THE EFFECT OF THICKNESS OF THE PROVISIONAL CROWN AND FIXED PARTIAL DENTURE MATERIALS ON THE TRANSLUCENCY AND MASKING EFFECT

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Statement of problem. Translucency and masking effect of provisional crown and fixed partial denture materials is an important esthetic consideration. But, provisional resin materials differ substantially in their ability to mask underlying colors.

Purpose. The purpose of this study was to evaluate the translucency differences of provisional resin materials at various thicknesses and the correlation between the translucency and the masking efficiency.

Material and methods. Two polymethyl methacrylate resins (Jet Tooth Shade, Alike) and three resin composites (Protemp 3 Garant, Luxatemp and Revotek LC) were used. Specimens (n=6) were fabricated from each material in 0.3, 0.5, 0.8, 1.0, 1.5, 2.0 and 3.0 mm thickness. The CIELAB parameters of each specimens were measured using a spectrophotometer. The translucency parameter (TP) values and the masking effect (ΔME^*_{ab}) values were computed and all data were statistically analyzed by one-way ANOVA and the multiple comparisons Scheffe test. The correlation between the thickness and the TP values and the correlation between the thickness and the ΔME^*_{ab} values were also evaluated by correlation analysis and regression analysis.

Results. The TP values and the ΔME^*_{ab} values were significantly related to the thickness in all specimens. The TP values were more sensitive to the change of thickness than the ΔME^*_{ab} values. The order of the translucency by brand was different from the order of the masking effect by brand in all thickness groups.

Conclusion. Within the limitations of this study, the translucency and masking effect of the provisional resin materials investigated were significantly related to their thickness. The masking effect of provisional resin was correlated with the translucency parameter, but the order of the masking effect by brand was different from the order of the translucency parameter.

Key Words

Provisional crown and fixed partial denture materials, Translucency, Masking effect

Provisional crown and fixed partial dentures (FPDs) are an important part of many prosthodontic treatment procedures.[1,2] The provisional restoration materials not only should satisfy mechanical requirements such as strength and resistance to wear, but must meet biologic and esthetic needs as well.[3,4] Although all of these requirements are important, esthetics is of prime importance to the patient when the provisional restoration is in the esthetic zone.[5]

Since human enamel has inherent translucency, esthetic restorations, such as dental ceramic and composite resin, should reproduce the translucency of natural teeth.[6,7] Likewise, the translucency of provisional materials could be of concern. The provisional restoration with the translucency of natural teeth would have lifelike appearance if the teeth have no discoloration or metallic cores. But clinically, the translucency of provisional materials may sometimes provide relatively poor color matches. Especially, a grayish shade is often seen because the provisional restorations are probably affected by the darkness of the oral cavity,[8] metal core,[9] and metal cylinder of temporary dental implant prostheses.[10] Opaque temporary cement also can be seen through the thin provisional restorations. Therefore, the choice of an provisional crown and fixed partial denture material could hinge on its ability to mask discoloration from an esthetic point of view.

Researchers have evaluated the translucency of esthetic restoration materials. However, there has been no study yet of the translucency of provisional crown and fixed partial denture materials. Changes in the thickness of dental materials influence the translucency.[11-14] Therefore an understanding of these effects on the translucency of provisional restoration materials is needed to improve esthetics. The purposes of this study were: (1) to evaluate the translucency differences of resin provisional restorative materials at various thicknesses, and (2) to evaluate the correlation between translucency and masking efficiency.

MATERIAL AND METHODS

A. Material

Two acrylic resin and three resin composite provisional restorative materials were evaluated. The acrylic resins were Jet Tooth Shade (Lang Dental, Wheeling, IL, USA) and Alike (GC, Tokyo, Japan) and the resin composites were Protemp 3 Garant (3M ESPE, Seefeld, Germany), Luxatemp (DMG, Hamburg, Germany), and Revotek LC (GC, Tokyo, Japan). Shades are not standardized among the various products. The product names, material type, shade, batch numbers, and manufacturers are listed in Table I.

