https://doi.org/10.5933/JKAPD.2024.51.3.220
ISSN (print) 1226-8496 ISSN (online) 2288-3819

JOURNAL OF THE KOREAN ACADEMY OF PEDIATRIC DENTISTRY JKAPD

Original Article

Comparison of the Ability to Mask the Color of Endodontic Filling Materials Using Several Types of Base Materials

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Abstract

In clinical pediatric dentistry, a base material with optical properties, including transparency, that can mask the color of the material used for root canal-filling is preferred. This study aimed to examine the optical properties of various base materials by thickness. The disk-shaped specimens were photopolymerized and fabricated using Ionosit (IN), TheraCal LC (TL), TheraCal PT (PT), and A2 shade of Filtek™ Supreme Flowable Restorative (FZ), Fuji II LC (FL), and Ketac™ Fil (KF) with 1 and 2 mm thickness. The color parameters of these specimens were measured using a spectrophotometer on a black and white background and were measured using the same method on a mold containing Vitapex® and gutta-percha. The translucency parameter (TP) and color difference were calculated for each group. The Kruskal-Wallis and Bonferroni tests were used in the statistical analyses. The TP decreased when the thickness was 2 mm compared with 1 mm. The TP values of TL and PT were the lowest at all thicknesses. The TP values of 2 mm thickness in all molds filled with Vitapex® and gutta-percha were the lowest for TL, PT, KF, and IN. In TL and PT, the color difference before and after the application of the canal-filling material was the smallest, regardless of material thickness. Within the limits of this in vitro study, TL, PT, KF, and IN demonstrated better masking of the color of canal-filling material. [J Korean Acad Pediatr Dent 2024;51(3):220-228]

Keywords

Base material, Translucency parameter, Masking effect, Color

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Article history
Received May 20, 2024
Revised June 23, 2024
Accepted June 25, 2024

Introduction

In primary teeth, pulpectomy is performed as a root canal treatment for pulp tissue with irreversible infection or necrosis caused by severe caries or trauma[1].

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Once the canals are cleared and dried, they are filled with a resorbable material such as a non-reinforced zinc/oxide eugenol, an iodoform-based paste, or a mixed paste of iodoform and calcium hydroxide[2-7]. Then, the tooth is restored to prevent any microleakage[1].

For permanent teeth with fully formed roots, a conventional endodontic procedure is performed to treat the teeth that are exposed, infected, or dead, in order to eliminate pulpal and periradicular infection[1]. This process involves removing the roof of the pulp chamber to gain access to the canals and eliminate all coronal pulp tissues[1]. Following debridement, disinfection, and shaping of the root canal system, the entire root canal is obturated with a biologically acceptable, non-resorbable filling material[1]. In accordance with the Guide to Clinical Endodontics, obturation as close as possible to the cementodentinal junction should be accomplished with gutta-percha or another suitable material[8].

Compared with previous treatment options, composite resins are the preferred materials for direct restorations in both anterior and posterior teeth, owing to their esthetic appearance and minimal removal of healthy tissues[9]. However, the inherent translucency of resin composites may pose challenges in achieving an accurate color match, particularly when used as a core material because the translucent properties of the material are influenced by the endodontic filling materials[10-15]. In such situations, composite resin-based restorations might exhibit a yellowish or brownish shade or display a mismatched color, which can cause esthetic problems, particularly in the maxillary anterior teeth.

To minimize the effect of the background color, base materials can be used to mask the color of the endodontic filling material that inhibits the natural color of the teeth. Appropriate knowledge of the differences in translucency and the required thickness to mask the color of the endodontic filling material is crucial when resin core restoration is applied after root canal treatment of the anterior primary and permanent teeth.

To the best of our knowledge, no studies have explored the capability of various base materials to cover canal-filling materials. Thus, to select materials that can best mask root canal-filling materials used in clinical pediatric dentistry, this study aimed to investigate the optical properties, including colorimetric values, translucency parameters, and color differences, of several types of base materials by two different thicknesses. The first null hypothesis is that the translucency parameter (TP) of the base materials in two thicknesses is not different. The second null hypothesis is that the color of the base materials is not different before and after the application of the endodontic filling material.

