Original Article

Comparative Radiopacity Evaluation of Eight Provisional Restoration Materials

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Abstract

Objectives: The purpose of this study was to evaluate the radiopacity value of eight provisional restorative materials.

Methods: The specimens were divided into 8 groups (n=10) based on commercial product which were UNIFAST Trad, Dentalon Plus, Luxatemp Star, Luxatemp Fluorescence, LuxaCrown, Protemp 4, SmarTemp X1 and VIPI BLOCK TRILUX. Disc specimens of provisional restoration materials (diameter: 6 mm and thickness: 1 mm) were fabricated by manufacturer's instruction. The samples were digitally radiographed together the aluminium step wedge used as standard for radiologic analysis. The digital radiographic images were performed and analyzed with Image J program. The relationship between the gray value for each specimen and the aluminium step wedge thickness were plotted. Data were analyzed using one-way analysis of variance (ANOVA) and Post hoc Tukey's test at 95% confidence level.

Results: Luxatemp Fluorescence showed the highest radiopacity value (p<0.05). While UNIFAST Trad and Dentalon Plus demonstrated the lowest radiopacity value (p<0.05) in all group of specimens. Protemp 4 did not show a statistically significant difference from VIPI BLOCK TRILUX groups (p>0.05).

Conclusions: There were statistically significant of radiopaque among eight groups of provisional restoration materials

Keywords: Bis-acryl composite materials, PEMA, PMMA, provisional restoration, radiopacity

Introduction

Before the final restoration, the provisional restoration plays an important part in the treatment procedure for a fixed prosthesis.[1,2] The provisional restoration protects the pulpal tissue from injuries that could be caused by physical, chemical, or thermal forces. It also ensures the tooth's stability, occlusal function, and periodontal health, and it allows for an evaluation in an area that is highly concerned with esthetics to achieve an acceptable emergence profile.[1-4]

The incidence of aspiration or ingestion of dental appliances and prosthesis materials has often been frequently reported[5-15], such as removable prostheses[5-7,10-12], crowns, inlays, orthodontic attachments, provisional crowns[13], bridges[14], impression materials[15], burs, and clamps. The present symptoms are choking, dyspnea, and dysphagia.[7] In severe cases, it may cause a harmful complication such as asphyxiation[8], bleeding from the digestive or airway tract mucosa[9-11], and septicemia.[12]

Many studies have tried to develop a radiopaque material because these materials can be localized to their position in radiographic examination.[16-19] On the other hand, radiolucent materials make it difficult to localize their position, so many studies suggest using radiopaque restorative materials in patients.[20] Hence, the provisional restoration materials should not only have an accepted mechanical property but also a desirable radiopaque property because, when they dislodge or fracture, their fragments can be detected in a radiographic image, and they could be removed if they impact the airway or digestive tract. Moreover, evaluating the marginal discrepancy of provisional restoration, which predicts the quality of temporalization and periodontal health.[3,4]

The International Standards Organization ISO10477: 2018 Dentistry-Polymer-based crown and bridge materials[21] does not define that radiopacity should be. Various studies propose that the optimal radiopacity for optimal clinical performance should be equal to or higher than the same thickness of aluminium[22,23], more radiopaque than human dentine[24,25] or slightly higher radiopaque than enamel.[26,27]

From the past to the present, polymethyl methacrylate (PMMA), polyethyl methacrylate (PEMA), and Bis-acryl composite materials have been used as provisional restoration materials. They have different strengths and weaknesses. In terms of radiopacity, many studies evaluated the effect of radiopacified agents such as lithium, barium, zirconium, strontium, zinc, or other metal compounds on dental restoration materials.[18,28-30] However, there are a few studies that compare the radiopacity of provisional restoration materials, especially between PMMA, PEMA, and Bis-acryl composite materials.

The objective of this study was to investigate the radiopacity of eight groups of provisional restorative materials. The null hypotheses were that the radiopacity of provisional restoration materials was not statistically different from each other.

Material and Methods

The provisional restoration materials used in this study are listed in Table 1. Disc-shaped specimens (n=10) from 8 provisional restoration materials were prepared according to the manufacturer's instructions with a silicone mold (6 mm in diameter and 1.4 mm in height) (Figure 1).