Table I. Experimental materials investigated in this study

Code	Brand	Material Type	Manufacturer	Shade	Lot No.
JT	Jet Tooth Shade	Acrylic resin	Lang Dental, Wheeling, IL, USA	66(A3)	1430-06DS
AL	Alike	Acrylic resin	GC Corp., Tokyo, Japan	67(A3)	612141
PT	Protemp 3 Garant	Resin Composite	3M ESPE, Seefeld, Germany	A3	154758
LT	Luxatemp	Resin Composite	DMG, Hamburg, Germany	A3.5	511597
RV	Revotek LC	Resin Composite	GC Corp., Tokyo, Japan	Universal-B2	505134

B. Preparation of specimens

Six disk specimens were fabricated for each product - thickness combination. Provisional resin was packed into a polytetrafluoroethylene mold of 14 mm in diameter and 0.3, 0.5, 0.8, 1.0, 1.5, 2.0 and 3.0 mm in thickness on an acetate strip. After packing the provisional material, resin-filled mold on a glassplate was covered with an acetate strip and pressed with a glass plate.

The PMMA specimens were fabricated at ambient temperature of 23±1℃ by mixing the polymer and monomer in a clean rubber bowl with a spatula at the 2:1 weight ratio recommended by the manufacturers. When the mix reached the dough stage, it was packed into the mold cavity slowly to avoid entrapment of air, the plastic strip and the glass were placed in position, and the entire assembly was placed in a hand press and compressed for 5 minutes to allow the material to completely flow out of the mold. Then the assembly was polymerized for 30 minutes without hand press. The bis-acrylic specimens were formed in the same manner, except that the material was supplied in an automixing cartridge. Prior to each application, a small amount material extruded from the mixing tip was discarded as recommended by manufacturers. The mix was packed directly into the mold cavity using an application tip supplied with the kit and covered with a transparent acetate strip. The assembly was also pressed down with hands for 5 minutes and polymerized for 30 minutes.

The light-activated materials were packed directly into the mold cavity with the appliances. Specimens were light-cured at five different sites from both sides, each for 20 seconds, using a light-curing unit (Curing Light XL 3000; 3M ESPE America, Norristown, PA, USA) with the intensity of 600 mW/cm^2. After light activation, the assembly was left for 10 minutes for enough polymerization. The acetate strip and glass slides were removed after fabrication of the specimens. Before color measurement, the specimens were stored in distilled water for 24 hours at 37℃.

C. Measurement of color

Color of specimens was measured according to CIELAB color scale, relative to the standard illuminant D65, on a reflection spectrophotometer (CM-3500d, Minolta, Osaka, Japan). The aperture diameter of the measuring port of the reflection spectrophotometer was 8 mm. The illuminating/viewing configuration was CIE diffuse/8° geometry, and standard observer 10 degrees. The specular component of reflection was excluded (SCE mode).

Before each measurement session, the spectrophotometer was calibrated according to the manufacturer' s recommendations by using the supplied zero calibration box and the white calibration standard. Color of the specimens were measured over a white background and a black background. The software used in this study was Spectra-Magic version 1.01 (Minolta, Osaka, Japan). Measurements were repeated three times for each specimen and the values were averaged to get the final reading.

For the evaluation of translucency, translucency paramenter (TP) was calculated by the equation[15],

$$TP=[(L^*_W-L^*_B)^2+(a^*_W-a^*_B)^2+(b^*_W-b^*_B)^2]^{1/2} \quad \cdots\cdots (Eq.\ 1)$$

where the subscript 'W' refers to CIELAB values for each specimen on the white background, and the subscript 'B' refers to the values for specimens on black background.

For the evaluation of masking efficiency, masking effect (ΔME^*_{ab}) was calculated as the color difference (ΔE^*_{ab}) between the black background itself and color specimen over the black background.[16]

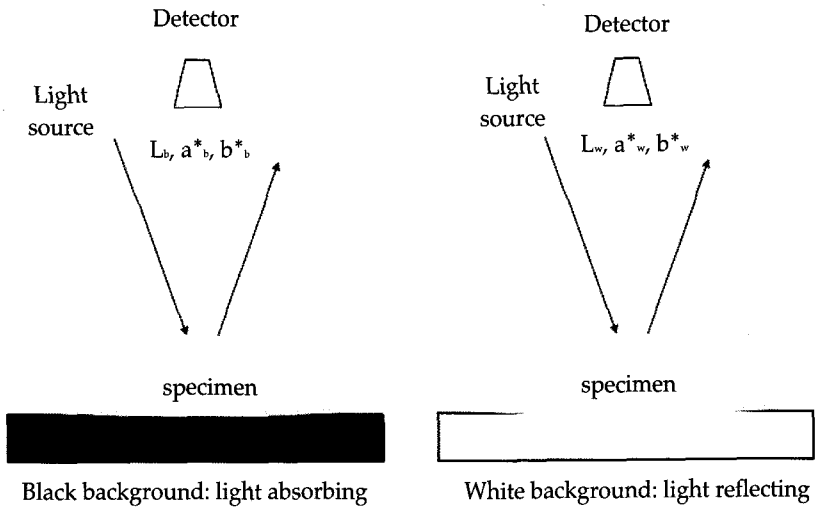

Fig. 1. Schematic diagram of color measurement for calculation of the TP value.