Materials and Methods

1. Preparation of base material specimens

In this study, five different materials, namely, Fuji II LC (GC Corporation, Tokyo, Japan), Ketac™ Fil Plus (3M ESPE, St. Paul, MN, USA), Ionosit (DMG, Hamburg, Germany), TheraCal LC (Bisco Inc., Schamburg, IL, USA), and TheraCal PT (Bisco Inc.), which are base materials commonly applied above the endodontic filling materials, were used as the experimental group. The A2 shade of Filtek™ Supreme Flowable Restorative (3M ESPE) was used as a control. Details of the materials according to the manufacturers are described in Table 1.

To prepare disk-shaped specimens, the materials were placed in polyvinyl siloxane cylindrical molds with 1 and 2 mm thicknesses and 8-mm-diameter holes. The top and bottom surfaces were covered by microscope slide glasses for 10 seconds to extrude the excess resin, and the glass slides were then removed. The specimens were then light-cured for 20 seconds with light-curing units (VALO™ Corded; Ultradent Products Inc., South Jordan, UT, USA). Light intensity was checked using a dental radiometer (Light Meter-200; Rolence Enterprise, Chungli, Taiwan), and the light output was between 1,150 and 1,350 mW/cm^2. The specimens were separated from the mold, and the edge flashing was removed (Fig. 1A, 1B). The diameters and thicknesses of the specimens were measured using a Vernier caliper to the nearest 0.01 mm. Six specimens per material were fabricated for each thickness, making a total of 72 specimens.

Table 1. Details of the materials according to the manufacturers

Code	Material	Composition	Shade	Lot number
FZ	Filtek™ Supreme Flowable Restorative (3M ESPE, St. Paul, MN, USA)	Matrix: Procrylat, BisGMA and TEGDMA resins Filler: 65% by weight (46% by volume). Average cluster particle size of 0.6 - 20 microns (silica, 20 nm; zirconia, 4 - 11 nm)	A2	9694803
FL	Fuji II LC (GC Corp., Tokyo, Japan)	Powder: fluoroaluminosilicate glass Liquid: aqueous solution of polycarboxylic acid, TEGDMA and HEMA	A2	Powder: 2112041 Liquid: 2111241
KF	Ketac™ Fil Plus (3M ESPE, St. Paul, MN, USA)	Powder: glass powder (93 - 98 wt %) Liquid: water (60 - 65 wt %), copolymer of acrylic acid-maleic acid (30 - 40 wt %), tartaric acid (5 - 10 wt %)	A2	9044463
IN	Ionosit (DMG, Hamburg, Germany)	Acrylic resin, glass powder, silica, aliphatic dimethacrylate, aromatic dimethacrylate, and polycarboxylic polymethacrylate	-	273219
TL	TheraCal LC (Bisco Inc., Schamburg, IL, USA)	Portland cement type III, PEGDMA, barium zirconate	-	2200007197 2200007131
PT	TheraCal PT (Bisco Inc., Schamburg, IL, USA)	Base: silicate glass-mix cement, PEGDMA, BisGMA, barium zirconate Catalyst: barium zirconate, ytterbium fluoride, and initiator	-	2200007057

BisGMA: bisphenol A-glycidyl methacrylate; TEGDMA: triethylene glycol dimethacrylate; PEGDMA: polyethylene glycol dimethacrylate; HEMA: 2-hydroxyethyl methacrylate.