For PMMA materials (UNIFAST Trad), they were prepared following a manufacturer's recommendation. powder/liquid ratio, which measured 1 g of powder to 0.5 ml of liquid. The liquid was then poured into a rubber cup. Next, add the powder, and mix thoroughly for 20-30 seconds with a mixing spatula. When the mixture reaches a dough state, put it into a silicone mold. The silicone mold surface was covered with a glass slide and constantly pressed by the weight of 1000 g for 10 minutes. After setting, remove the specimen from the mold.

For PEMA materials (Dentalon Plus), they were also prepared following a manufacturer's instruction, the powder/liquid ratio, which measured 2 g of powder to 1.2 ml of liquid. The liquid was then poured into a rubber

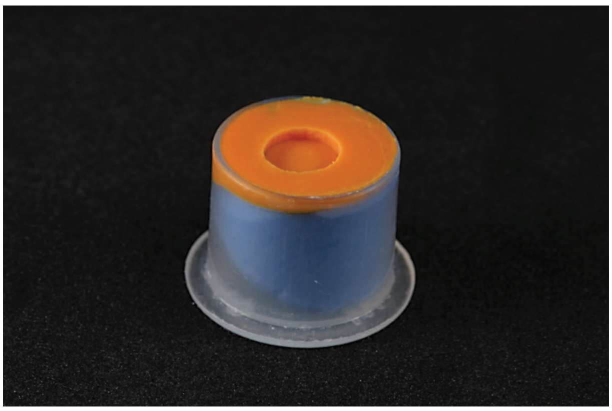

Figure 1: Silicone mold with a hole in the middle.

cup. Next, add the powder, and mix for 40 seconds with a mixing spatula. The process after these is like the PMMA materials previously described.

For Bis-acryl materials (Luxatemp Star, Luxatemp Fluorescence, LuxaCrown, Protemp 4 and SmarTemp X1), they were directly dispensed into silicone mold by using a dispensing gun. The process after these as the similar as PMMA materials that previously described.

For milling PMMA material (VIPI BLOCK TRILUX), the block was designed and milled at the bottom part to obtain the shade A3 by a milling machine (VHF CAM 5-S1 Impression, Bimedis, Ternopil Region, Ukraine).

All specimens were polished on both sides with 2000-grit silicon carbide paper (PACE Technologies, Tucson, AZ, USA). A digital vernier caliper (Model CD-6 CS, Mitutoyo Corp., Kanagawa, Japan) was utilized to verify their dimensions of 6 mm in diameter and 1 mm in height, which determined a critical tolerance of 1±0.01 mm and evaluated and excluded the defective specimens with a stereomicroscope (Olympus Stereo Microscopes, SZ61, Tokyo, Japan) at a magnification of ×40. All specimens were cleaned with distilled water using an ultrasonic cleanser for 10 minutes and soaked in distilled water in an incubator (Contherm 160M, Contherm Scientific Ltd., Korokoro, Lower Hutt, New Zealand) for 24 hours before starting the test. The metal step wedge was prepared from 98% pure aluminium (DHEF Inc., Taipei, Taiwan). It had 5 steps, each of which had a thickness of 0.5 mm, a width of 4 mm, and a length of 6 mm (Figure 2).

The specimens from each group were placed on a digital radiograph sensor (3x4 cm Digora Imaging Plate) in two lines at 2 mm distances from each other. The metal step wedge was placed beside these two lines (Figure 3).

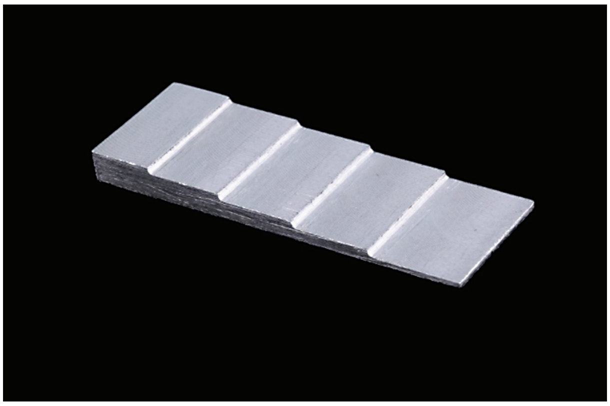

Figure 2: 5-step wedge made from aluminium.