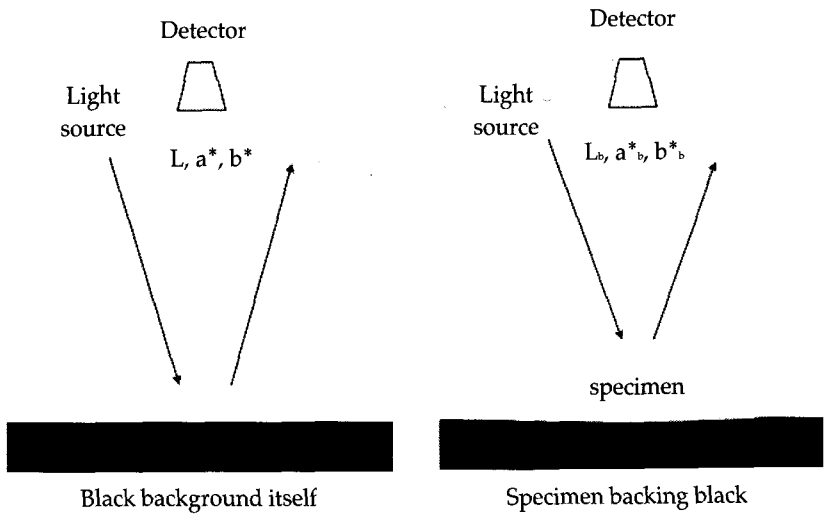

Fig. 2. Schematic diagram of color measurement for calculation of the ΔME^*_{ab} value.

D. Statistical analyses

The mean values and standard deviations of the TP values and the ΔME^*_{ab} values were computed. To detect any statistical differences in the TP values and the ΔME^*_{ab} values, one way ANOVA and the multiple comparison Scheffe test was carried out for each brand and for each thickness at the 0.05 significance levels. To determine the correlation between the thickness and the color parameters, TP and ΔME^*_{ab}, correlation analyses and regression analyses were performed

for each product. SPSS software (Version 12.0, SPSS Inc., Chicago, IL, USA) was used for these statistical analyses.

RESULTS

A. Evaluation of the mean value of TP and ΔME^*_{ab}

Change of the TP values depending on the thickness are illustrated according to the brand in Fig. 3. One-way ANOVA and the multiple comparison Scheffe post hoc test indicated that the TP values of Jet Tooth Shade and Revotek LC were significantly different from those of Alike, Protemp 3 Garant, and Luxatemp. There were little differences among the TP values of Alike, Protemp 3 Garant, and Luxatemp. Ranging from the most translucent to the least with statistical significance, the rankings were Protemp 3 Garant, Alike, Luxatemp > Revotek LC > Jet Tooth Shade, except in 1.0, 1.5 and 3.0 mm thickness.

There was negative correlation between the thickness and the TP values. The increase of thickness resulted in the decrease of translucency regardless of the brand, when the increase of thickness was the same, a larger increase of TP values was observed in the thinner parts.

Revotek LC showed the highest ΔME^*_{ab} value in the materials investigated and the ΔME^*_{ab} value of Revotek LC was significantly different from those of Jet Tooth Shade, Alike, Protemp 3 Garant, and Luxatemp. There was no significant difference between the ΔME^*_{ab} values of Alike and Luxatemp in all thickness groups, except 0.8 mm and 2.0 mm thickness groups. Ranging in the order of masking efficiency, the rankings were Revotek LC > Jet Tooth Shade > Protemp 3 Garant > Alike, Luxatemp, except in 0.3 mm thickness group.

Change of the ΔME^*_{ab} values depending on the thickness are also illustrated according to the brand in Fig. 4. There was positive correlation between the thickness and the ΔME^*_{ab} values. Like TP values, a larger increase of ΔME^*_{ab} was observed in the thinner parts when the increase of thickness was the same.