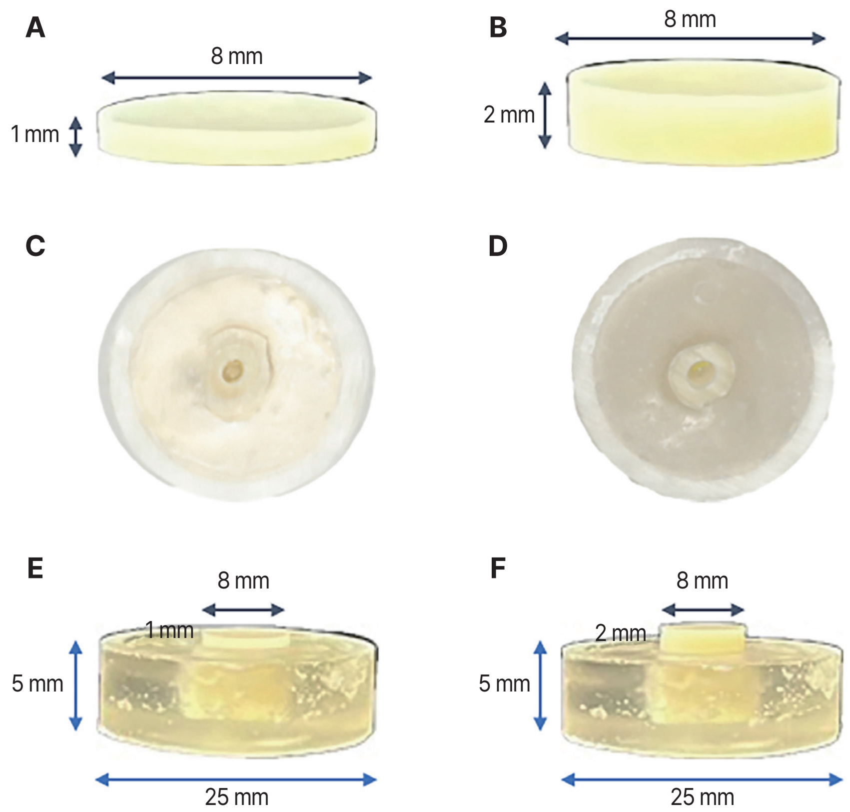


Fig. 1. Photographs of the specimens used in this study.
The experiment consisted of a combination of five base material groups and one composite resin group in (A) 1 mm and (B) 2 mm thicknesses (n = 6 for each group). Two different tooth specimens (C and D) were prepared to imitate the tooth with a root canal after endodontic treatment. Disk-shaped specimens of base materials with (E) 1 mm and (F) 2 mm thickness were used to mask the color of endodontic filling materials.

2. Preparation of tooth specimens

In this study, two tooth samples were prepared using the roots of the extracted premolars. To cut each tooth specimen in the desired thickness of 5 mm from the cemento-enamel junction, a low-speed precision cutter (Isomet®; Buehler Ltd., Lake Bluff, IL, USA) was used under water. The tooth specimens were mounted on translucent acrylic rings with a 25-mm diameter, a 5-mm height, and a 21-mm hole in the center used as a mold. The mounting medium was a clear shade of self-curing resin (Ortho-Jet Acrylic Resin; Lang Dental, Wheeling, IL, USA). The tooth specimen was oriented in the center of the acrylic ring, and the self-curing resin was mixed and encapsulated the tooth according to the manufacturer's instructions. After the polymerization, every tooth specimen was stored for 24 hours in a light-blocked case filled with saline to prevent color change and drying of the tooth specimen.

In the center of the tooth specimen, a 2-mm hole was made using pulp shaper burs (EAPSB; Dentsply, Charlotte, USA) to imitate the root canal after endodontic treatment (Fig. 1C, 1D). The hole was filled with root canal medicament Vitapex® (Neo Dental Chemical Products Co., Tokyo, Japan) containing iodoform (40.4%), calcium hydroxide (30.3%), and silicone (22.4%) and the permanent root canal-filling material gutta-percha (B&L Biotech, Ansan, Korea) containing 20% gutta-percha (matrix), 66% zinc oxide (filler), 11% heavy metal sulfates (radiopacifier), and 3% waxes and/or resins (plasticizer) as endodontic filling materials[16].

