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In Vitro Comparison of Mechanical and Physical Properties of Various Provisional Restoration Materials

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Abstract

Objective: Provisional restorations should not fracture, get deformed, and show discoloration while in use. In our study, 6 different provisional restoration materials were subjected to microhardness test and flexural test in order to measure mechanical strength, surface roughness test, and discoloration test in order to evaluate esthetics.

Methods: Specimens for the 3-point bending test were loaded with a universal testing machine until fracture occurred. Baseline color measurements were made after Vickers microhardness and surface roughness tests. All specimens were immersed in the coffee solution for 7 days. Second color measurements were made and ΔE values were calculated. Statistical analysis of the data was made with Statistical Package for the Social Sciences for Windows 11.5. Kruskal–Wallis test was used in order to evaluate the level of significance ($P < .05$).

Results: Flexural strength values varied between 146 MPa and 63 MPa. The strongest groups were Imident and Protemp 4. Microhardness and surface roughness evaluation showed methacrylate resins are stronger than other groups. As for color stability, polymethyl methacrylate groups were found to discolor less than other groups. Revotek LC and Protemp 4 showed clinically unacceptable ΔE values ($\Delta E > 3.3$).

Conclusions: Based on this study data, it is advised to use heat-polymerized polymethyl methacrylate when long-term use is indicated.

Keywords: Provisional restoration, acrylic resins, CAD/CAM, discoloration, flexural strength

INTRODUCTION

The glossary of prosthodontic terms defines provisional restoration as "a fixed or removable dental prosthesis, or maxillofacial prosthesis designed to enhance esthetics, stabilization and/or function for a limited period of time, after which is to be replaced by a definitive dental or maxillofacial prosthesis."[1] It is important to use a provisional restoration during fixed prosthetic treatment in order to protect hard and soft tissues and maintain patient comfort.[2] Provisional restorations should be strong enough to withstand functional loads, stabilize teeth, protect pulp and periodontium, and have a good esthetic appearance. A decent provisional restoration should not be very different from a definitive restoration.[2,3] These restorations are particularly important in the anterior region where esthetics is an utmost necessity.[4] It is crucial that provisional restorations do not show discoloration during use.[5] A discolored provisional restoration leads to patient dissatisfaction and additional costs due to replacement.[6] Provisional restorations exhibit lower fracture strength values compared to definitive restorations. Therefore, more durable provisional restoration materials are needed when long-term temporary restorations, multi-unit bridges, temporomandibular rehabilitations, and occlusal vertical dimension alterations are indicated. Also, stronger materials are needed while treating patients with bruxism.[7-9] Various methods are recommended to strengthen provisional restorations. However, these methods complicate fabrication since additional materials, additional costs, and technical knowledge are needed. Recently, computer-aided design/computer-aided manufacturing (CAD/CAM)

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provisional materials are introduced in dentistry. These CAD/CAM materials are fabricated under optimal conditions, and increased strength is expected. Also, porosities and voids are prevented since the material is not mixed and cured in clinic or laboratory conditions. The CAD/CAM-fabricated provisional restorations reduce chairside time and produce good esthetic results.[10]

The aim of this study is to compare mechanical strength and esthetic outcomes of various provisional restoration materials including CAD/CAM blocks and traditional resin materials. In order to evaluate esthetic outcomes, surface roughness and discoloration of the materials were tested. Additionally, microhardness and flexural strength tests were performed for the purpose of evaluating mechanical strength.

The null hypothesis of this study is that CAD/CAM provisional materials will exhibit superior mechanical and physical properties than conventional materials.

MATERIAL AND METHODS

This study tested 6 different provisional restoration materials: 2 CAD/CAM resin materials, 1 auto-polymerizing acrylic resin, 1 heat-polymerizing acrylic resin, 1 visible light cure resin, and 1 auto-polymerizing bis-acryl resin (Table 1). Materials were selected in order to represent products available for dental use with different polymerization types and contents.