B. Correlation analyses among thickness, TP, and ΔME^*_{ab}

The simple correlation coefficients (r) among the thickness, the TP values and the ΔME^*_{ab} values are listed in Table II. The correlation coefficients

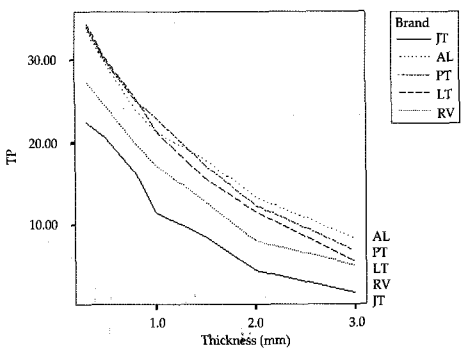

Fig. 3. Change of the mean TP values depending on the thickness.

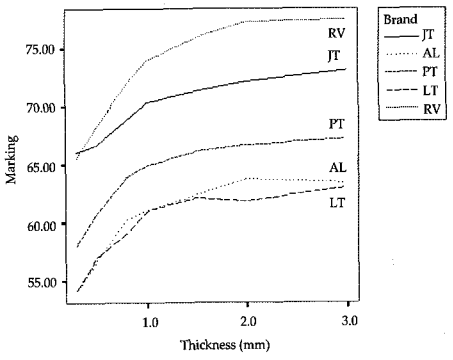

Fig. 4. Change of the mean ΔME^*_{ab} value depending on the thickness.

Table II. Simple correlation coefficient (r) between the thickness and the TP value, between the thickness and the ΔME^*_{ab} value, and between the TP value and the ΔME^*_{ab} value

Brand	Thickness - TP	Thickness - ΔME^*_{ab}	TP - ΔME^*_{ab}
JT	-0.943	0.895	-0.981
AL	-0.959	0.810	-0.937
PT	-0.975	0.826	-0.923
LT	-0.966	0.818	-0.931
RV	-0.956	0.855	-0.963
Total	-0.882	0.477	-0.718

Table III. Simple regression equation, standardized regression coefficient (β) and coefficient of determination (R^2) between the thickness and the TP value

Brand	Regression equation	β	R^2
JT	TP = -7.904 T + 22.497	-0.943	0.886
AL	TP = -9.069 T + 32.947	-0.959	0.918
PT	TP = -9.986 T + 34.190	-0.975	0.950
LT	TP = -10.623 T + 34.409	-0.966	0.932
RV	TP = -8.375 T + 27.284	-0.956	0.911
Total	TP = -9.191 T + 30.265	-0.882	0.778

Table IV. Simple regression equation, standardized regression coefficient (β) and coefficient of determination (R^2) between the thickness and the ΔME^*_{ab} value

Brand	Regression equation	β	R^2
JT	ΔME^*_{ab} = 2.608 T + 66.408	0.895	0.802
AL	ΔME^*_{ab} = 3.174 T + 56.103	0.810	0.656
PT	ΔME^*_{ab} = 3.006 T + 60.051	0.826	0.683
LT	ΔME^*_{ab} = 2.841 T + 56.035	0.818	0.67
RV	ΔME^*_{ab} = 4.211 T + 67.439	0.855	0.732
Total	ΔME^*_{ab} = 3.168 T + 61.207	0.447	0.200

between the thickness and the TP values ranged from -0.975 to -0.943 depending on brands. When based on overall specimens, the correlation coefficient between the thickness and the TP values was 0.882.

The correlation coefficients between the thickenss and the ΔME^*_{ab} values ranged from 0.810 to 0.895 depending on brands. When based on overall specimens, the correlation coefficient between the thickness and the ΔME^*_{ab} values was 0.477.

The coefficient of determination (square of correlation coefficient: r^2) between the thickness and the TP valus was larger than that between the thickness and the ΔME^*_{ab} values irrespective of the brand.

The correlation coefficient between the TP value and the ΔME^*_{ab} vlaue was ranging from -0.923 to -0.981 depending on brands.

C. Regression analyses between thickness and each parameters

The regression coefficients (B) between the thickness and the TP values ranged from -7.904 to -10.623 depending on brands, and a regression equation,

$$TP = -9.191 \text{ thickness} + 30.265 \quad \cdots\cdots\cdots \text{ (Eq. 2)}$$

was calculated based on overall specimens. The regression equations between the thickness and the TP value for each brand are listed in Table III. The standardized regression coefficient ranged from -0.943 to -0.975 depending on brands.