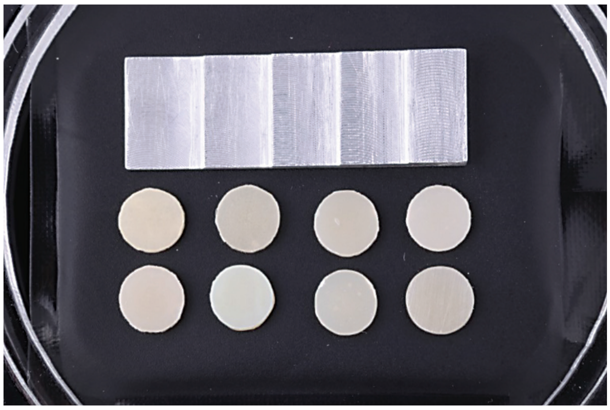

Figure 3: Specimens and aluminium step wedge placed on the sensor.

Two clear acrylic plates were produced for a stabilized base and a fixed, constant distance from the radiation source of 12 mm (Figure 4). Specimens were radiographed by a dental X-ray system (Planmeca Prox machine, Planmeca Oy, Helsinki, Finland) at 60 kV and 7 mA for a 0.211-second exposure time. After that, all 10 digital files of specimens and an aluminium step wedge (Figure 5) were transferred to Image J software (Image J1.41, Wayne Rasband, National Institutes of Health, Bethesda, MD, USA) for analysis in grayscale. The digital analysis area was 60 mm^2. The mean gray values, which were obtained from 10 gray valves, were calculated into the mean gray value, and plotted for equations and calibration curves: $Y= 92.607\ln(x) + 109.78$ or $x = e^{(\frac{y-109.78}{92.607})}$, which was a relation between aluminium thickness (Y) and gray value (x) (Figure 6).

For each specimen, the gray values were obtained from 12.5 mm^2 of specimen area. The mean gray value of each specimen group was obtained from 10 readings per material (n=10). The equation and calibration curves were then used for calculating the mean gray value of the material group and turned into equivalent aluminium thickness values.

The aluminium thickness values of specimens were calculated, and the data were statistically analyzed using one-way analysis of variance (ANOVA) followed by Tukey's test at a significant level of $p<0.05$.

Results

The equation and calibration curves $Y= 92.607\ln(x) + 109.78$ or $x = e^{(\frac{y-109.78}{92.607})}$, which was a relation between aluminium thickness (Y) and gray value (x) (Figure 6) was used for converting the gray values of provisional

Figure 4: Clear acrylic hallow platform which covered the specimens and aluminium step wedge.

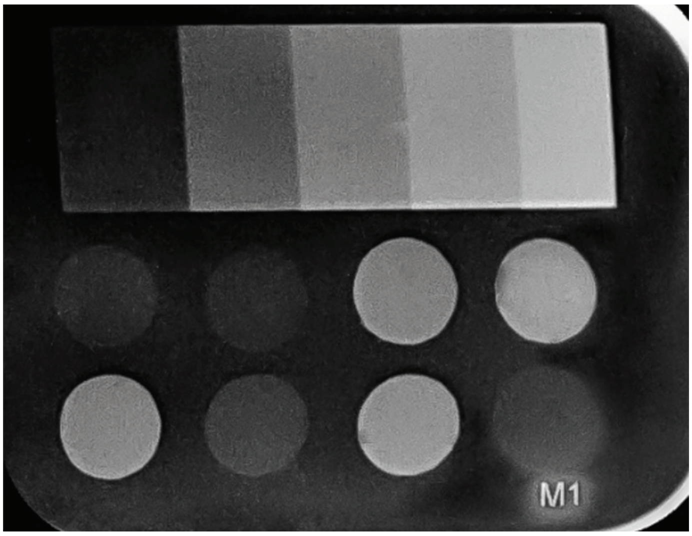

Figure 5: Digital radiograph image of specimens from 8 specimens and aluminum step wedge.