For flexural strength testing, standard specimens for 6 materials were manufactured with dimensions of 2 × 2 × 25 mm according to ISO 4049:2000 (Dentistry-Polymer-Based-Restorative Materials). Sample size for each group was n=15. The CAD/CAM resin specimens were cut to the determined size using a precision saw (Isomet 4000, Buehler IL, ABD). Revotek LC, Protemp 4, and Dentalon Plus specimens were polymerized according to the manufacturer's instructions with the help of a silicone mold that was compressed between 2 glass plates. Light-cured resin Revotek LC was polymerized for 40 seconds using a light curing unit (Hilux Optimax, 800 mW/cm^2, Benlioglu Dental, Ankara, Turkey). Imident specimens were prepared by flasking and heat polymerized according to the manufacturer's instructions. All specimens were polished with 400, 800, 1200, and 2400 grit SiC sandpaper, respectively. After polishing, specimens were stored in distilled water at 25°C for 1 week until testing.

For other tests, disc-shaped specimens with 2 mm thickness and 10 mm diameter were manufactured for the 6 tested materials (sample size for each group is n=15). The CAD/CAM resin specimens were cut initially as a square with 2 × 10 × 10 mm dimensions using a precision saw (Isomet 4000, Buehler IL, ABD). Square specimens were then cut to meet 10 mm standard discs with a rotary laboratory tool. Revotek LC, Protemp 4, and Dentalon Plus specimens were polymerized according to the manufacturer's instructions with the help of a silicone ring mold sandwiched between 2 glass plates. Glass plates were used during polymerization in order to compress and shape the material. Light-cured resin Revotek LC was polymerized for 40 seconds (20 seconds on each side) using a light curing unit (Hilux Optimax, 800 mW/cm^2, Benlioglu Dental, Ankara, Turkey). Imident specimens were prepared by flasking and heat polymerized according to the manufacturer's instructions. All specimens were polished with 400, 800, 1200, and 2400 grit SiC sandpaper, respectively. After polishing, specimens were stored in distilled water at 25°C for 1 week until testing.

Surface roughness (R_a) of specimens was tested with a profilometer (Perthometer M2, Mahr GmbH, Göttingen, Germany) before treating them with coloring agents. For each specimen, 3 readings were made by turning the position of the profilometer 120° clockwise after each reading. The average surface roughness values of 3 readings were calculated for each specimen.

Microhardness was measured with a microhardness tester (Shimadzu HMV-2, Tokyo, Japan). Vickers hardness values were measured from each specimen 4 times with 98.07 Nm force for 15 seconds. The average values of 4 readings were calculated for each specimen.

Color measurements were made in 2 stages as baseline and color treated (Datacolor SF-600 Spectrophotometer, NJ, USA). Baseline measurements were made following polishing procedures and 1-week storage in distilled water. L_1, a_1, and b_1 data were recorded. After all baseline measurements

Table 1. The Tested Materials, Compositions, Batch Numbers, and Manufacturers of the Test Groups

Materials	Composition	Batch Number	Manufacturer
CAD-Temp	Polyacrylic resin with 14% micro fillers	45870/34760	Vita Zahnfabrik, Bad Sackingen, Germany
Telio CAD	99.5% PMMA polymer	T20206	Ivoclar Vivadent, Schaan, Liechtenstein
Revotek LC	Visible light cure UDMA	1401272	GC, Tokyo, Japan
Protemp 4	Auto-polymerizing bis-acrylic resin	555927	3M ESPE, Neuss, Germany
Dentalon Plus	Auto-polymerizing PEMA/PMMA	010215/010293	Heraeus Kulzer, Hanau, Germany
İmident	Heat polymerized PMMA	13351/14164	İmicryl, Konya, Turkey

CAD, computer-aided design; PEMA, poly(ethyl methacrylate); PMMA, poly(methyl methacrylate).

were completed, all specimens were immersed in the coffee solution in order to color specimens. The coffee solution was prepared by mixing 2 g of instant coffee (Nescafe Classic, Nestle, Switzerland) with 200 mL of hot water and was refreshed every day for 7 days. The coffee solution was set aside for cooling after preparation until it reaches room temperature which is approximately 25°C. After cooling down to room temperature, specimens were immersed in the solution. At the end of the 7-day coloring period, all specimens were washed with distilled water for 20 seconds and blot dried with a paper towel. Second measurements were made, and L_2, a_2, and b_2 data were recorded. ΔE was calculated with the formula $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$.