The regression coefficients (B) between the thickenss and the ΔME^*_{ab} values ranged from 2.608 to 4.211 depending on brands, and a regression equation,

$$\Delta ME^*_{ab} = 3.168 \text{ thickness} + 61.207 \quad \cdots\cdots\cdots\cdots\cdots\cdots \text{ (Eq. 3)}$$

was calculated based on overall specimens. The regression equations between the thickness and the ΔME^*_{ab} values for each brand are also listed in Table IV. The standardized regression coefficients ranged from 0.810 to 0.895 depending on brands.

DISCUSSION

Translucency means the ability of the material to allow light to pass through it, whereas opacity means the ability of a material to block out the passage of light.[17,18] Translucency is a more common term to describe the ability to hide underlying color in dentisty, because healthy young natural teeth are not opaque but rather allow some noticeable amount of light to pass through them.18 Besides, translucency measurement seems to be simpler and easier to understand than that of opacity when compared with opacity.[19]

Translucency of esthetic dental materials has usually been determined with the contrast ratio or the translucency parameter.[15] Contrast ratio (CR) is the ratio between the reflectance of a specimen when backed by a black standard and the reflectance of the same specimen when backed by a white standard having a daylight apparent reflectance of 70% (or sometimes 100%) relative to magnesium oxide.[20] The translucency parameter (TP) is the color difference between the specimen on a white background and the specimen on a black background. For a totally opaque material, the TP value would be zero since the color of material would be the same for any backing. Therefore, the greater the TP value, the less the masking ability of the material. In this study, TP was used to evaluate translucency because the TP value corresponds directly to common visual assessment of translucency.[15,21]

There was a strong negative correlation between thickness and translucency in this study. The increase of thickness resulted in the decrease of translucency regardless of the brand. Although the degree of correlation was a little different by brand, the correlation coefficient was near 1 (perfect correlation) in all brands. This was probably because of the decrease in light transmission as the specimens increased in thickness. When the increase of thickness was the same, a larger increase of TP values was observed in the thinner parts. This finding corresponds to the results of Kamishima and Ikeda.[11] They studied the translucency of resin composites at various thickness and reported that there existed a strong exponential relationship between thickness and TP values regardless of product and shades.

In the present study, the difference in translucency by the brand may be due to the difference in the resin composition and shades. Protemp 3 Garant and Luxatemp demonstrated similar

patterns for TP. TP values of these two bis-acrylic resins showed no difference at the same thickness except 1.5 mm and 3 mm. However UDMA resin, Revotek LC, showed statistically different TP values in all thicknesses. Because this brand has only universal B2 shade and only silica crystalline as filler, not glass filler as in Protemp 3 Garant and Luxatemp, and it is not clear whether the difference is attributed to the shade or the combination of filler and resin matrix. TP values of two PMMA resins, Jet Tooth Shade and Alike, were significantly different. Jet Tooth Shade showed the lowest TP values, whereas Alike showed the highest TP values. The different optical behavior between Alike and Jet Tooth Shade may be due to the barium silicate glass in powder of Alike.[15]

There was a strong positive correlation between thickness and masking effect. The masking effect(ΔME^*_{ab})[16,22] value is the color difference (ΔE^*_{ab}) between the black background itself and color specimen over the black background. A higher ΔME^*_{ab} value means a higher color difference, thus a higher masking effect. In this study, as the provisional material got thicker, the more masking effect was achieved. Because a lower translucency parameter indicates greater masking ability,[15] this corresponds to the results of this study for the correlation between the thickness and the TP values.

Like TP values, a larger increase of ΔME^*_{ab} was observed in the thinner parts when the increase of thickness was the same. Lee et al.[16] reported that masking effect was correlated with TP values when the TP values of materials were obviously different. In this study, ΔME^*_{ab} values were strongly correlated with TP values and the correlation coefficients ranged from - 0.923 to - 0.981 by brand based on regression analysis.

However, ΔME^*_{ab} values were less sensitive to the change of thickness than TP values. The correlation coefficients between the thickness and ΔME^*_{ab} values were 0.810 to 0.895 and the correlation coefficients between the thickness and TP values were -0.943 to -0.975. In the regression analysis, numerical value of standardized regression coefficient between the thickness and the TP value ($|\beta| > 0.9$) was larger than that between the thickness and the ΔME^*_{ab} values ($0.9 > |\beta| > 0.8$). In addition, the order of TP values by brand was different from that of ΔME^*_{ab} values. Protemp 3 Garant was the most translucent brand but did not have the least masking ability. Revotek LC had the strongest masking ability but was not the least translucent brand. This indicates that translucency could not be directly translated to the masking efficiency although transluceny and masking efficiency are related closely. Furthermore, this result suggests that the translucent material with high masking ability could be selected to optimize the esthetic requirements needed to produce an acceptable match of the provisional prosthesis to the adjacent teeth.