3. Color measurement and colorimetric evaluation

In this study, color was evaluated using the CIE L*a*b*(CIELAB) technique. This system quantifies color in three values: L* for lightness, ranging from 0 (completely black) to 100 (completely white); a* for the red-green spectrum; and b* for the yellow-blue spectrum. Positive values of a* indicate redness, and positive b* values denote yellowness[17]. Specular component included (SCI) and specular component excluded (SCE) were two distinct measurement setups employed with a spectrophotometer featuring an integrating sphere. The specular component denoted the light reflected directly from the surface where the angle of reflection matched the angle of incidence[18]. A 3-mm-diameter section was assessed under both SCI and SCE conditions against white and black backgrounds. To determine the CIELAB values of each specimen with each background, color measurements were performed by employing a spectrophotometer (CM 700d; Konica Minolta, Osaka, Japan) with diffusive illumination and 8° viewing angle.

The experiment consisted of a combination of five base material groups and one composite resin group in 1 and 2 mm thicknesses (n = 6 for each group). Two different tooth specimens were prepared to imitate a tooth with a root canal after endodontic treatment. For CIE color measurements, a single disk-shaped specimen was placed at the center of each tooth specimen (Fig. 1E, 1F). To standardize the measurement throughout the study, the same examiner measured the central part of each sample's surface five times at a consistent location using a D65 standard illuminant. Before each measurement, the spectrophotometer was subjected to zero calibration. The CIE values and standard deviation for each background were determined independently, with five separate measurements for analysis: L* = 95.71(0.01), a* = -0.76(0.01), b* = 3.14(0.01) for the white background and L* = 28.97(0.14), a* = 0.89(0.03), b* = -0.60(0.02) for the black background.

4. Calculation of color differences and TP

The TP of the material at various thicknesses was calculated using the following equation:

$$TP = [(L^*_W - L^*_B)^2 + (a^*_W - a^*_B)^2 + (b^*_W - b^*_B)^2]^{0.5}$$

The subscripts "W" and "B" refer to the CIELAB values for each specimen on white (W) and black (B) backgrounds, respectively.

To determine the ability of each material to mask endodontic canal-filling materials, the ΔE_{ab} of the base materials between the materials on empty tooth specimens

(E_a) and materials on Vitapex® or gutta-percha-filled tooth specimens (E_b) over a white background was calculated using the following equation:

$$\Delta E_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$$

The CIELAB 50% : 50% acceptability threshold of 2.7 and the 50% : 50% perceptibility threshold of 1.2 were used in this study[19]. A low ΔE_{ab} means that the base material can mask the color of gutta-percha or Vitapex® and can better reproduce the shade of the natural teeth. The calculated ΔE_{ab} was compared with the respective thresholds of clinical acceptability threshold and perceptibility threshold to determine the degree of masking ability.

5. Statistical analysis

Statistical analyses were performed to assess the TP and color difference (ΔE_{ab}) across varying thicknesses of each composite and to compare these metrics among different materials at identical thicknesses. Initially, the Kolmogorov-Smirnov test determined the normality of the data. Group comparisons were made using the paired t-test for normally distributed data, whereas the Wilcoxon signed ranks test was applied to nonnormally distributed data. When the data satisfied both normality and homogeneity of variance criteria, as verified by Levene's test, a one-way analysis of variance was conducted for within-group analyses. Depending on Levene's statistic outcomes, post hoc analyses were performed using either Tukey's or Dunnett's T3 method for normally distributed data, whereas the Kruskal-Wallis test with Bonferroni correction was employed for nonnormally distributed data. These statistical evaluations were performed at a 0.05 significance level using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA).

Results

Fig. 2 shows the TPs of each material at 1 and 2 mm thickness.

Regarding the thickness of the base material, the TP value decreased when the thickness was 2 mm compared with that of 1 mm. At a thickness of 1 mm, the TP value followed the order of FZ > FL > IN > KF > PT, TL, with no significant difference between TL and PT. At a thickness of 2 mm, the TP value followed the order of FL, FZ > IN, KF > PT, TL, with all experimental groups, except for FL, showing significantly lower TP values than FZ (control group).

The mean ΔE_{ab} values of each material at 1 and 2 mm thickness on each endodontic filling material in tooth specimens 1 and 2 are shown in Fig. 3 and Fig. 4.

In TL and PT, the color difference was the smallest, regardless of the thickness. In addition, IN and KF showed similar values to PT with a 2 mm thickness.