After 1-week storage in distilled water, 2 × 2 × 25 mm-sized specimens were positioned on a flexural strength testing apparatus with 20 mm support separation. A 3-point bending test was carried out with a universal testing machine (Lloyd Instruments, Fareham, Hampshire, England) until fracture occurs at a crosshead speed of 5 mm/min according to ISO 1567. Maximum load at the time of fracture was recorded for each specimen in MPa units. Flexural strength was calculated by using the following equation:

$$\sigma = 3FL/2bh^2$$

where *F* is the maximum load exerted on the specimen, *L* is the distance between the supports, *b* is the width at the center of the specimen, and *h* is the height at the center of the specimen.

Statistical analyses were performed using Statistical Package for the Social Sciences for Windows (release 11.5, SPSS Inc., Chicago, Ill, USA) on a significance level of 5%. Assessment of normality was tested using Kolmogorov–Smirnov test and homogeneity of variance was assessed using Levene's test. Descriptive statistics were shown as median and interquartile range. Kruskal–Wallis test was used in order to investigate the significance of the difference between groups. Spearman's Correlation test was used to investigate whether there was a statistically significant relationship between constant variables.

Ethical statement

This research did not need an ethics committee approval since it was solely designed with dental restorative materials, did not contain human or animal subjects. Therefore there was no need for an informed consent.

RESULTS

Surface roughness measurement data of the tested materials are shown in Table 2 and Figure 1. In terms of median data, the maximum surface roughness values were observed in Revotek LC. While Protemp 4 and Cad-Temp showed similar surface roughness values, the lowest values were observed in the heat-cure acrylic material Imident. According to Kruskal–Wallis test, the difference between Imident and the other groups was found statistically significant.

Microhardness measurement data of the tested materials are shown in Table 2 and Figure 2. In terms of median data, the maximum microhardness values were found in Cad-Temp group. Imident and Telio-Cad groups showed similar microhardness values. The Protemp 4 group showed markedly lower microhardness values.

Discoloration data of the tested materials are shown in Table 2 and Figure 3. According to the data, the highest ΔE values were observed in group Protemp 4. Although all specimens showed discoloration, the lowest ΔE values were observed in Cad-Temp and Telio-CAD groups which were CAD/CAM materials of this study.

Flexural strength data of the tested materials are shown in Table 2 and Figure 4. In terms of median data, the highest values were observed in Imident and Protemp 4 groups, and the lowest values were observed in Dentalon Plus group.

DISCUSSION

Provisional crowns and bridges are made in order to protect teeth and surrounding tissues while definitive restorations are prepared. Provisional restorations should have the following goals in fixed prostheses: They should be esthetic, comfortable, allow for decent function and speech, maintain periodontal health and maxillomandibular relations, and act as a trial for definitive restorations.[4]

Materials and techniques used in provisional restorations should be in a way to fulfill the requirements of planned treatment. As in all dentistry areas where material knowledge plays an important role, an ideal provisional material

Table 2. Median and Interquartile Range Values of Flexural Strength, Microhardness, Surface Roughness, and ΔE for the Tested Materials

	Flexural Strength (MPa)	Microhardness	Surface Roughness (R_a)	Color Stability ΔE
Vita	78.21 (11.25)	27.97 (2.48)	0.27 (0.17)	1.73 (1.18)
Ivoclar	116.80 (61.82)	24.72 (2.58)	0.17 (0.06)	1.92 (0.58)
Revotek	83.59 (23.34)	14.47 (1.25)	0.43 (0.23)	4.64 (0.79)
Protemp	146.23 (33.99)	3.19 (0.58)	0.35 (0.17)	5.80 (2.59)
Dentalon	63.09 (19.53)	13.57 (1.60)	0.19 (0.03)	3.16 (0.72)
Imicryl	146.09 (28.32)	26.65 (3.08)	0.11 (0.02)	2.83 (0.76)

