L^*$, $a^*$ and $b^*$ of CIELab color space were recorded. The backings used in this study were photographic background papers. The color of the backings was measured by a spectrometer PG2000-Pro (Shanghai Ideaoptics, Shanghai, China). It is considered that optical contact between the incisor and the backings should be made to eliminate the internal reflection. However, optical contact was not obtained in this intraoral study due to the paper backings and the irregular shape of the lingual surface of the incisor. To reduce the error, 3 measurements were repeated on each background, and the averages were calculated. The color difference before black and white backings for each tooth was calculated using the CIEDE2000 color difference formula mentioned above.

The difference in the translucency parameter ($\Delta TP$) between the left and right maxillary central incisors of the same individual was calculated by using the following formula: $\Delta TP = |TP_{11} - TP_{21}|$, where the subscript 11 denotes the right maxillary central incisor and the subscript 21 represents the left maxillary central incisor. The absolute values of $ATP$ were used because there was no need to distinguish which TP was higher.

Statistical evaluation of the findings was performed with univariate analysis of variance (ANOVA) and LSD comparison by using the SPSS 18.0 software program (SPSS, Chicago, IL, USA).

RESULTS

The average color coordinates of the backings used in

![Fig. 1](image-url)  
Fig. 1 Photograph of the relative position between the tooth crown and probe during measurement.  
P: Easyshade probe; S: measuring stop; B: backings

| Table 1 Numbers of subjects in each group |
|------------------------------------------|
| Young | Middle-aged | Senior | Total |
|-------|-------------|--------|-------|
| Male  | 18          | 19     | 15    | 52    |
| Female| 20          | 18     | 16    | 54    |
| Total | 38          | 37     | 31    | 106   |
this study were as follows: $L^* = 97.1; a^* = -5.9; b^* = -6.9$ (for the white backing); $L^* = 28.9; a^* = -2.2; b^* = -1.8$ (for the black backing).

$L^*, a^*, b^*$ of the unrestored vital maxillary central incisors were measured before black and white backings three times on each subject. TP values were calculated. A total of 1,272 measurements were made on each of the 106 subjects.

The statistical descriptions of $L^*, a^*, b^*$ and TP for different groups are shown in Tables 2 and 3. The results of ANOVA (Table 4) indicated statistically significant differences among age groups and gender groups ($p < 0.05$). The interaction between age and gender groups was not statistically significant according to the ANOVA test results (Table 4). The mean value for the TP of females was 8.73, which was significantly higher than the TP of males ($p < 0.05$).

For the age groups, multiple comparisons indicated statistically significant differences between young and middle-aged as well as middle-aged and senior subjects ($p < 0.05$, Table 5). TP of the young group was 8.56, which was higher than that for the middle-aged group (7.57). The TP of the senior group (8.58) was also higher than that of the middle-aged group. No significant difference was found between the young and senior groups.

A boxplot of $\Delta TP$ between the left and right maxillary

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**Table 2**  TP and $L^*a^*b^*$ values of age and gender groups

|       | TP     | $L^*_B$ | $a^*_B$ | $b^*_B$ | $L^*_W$ | $a^*_W$ | $b^*_W$ |
|-------|--------|---------|---------|---------|---------|---------|---------|
| Young | 8.56   | 69.67   | -0.46   | 14.84   | 79.87   | 0.81    | 18.68   |
|       | (2.73) | (7.69)  | (1.01)  | (3.31)  | (7.76)  | (1.00)  | (3.53)  |
| Middle-aged | 7.57 | 71.04   | -0.10   | 15.39   | 81.13   | 1.03    | 19.02   |
|       | (1.58) | (5.44)  | (1.21)  | (2.10)  | (5.43)  | (1.15)  | (2.26)  |
| Senior | 8.58  | 71.30   | -0.30   | 16.55   | 81.86   | 0.68    | 21.00   |
|       | (1.85) | (3.83)  | (1.49)  | (5.34)  | (3.96)  | (1.40)  | (4.36)  |

**Table 3**  Statistical description of TP and $\Delta TP$ of upper central incisors

|       | Mean (Std. Dev.) | 95% Confidence interval for the mean | Minimum | Maximum |
|-------|-------------------|-------------------------------------|---------|---------|
|       |                   |                                     | Lower bound | Upper bound |
| TP    | 8.22 (2.24)       |                                      | 7.91     | 8.52    | 2.00  | 19.24  |
| $\Delta TP$ | 1.33 (1.12)   |                                      | 1.11     | 1.54    | 0.00  | 5.06   |

**Table 4**  Analysis of variance results for the groups

| Source             | Sum of squares | df  | Mean square | F-value | Sig.  |
|--------------------|----------------|-----|-------------|---------|-------|
| Corrected model    | 108.447        | 5   | 21.689      | 4.687   | 0.000 |
| Intercept          | 13,386.229     | 1   | 13,386.229  | 2,892.811 | 0.000 |
| Gender             | 39.461         | 1   | 39.461      | 8.528   | 0.004 |
| Age                | 31.334         | 2   | 15.667      | 3.386   | 0.036 |
| Gender*Age         | 22.316         | 2   | 11.158      | 2.411   | 0.092 |
| Error              | 953.247        | 206 | 4.627       | —       | —     |
| Total              | 15,374.369     | 212 | —           | —       | —     |
| Correct Total      | 1,061.694      | 211 | —           | —       | —     |
central incisors is shown in Fig. 2. The mean $\Delta TP$ was 1.33 with a 95% confidence interval from 1.11 to 1.56.