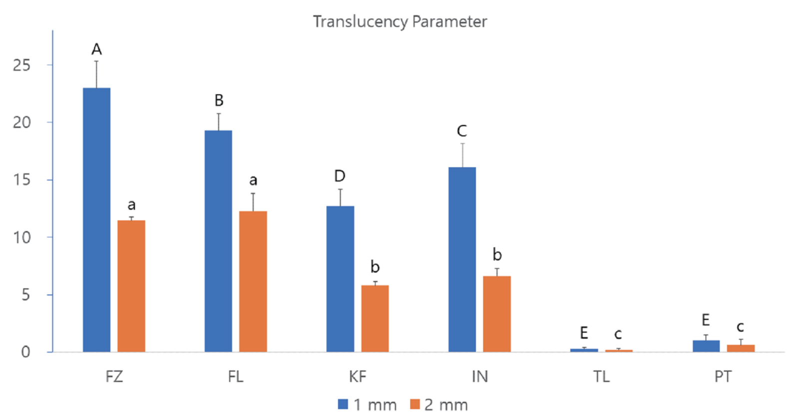


Fig. 2. Translucency parameters of each material at 1 and 2 mm thicknesses.
Bars with the same letter did not differ significantly. Vertical bars refer to the standard deviation.
FZ: Filtek Supreme Flowable Restorative; FL: Fuji II LC; KF: Ketac Fil Plus; IN: Ionosit; TL: TheraCal LC; PT: TheraCal PT.

Fig. 3. Mean ΔE^*_{ab} color differences of each base material at 1 and 2 mm thicknesses on each Vitapex-filled tooth specimen. (A) Tooth specimen 1, (B) Tooth specimen 2.
Bars with the same letter did not differ significantly. Vertical bars refer to the standard deviation.
FZ: Filtek Supreme Flowable Restorative; FL: Fuji II LC; KF: Ketac Fil Plus; IN: Ionosit; TL: TheraCal LC; PT: TheraCal PT.