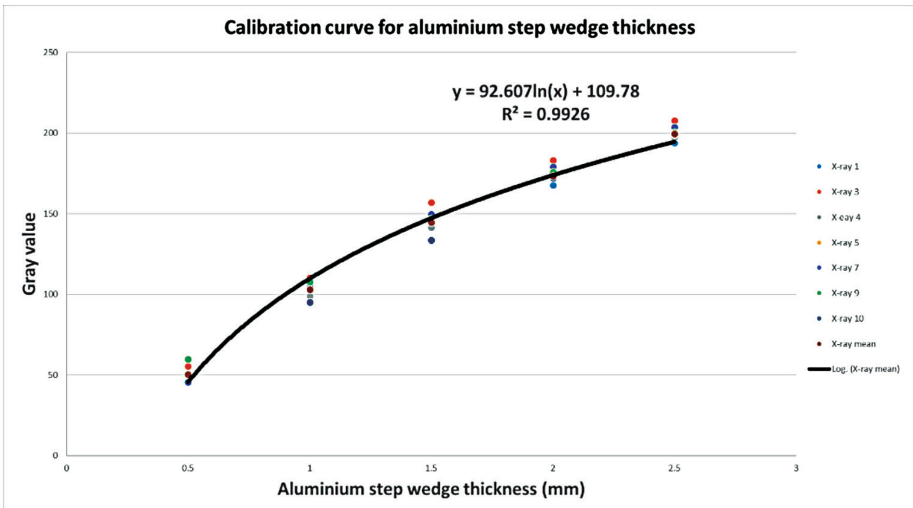

Figure 6: Calibration curve and linear equation related between the gray value (Vertical axis) and aluminium thickness value (Horizontal axis) in millimeter.

Table 1: Description of provisional restoration materials, manufacturer and composition used in this study

Brands, shade and Batch number	Manufacturer	Composition
UNIFAST Trad Ivory **Batch number** Powder: 1704201 Liquid: 308282	GC America, IL, USA	**Powder:** poly[(ethyl methacrylate)-co-(methyl methacrylate)] poly(methyl methacrylate), dibenzoyl peroxide, titanium dioxide, iron(III) oxide, cellulose acetate **Liquid:** Methyl methacrylate, N,N dimethyl-p-toluidine
Dentalon Plus L (light) **Batch number** Power: K010039 Liquid: K010100	Heraeus Kulzer GmbH, Hanau, Germany	**Powder:** n-butyl methacrylate, ethyl methacrylate, 2-(2-Hydroxy-3,5-di-tert-pentylphenyl)-2H-benzotriazol **Liquid:** n-butyl methacrylate, diurethandimethacrylate, ethyl methacrylate, methyltrioctylammonium chloride
Luxatemp Star A3 **Batch number** 212407	DMG, Hamburg, Germany	Glass filler in a matrix of multifunctional methacrylates; catalysts, stabilizers and additives. Free of methyl methacrylate. Total filler volume: 44% wt.% or 24 vol.% (0.02 to 1.5 µm)
Luxatemp Fluores-cence A3 **Batch number** 758441	DMG, Hamburg, Germany	Glass powder and silica, Urethane dimethacrylate, Aromatic dimethacrylate, Glycol methacrylate, catalysts, stabilizers, additives. Free from methyl methacrylate and peroxides. Filler content: 43 wt.-% or 24 vol.-%. (0.02 to 1.5 µm)
Luxacrown A3 **Batch number** 212209	DMG, Hamburg, Germany	Glass filler material in a matrix of multifunctional methacrylates, catalysts, stabilizers, and additives. Filler content: 46 wt.% = 26 vol.%. (0.02 to 1.5 µm)
Protemp 4 A3 **Batch number** 3704381	3M ESPE, Seefeld, Germany	**Catalyst Paste:** Ethanol, 2,2'-[(1-methylethylidene) bis(4,1-phenyleneoxy)] bis-, diacetate, Benzyl-phenyl-barbituric acid, Silane treated silica, Tert-butyl peroxy- 3,5,5-trimethylhexanoate **Base Paste:** dimethacrylate (BISEMA 6), silane-treated amorphous silica, reaction products of 1,6-diisocyanatohexane with 2-[(2-methacryloyl) ethyl] 6- hydroxyhex-anoate and 2- hydroxyethyl mathacrylate (DESMA), silane-treated silica
SmarTemp X1 A3 **Batch number** 1913619136	Parkell Dental, Edgewood, New York, USA	**Catalyst Paste:** 2,4,6(1H,3H,5H)-Pyrimidinetrione, 5-phenyl-1-(phenylmethyl)-, Titanium dioxide **Base Paste:** Poly(oxy-1,2-ethanediyl), .alpha.,.alpha.'-[(1-methylethylidene) di-4,1-phenylene]bis[.omega.-[(2-methyl-1-oxo-2-propenyl)oxy]-, 2-Propenoic acid, 2-methyl-, (1-methylethylidene)bis[4,1-phenyleneoxy(2-hydroxy-3, 1-propanediyl)] ester, 2-Propenoic acid, 2-methyl-, 1,6-hexanediyl ester, Tripropylene glycol diacrylate Copper, bis(2,4-pentanedionato-O,O')
VIPI BLOCK TRILUX Monocolor A3	Dental Vipi Ltda., Pirassununga, SP, Brazil	Polymethyl methacrylate, pigments, Polymerized Ethylene Dimethacrylate (EDMA), Fluorescent