**DISCUSSION**

Maxillary central incisors are the most influential teeth with respect to facial appearance and are the largest of the anterior teeth, which makes them convenient for carrying out various measurements and studies. Among the various factors affecting the appearance of maxillary central incisors, translucency is also an important parameter in addition to the color parameters $L^*$, $a^*$, and $b^*$. In particular, a clear transparent layer appears in the incisal edge of the maxillary central incisors of nearly 97.3% of individuals\(^{25}\). In this experiment, the mean TP value of the maxillary central incisors was 8.22, and the range of the 95% confidence interval was 7.91–8.52, which was consistent with the existing research data. Hasegawa *et al.* found that the TP value of maxillary central incisors was 6–15\(^{12}\).

In this experiment, the range distribution of TP was narrow. However, an extreme maximum and minimum (19.24 and 2.00, respectively) existed. This finding might indicate that the translucency of anterior teeth is similar in most individuals, and a good esthetic effect could be obtained by conventional restorations. However, a few individuals presented a particularly obvious translucent effect in their maxillary central incisors or, at the other extreme, the lack of a transparent layer. In such situations, a satisfactory esthetic effect would not be achieved if not enough attention is given.

Age has a significant effect on the translucency of maxillary central incisors. In this study, the translucency of the young group was higher than that in the middle-aged group, which could be because the enamel at the incisal edge of the young maxillary central incisors had not been worn out and there was a clear transparent layer. Clinically, it is often found that there is obviously transparent enamel in the central incisors of young people. Furthermore, the translucency in the senior group was higher than that in the middle-aged group, which might be related to the reduction in the incisal edge thickness of the central incisors\(^{26}\). At the same time, the dentin also displayed an increasing trend of translucency with age\(^3\), which also led to the increase in translucency in the central incisors.

Gender also had an important influence on the translucency of maxillary central incisors. The mean TP of females was higher than that of males in this study. The cause of this phenomenon might be that the thickness of the buccolingual diameter of the maxillary central incisors was less in females than in males\(^{27}\). The smaller the thickness of the buccolingual diameter, the greater was the translucency. The above results suggest that much attention should be paid to female patients undergoing anterior esthetic restoration to achieve a good translucency effect.

In general, it is believed that healthy maxillary central incisors are symmetrical, that is, under the circumstance of gross appearance, except for exogenous factors, two maxillary central incisors of the same individual should have the same shape, color and translucency. However, when an instrument is used for measurement, it is found that teeth of a symmetrical occlusal type have different colors and translucencies in the same individual. This shows that the resolution of

| (I) Age | (J) Age | Mean difference (I–J) | Std. error | Sig. |
|--------|--------|----------------------|------------|-----|
| Youth  | Middle | 0.987*               | 0.359      | 0.006 |
| Youth  | Senile | −0.987*              | 0.359      | 0.006 |
| Senile | Middle | −0.778*              | 0.390      | 0.047 |

*The mean difference is significant at the 0.05 level.

![Boxplot of $\Delta TP$ between left and right maxillary central incisors.](image)

The sign “o” denotes mild outliers. The horizontal line indicates the mean value of $\Delta TP$. 

Fig. 2  Boxplot of $\Delta TP$ between left and right maxillary central incisors.
human vision is limited to a certain extent and cannot reach the accuracy of instruments. Therefore, the concept of the threshold for color difference is established. When the color difference between the two objects is smaller than the threshold for color difference, it is thought that this difference cannot be perceived by human vision, and it can be assumed that the two objects have the same color. Consequently, the threshold for color difference is widely used in dental clinic practice and research. Nevertheless, the corresponding threshold standard has not been established to date with respect to translucency. In the present study, the TP value of the two maxillary central incisors was measured in the same individual, and the difference between the TP was calculated at the same time. The mean value of ΔTP was 1.33. The experimental subjects were all healthy maxillary incisors, and there was no visible difference between the left and right maxillary central incisors, which were considered to have the same translucency by visual inspection. If the difference in the translucency between the prosthesis and natural teeth was not more than the difference between natural teeth, a good prosthetic effect could be obtained. Therefore, the ΔTP value of the left and right maxillary central incisors could be used as a reference value for the threshold of translucency, thus guiding the fabrication of clinical prostheses.

CONCLUSIONS

Under our experimental conditions, the 95% confidence interval for the TP of maxillary central incisors is 7.91–8.52. Both age and gender have a significant effect on the translucency of maxillary central incisors. The middle-aged group has the lowest translucency, and the difference between the TP was calculated at the same time. The mean value of ΔTP was 1.33. The experimental subjects were all healthy maxillary incisors, and there was no visible difference between the left and right maxillary central incisors, which were considered to have the same translucency by visual inspection. If the difference in the translucency between the prosthesis and natural teeth was not more than the difference between natural teeth, a good prosthetic effect could be obtained. Therefore, the ΔTP value of the left and right maxillary central incisors could be used as a reference value for the threshold of translucency, thus guiding the fabrication of clinical prostheses.

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