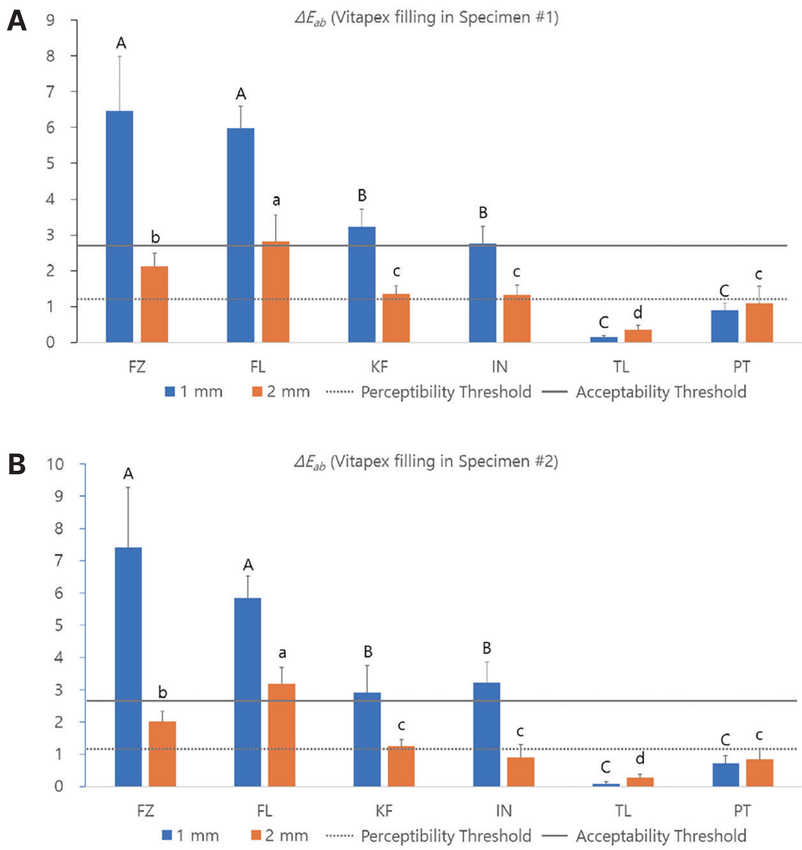
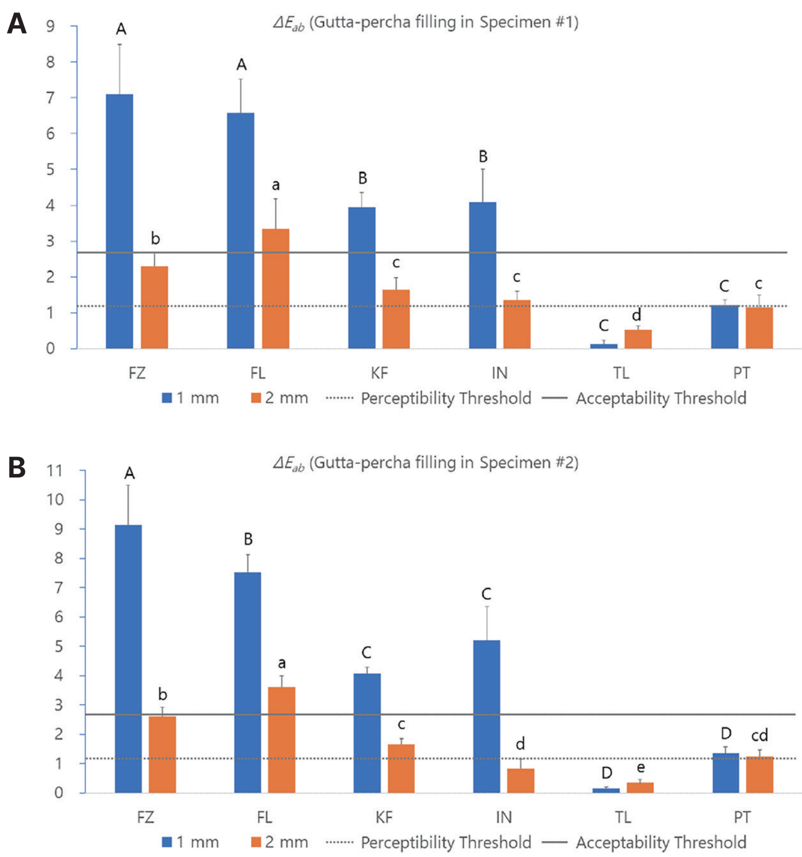


Fig. 4. Mean ΔE^*_{ab} color differences of each material at 1 and 2 mm thicknesses on each gutta-percha-filled tooth specimen. (A) Tooth specimen 1, (B) Tooth specimen 2.
Bars with the same letter did not differ significantly. Vertical bars refer to the standard deviation.
FZ: Filtek Supreme Flowable Restorative; FL: Fuji II LC; KF: Ketac Fil Plus; IN: Ionosit; TL: TheraCal LC; PT: TheraCal PT.



Discussion

The first null hypothesis, i.e., the TP values were not different among the base materials used in this study, was rejected. The TP values were significantly lower in all base materials, except for FL, than in FZ in all thicknesses. Composite resins used in dentistry typically contain a mixture of inorganic filler particles (such as quartz, glass, and silica) suspended in a resin matrix (usually acrylic or methacrylate type). The inorganic filler and the amount of BisGMA used in the resin mixture are the main components of composite resins that significantly affect the translucency[20]. The translucent nature of composite resin is influenced by the way light travels through the material. When light encounters the composite resin, it penetrates the material and scatters in multiple directions because filler particles are present[21]. This scattering of light creates a diffuse transmission of light depending on the thickness of the material, giving it a translucent appearance[20,22].

Resin-modified glass ionomer cements (RMGICs) are a type of glass ionomer cement that offers enhanced setting time, handling characteristics, working time, strength, wear resistance, and improved color matching and translucency[23]. Despite being translucent, RMGICs contain radiopaque fluoroaluminosilicate glass, which contributes to their opacity[24]. However, a previous study indicated that the opacity of RMGICs may not be adequate to effectively conceal dark or black colors[25]. Although we tested the specimens on different backgrounds, our results were in line with these findings.