restoration materials to aluminium thickness mean values (Table 2).

This result showed that the radiopacity of provisional restoration material ranged from 0.493 to 1.622 mm aluminium thickness. Luxatemp Fluorescence had the significantly highest aluminium thickness value in all groups of specimens ($p<0.05$). SmarTempX1 and Luxatemp Star showed significantly higher aluminium thickness values than LuxaCrown ($p<0.05$). VIPI BLOCK TRILUX had a significantly higher aluminium thickness value than UNIFAST Trad and Dentalon Plus ($p<0.05$). While Protemp 4 did not show a statistically significant difference from VIPI BLOCK TRILUX groups ($p>0.05$). Moreover, both UNIFAST Trad and Dentalon Plus had the lowest aluminium thickness values in all groups of specimens ($p<0.05$).

Discussions

The result of this study revealed that eight provisional restoration materials showed different radiopacity values. Therefore, the null hypothesis of this study was rejected. Today, dental resins are often employed; however, some of them are radiolucent and cannot be scanned with conventional radiographic methods. The detection of these materials may be extremely challenging in cases of unintentional ingestion, aspiration, or traumatic impaction, necessitating invasive procedures or advanced imaging methods. Delays in locating or removing the foreign body could endanger the patient's life. Swallowing or aspirating dental prostheses are relatively uncommon, although it is rare. The bulk of foreign bodies originate through the oral, resulting in frequent injuries and fatalities.(31-34)

Consequently, radiopaque properties are essential for dental materials, including temporary restorations, that are used in the oral cavity. Furthermore, the radiopaque properties enable the operator to identify the marginal adaptability of temporary restoration.

In this investigation, a pure aluminium step wedge was utilized since its radiopacity value is more consistent than that of human dentin and enamel, whose values are highly variable.

Human tooth enamel is the hardest and most highly mineralized substance in the human body. It is a bone and not a tissue, which is composed of 92-96% inorganic matter, 1-2% organic material, and 3-4% water in weight.(35) Most of the inorganic matter is $Ca_{10}(PO_4)_6(OH)_2$, hydroxyapatite, but other atomic elements can be detected as Copper, Potassium, Chloride, Zinc, Iron, Titanium, Strontium, Vanadium, Manganese and Zirconium by using Particle-induced X-ray emission (PIXE) and Particle-induced x-ray emission (PIGE) techniques.(36) Regarding a hydrated biological composite, human dentin has a lower inorganic concentration than enamel, and it is made of 70 % inorganic material, 18 % organic matrix, and 12 % water (wt.%).(37) This different composition not only affects the mechanical properties of each tooth tissue(38) but, since teeth of different animal species may have different composition, the radiodensity of tooth structures are also expected to be influenced. Therefore, many studies reported that the radiopacity of human dentin and enamel was equal to 0.7-1.16 mm and 1.84-2.20 mm thickness of aluminium, respectively.(39-41) Although ISO 4049:2019 Dentistry — Polymer-based restorative materials recommended that the radiopacity should be slightly higher than that of dentin radiopacity(42), The

Table 2: Means and standard deviations (SD) of gray value and equivalent aluminium step wedge thickness values of the tested materials.