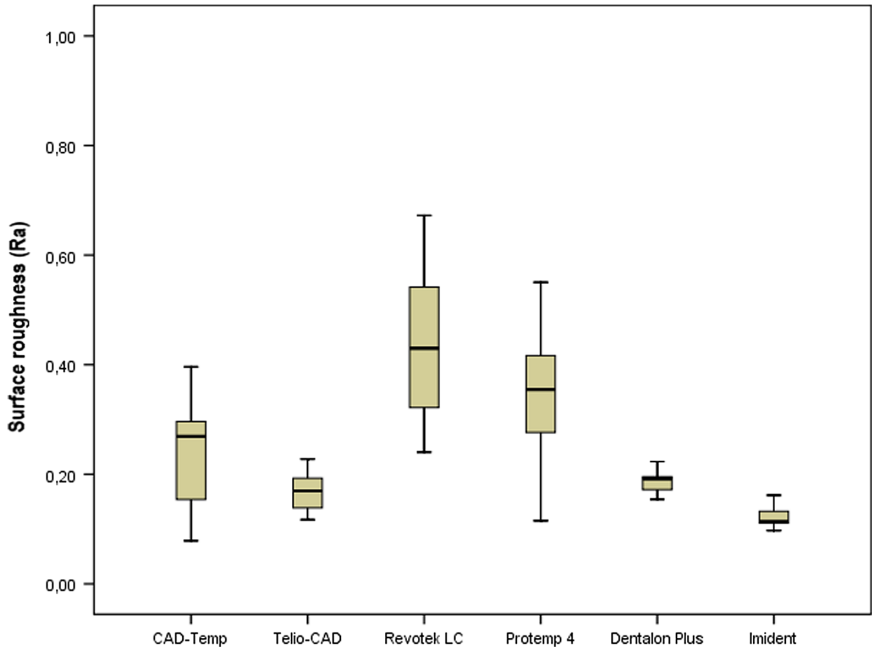

Figure 1. Surface roughness values.

to suit every clinical situation and treatment planning does not exist. The dentist should choose an appropriate material according to the type and duration of treatment. For instance, a restoration in the anterior area needs to be more esthetic than a restoration in the posterior region. It should match natural tooth color, not show discoloration, be translucent, and allow for color modifications.[4,11] Long-term provisional restorations or restorations with long pontics should be mechanically more resistant.[4,8,12]

Mechanical and physical properties are important for material selection for provisional crowns and bridges. Material

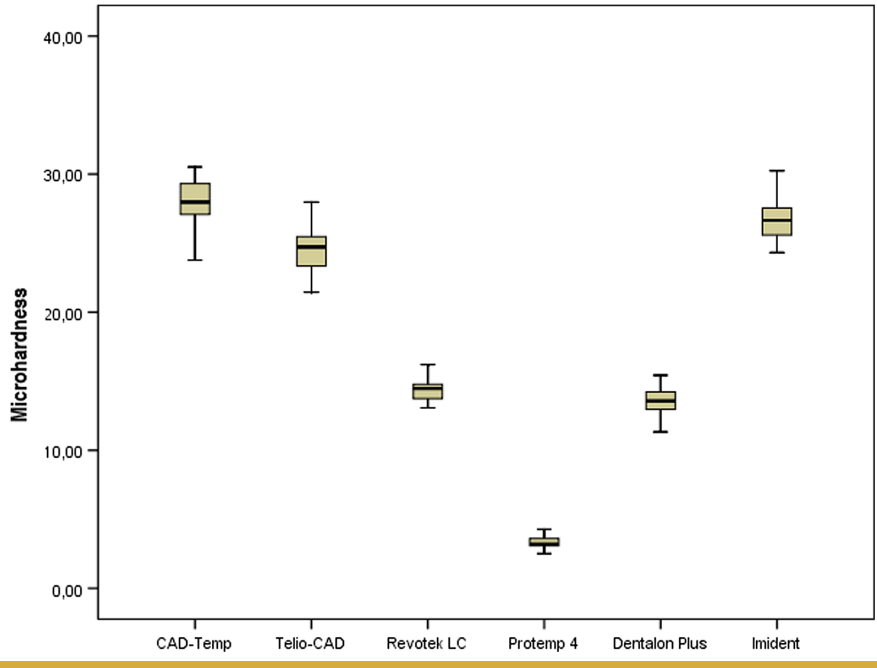

Figure 2. Microhardness values.