The second null hypothesis that the color of the base materials measured before and after the application of the endodontic filling materials was not different was rejected. Similar to the results on TP, all base materials, except for FL, showed significantly lower ΔE_{ab} than FZ in all thicknesses. FL showed similar ΔE_{ab} to FZ in 1 mm thickness and showed higher ΔE_{ab}, in 2 mm thickness compared to other groups.

Resin-based materials showed the highest translucency and ΔE_{ab} values, whereas they were the lowest for calcium silicate-based materials. However, calcium silicate-based materials can exhibit dark discoloration if the following conditions are present simultaneously: an oxygen-free environment, irradiation with a light-curing or fluorescent lamp, and the presence of bismuth oxide[26]. A previous study compared the color stability induced by TheraCal PT, Biodentine, and ProRoot MTA in teeth subjected to full pulpotomy for 6 months, and Biodentine and TheraCal PT showed stable colors ($\Delta E_{ab} \leq 3.7$)[26]. Another study tested the discoloration potential of calcium silicate-based materials (GMTA Angelus, ProRoot WMTA, Biodentine, TheraCal, and TotalFill) and found that TheraCal LC caused moderate discoloration but more than that caused by Biodentine and TotalFill[27].

The minimum discernible color distinction, known as a just-noticeable difference or perceptibility threshold, signifies the smallest color variation detectable by an observer. A 50% : 50% perceptibility threshold indicates that half of the observers detect a color difference between two objects, whereas the remaining half do not[28]. Similarly, the color variation judged acceptable by 50% of the observers aligned with a 50% : 50% acceptability threshold[28].

This study followed the suggestions of Paravina et al.[19]. They suggested CIELAB 50% : 50% acceptability threshold of 2.7 and 50% : 50% perceptibility threshold of 1.2. According to this classification, the TL showed $\Delta E_{ab} < 1.2$ with 1 and 2 mm thicknesses in Fig. 3 and Fig. 4, which means that TL could mask the color of the endodontic filling materials in relatively thin thicknesses of 1 or 2 mm. PT also showed $\Delta E_{ab} < 1.2$ in both thicknesses when they were applied to Vitapex®-filled tooth specimens. However, ΔE_{ab} values of PT were between 1.2 and 2.7 when they were applied on gutta-percha-filled tooth specimens. This means that PT masked the color of Vitapex® better than that of gutta-percha, indicating that PT may be more useful for the endodontic treatment of primary teeth than permanent teeth. KF and IN also showed $\Delta E_{ab} < 2.7$ at a thickness of 2 mm. Thus, these materials could mask the color of the endodontic filling materials in this thickness successfully. TL and PT had high masking ability regardless of thickness, whereas IN and KF could be considered to have advantages in masking ability when applied in 2 mm thickness. IN and KF have similar masking ability in 2 mm thickness. However, IN can be clinically more favorable in terms of easy handling and short setting time.

The limitation of this study was that we have not investigated whether there were significant differences in TP or ΔE_{ab} according to thickness for the same material. Another limitation was that although calcium silicate-based materials showed high masking potential in this study, we did not observe color differences in calcium silicate-based materials over time. Furthermore, in addition to the two endodontic filling materials used in this study, namely, Vitapex® and gutta-percha, various types of materials are used for canal-filling[29]. Because the endodontic materials have different colors, a study comparing the masking abilities of other endodontic filling materials, such as a KRI paste and an MTA sealer, is also needed.

Conclusion

When selecting a base material for application above the endodontic filling material, the color masking ability must be considered. Within the limits of this in vitro study, TL and PT masked the color of root canal-filling material with 1 and 2 mm thicknesses. Thus, resin-based materials can be inappropriate for base materials with respect to masking the shade of canal-filling materials, whereas calcium silicate-based materials can be recommended. TL and PT demonstrated high masking ability regardless of thickness, and IN and KF showed sufficient masking ability with 2 mm thickness, demonstrating that IN and KF can have masking ability when applied in 2 mm thickness.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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