Brands	Gray value (Mean±SD)	Aluminium thickness value (Mean±SD)#
UNIFAST Trad	49.104±7.808	0.538±0.045^{E}
Dentalon Plus	51.172±10.609	0.552±0.062^{E}
Luxatemp Star	117.384±5.589	1.315±0.104^{B}
Luxatemp Flourescense	149.373±5.219	1.536±0.086^{A}
LuxaCrown	111.473±15.770	1.066±0.184^{C}
Protemp 4	75.455±4.291	0.714±0.032^{D}
SmarTempX1	122.981±9.858	1.197±0.128B^{C}
VIPI BLOCK TRILUX	88.723±4.538	0.824±0.040^{D}

Identical letters in the column indicate no statistically significant differences ($p>0.05$), while non-identical letters in the column indicate statistically significant differences ($p<0.05$).

result of these studies demonstrated that UNIFAST Trad, Dentalon Plus, and Protemp 4 had lower radiopacity values than dentin. Moreover, their radiopacity values were lower than 1 mm of aluminium thickness, which means that the radiopacity properties of these materials did not meet the requirements of the restorative materials.[22]

Nowadays, the radiopacity value of restorative resin used to reconstruct teeth should be distinguished from dentin in accordance with ISO requirements. However, X-rays will locate these materials in the event of an accident (such as one involving the GI tract or airway) but the radiopacity value is still not specified by any standard for these accidental occurrences. Thus, this investigation followed ISO 4049.

The radiopacity of provisional material groups shows significant difference because of radiopaque filler in their composition, as shown in Table 1.

In terms of radiopacity for provisional restoration materials, some of the tested materials were not specific in the type of fillers used in their formulation. But in basic knowledge, it is well known that the high atomic number elements of inorganic filler compounds play an important role in radiopaque value, such as titanium, strontium, yttrium, zirconium, barium, bismuth, and ytterbium. Therefore, many studies endeavored to develop radiopaque polymer-based dental materials[43,44], but the amount of radiopaque compound was limited by its physical and mechanical properties.[43,45]

Luxatemp Fluorescence is a material exhibiting fluorescent properties that impacts the optical behavior of provisional restoration in the oral cavity. Fluorescence is a phenomenon that happens when radiation with a shorter wavelength hits a natural tooth and causes it to be absorbed, and then visible light is emitted again. In this study, Luxatemp Fluorescence demonstrated the highest radiopacity because it might be composed of more inorganic filler and rare earth oxide[46], which are commonly used as fluorescence compounds for simulating natural tooth appearance under ultraviolet rays. The high atomic number of rare earth oxides may participate in the radiopaque of this specimen group. While SmarTempX1 has titanium dioxide and copper, which have a higher atomic number than the silica filler found in Protemp 4, there was no statistically significant difference between the Dentalon Plus group and UNIFAST Trad group because they might have a few radiopaque compounds.

VIPI BLOCK TRILUX is composed of three layers of PMMA with OMC nanotechnology, which can be used to create prostheses with a natural appearance. In addition, it ensures a high molecular weight as well as superior mechanical, chemical, and abrasion resistance. All this manufacturing claims the possibility of being provisional for long-term use. But it demonstrated a radiopacity value of only 0.824±0.040 mm thickness of aluminium for a haft of Luxatemp Fluorescense (1.536±0.086 mm thickness of aluminium). This may not contain the high-atomic-number element. According to this study, the chemical makeup of various materials causes them to have distinct radiopacities. Without compromising the material's optical and physical properties, radiopacity is primarily produced by adding heavy elements (atomic number>20) to the inorganic filler phase. Due to their potential negative effects on aesthetic materials' translucency and color stability, the addition of radiopacifiers is a process that is controlled by their properties. One of the most popular radiopacifiers is barium, although its inclusion is limited because of how it affects transparency. Because of this, the esthetic provisional materials had low radiopacity. Therefore, it is necessary to develop radiopaque aesthetic temporary materials.

Conclusions

The radiopacity of provisional restoration materials was not more than 2 mm of aluiminium thickness. The Bis-acryl composite material groups had a wide range of radiopacity values. Luxatemp Fluorescence showed the highest radiopaque. However, Protemp 4, UNIFAST Trad, and Dentalon Plus demonstrated the lowest radiopaque in this study.

Acknowledgments

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Conflicts of interest

The authors declare no conflicts of interest.

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