Because both parameters used in this study, TP and ΔME^*ab, represent the CIELAB color difference, the "perceptible" or "acceptable" threshold for color difference could be used to evaluate TP values and ΔME^*ab values. The literature is not in agreement with the limit for the human eye to appreciate differences in color, considering that this limit differs from individual to individual as it is a combination of eye characteristics and skill from the operator.[23-31]

The American Dental Association shade guide tolerance allows a 2.0 ΔE unit error.[41] Gross and Moser[28] also suggested 2.0 ΔE units as visually "perceptible" baseline. However, it must be remembered that a limited range of color mismatch may be considered "acceptable" because of the interim nature of the restoration5 in the oral environment.[29] Based on the study of Johnston and Kao[29], a value of 3.7 ΔE unit also can be used as threshold for a clinical shade match and a value of 6.8 ΔE unit can be used as threshold for a clin-

ical mismatch.

In this study, if a color difference of 2.0 ΔE units is used as the "perceptible" threshold according to the study of Gross and Moser[28], TP values of all specimens are not regarded as "perceptible" with the exception of 3.0 mm thickness Jet Tooth Shade specimens. Granted that a color difference of 3.7 ΔE units was used as the "acceptable" threshold according to the study of Johnston and Kao[29], TP values of all specimens were not regarded as "acceptable", except 3.0mm thickness Jet Tooth Shade specimens.

However, the provisional restoration with 3.0mm thickness is not clinically possible in conventional fixed prosthesis, but pontics, because the required reduction of an anterior tooth is 1.5 to 2 mm incisally, 1.2 to 1.5 mm facially for a crown preparation.[3]

When the thickness is limited, the differences of ΔME^*_{ab} values between the largest and the lowest depending on brand are greater than 6.8 ΔE units. However, when the brand is limited, the differences of ΔME^*_{ab} values between 0.8 mm thickness and 2.0 mm thickness (clinically relevant thickness) are lower than the 3.7 ΔE units regardless of the brand. This means that the masking effect was not changed significantly depending the thickness but changed significantly depending on the brand when evaluated with a visual significance. This is also verified from the statistical data listed in Table II and Table IV. The correlation coefficient and the standardized regression coefficient between the thickness and the ΔME^*_{ab} values based on overall specimens were considerably different from those based on each brand specimens. These discrepancies are related the variation of the ΔME^*_{ab} values among all the brands.

Therefore, to select the appropriate brand is more important than to increase the thickness of the provisional restoration for the masking efficiency. In addition, selection of the temporary cement could be a considerable factor for an esthetic provisional restoration because all the provisional materials investigated in this study could not compromise with the background below the "acceptable" threshold when the material was thinner than 2.0 mm. Although the most important function of a temporary cement is to provide a seal, thus, preventing marginal leakage and pulpal irritation,[33] the optical requirement for a temporary cement should be also regarded as an important factor. Clear temporary cement might be needed instead of opaque temporary cement for an acceptable provisional restorations on a tooth with no discoloration, especially when the thickness is extremely limited.

This result can be also applied to the implant interim restoration. The diameter of implant temporary cylinder is usually 3.75 mm. For comparision, the cervical diameter averages between 6 and 7 mm for a maxillary incisor and between 4 and 5 mm for a mandibular incisor.[34] These differences in diameter might allow small space for provisional material in implant provisional restorations and result in discrepancies of color. This supports the implant interim restoration systems which consists of metal temporary cylinders that have been opaqued to neutralize the metallic color.[10] Alternatively, white plastic temporary cylinder could be used in the areas where the force factor is small.

To better understand and predict the clinical appearance of the provisional resins, masking abilities of layered combinations with temporary cement, metal core or titanium cylinder as a function of thickness must be determined.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The masking effect of provisional resin was highly correlated with the translucency para-

meter, but the order of the masking effect by brand was different from the order of the translucency parameter.

2. There was significantly negative correlation between the thickness and the translucency parameter of provisional resin materials investigated regardless of the brand.
3. There was significantly positive correlation between the thickness and the masking effect of provisional resin materials investigated regardless of the brand.
4. The translucency parameter was more sensitive to the change of thickness than the masking effect based on the standardized regression coefficient.
5. The masking effect was a brand-dependent variable rather than a thickness-dependent variable based on the statistical analyses and the visual assessment.

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