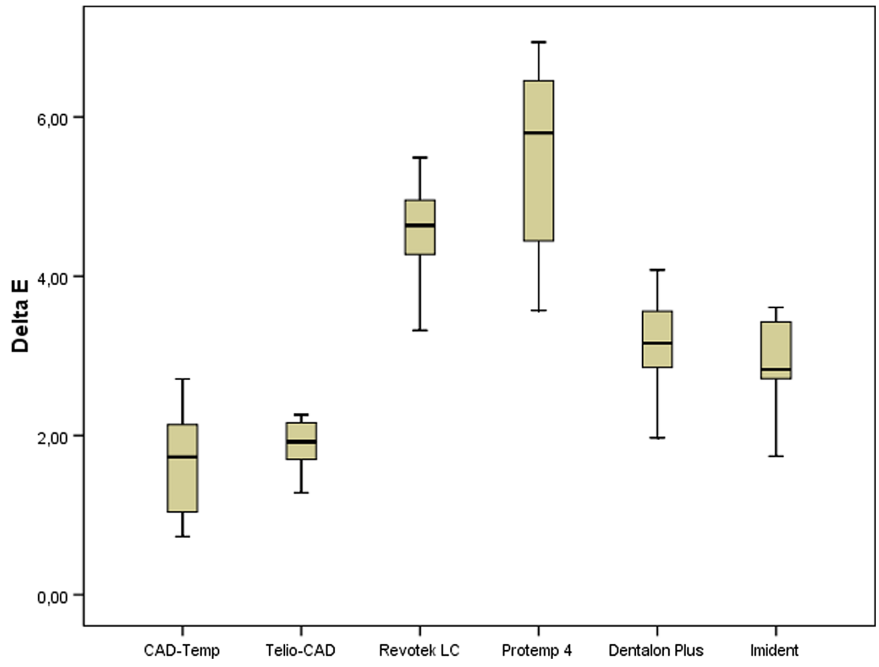

Figure 3. Delta E values.

selection should be made in accordance with the strengths and weaknesses of the material in order to fulfill the clinical requirements of the treatment.[13] Material selection for provisional restorations affects mechanical and physical properties, ease of use, and biocompatibility.[14]

In our study, we compared the physical and mechanical properties of 6 different provisional restoration materials. When choosing the materials, we tried to include bis-acryl, urethane dimethacrylate (UDMA) and methacrylate materials, and CAD/CAM blocks which are widely used in clinics.

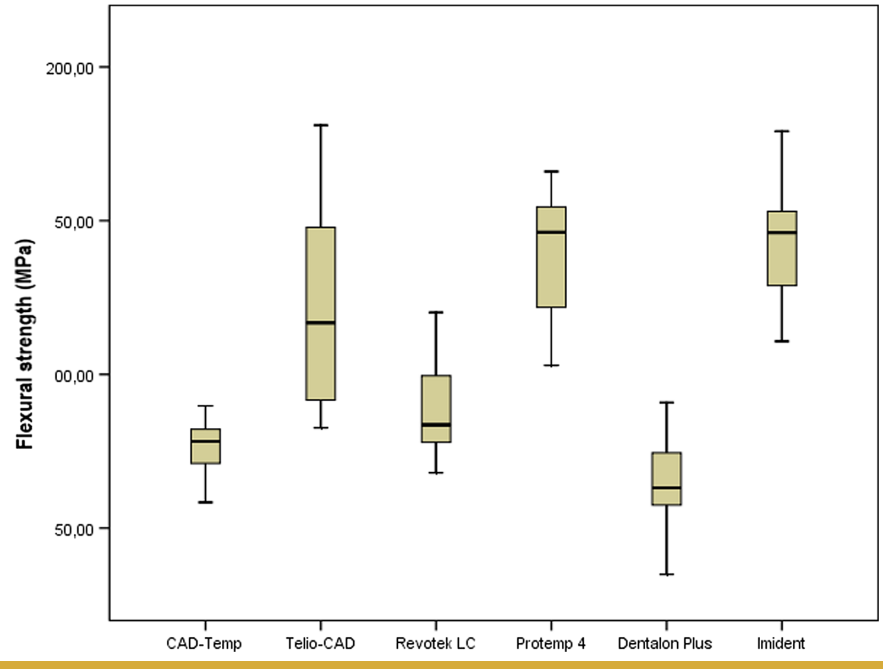

Figure 4. Flexural strength values.

Yao et al[15] studied the bending strengths of 2 bis-acryl resin (Protemp 4, Structure 2 SC/QM) and 2 CAD/CAM blocks (Telio-CAD and Cad-Temp).[15] Twenty samples from each group were prepared in 25 × 2 × 2 mm dimensions and subjected to a 3-point bending test. In the results, while Telio-CAD showed the highest bending resistance, Cad-Temp had the lowest bending resistance. They also found that other bis-acryl materials had similar values and they were higher than Cad-Temp.

Sharma et al[16] compared the flexural strength of UDMA with auto-polymerizing polymethyl methacrylate (PMMA) temporary restoration materials. Rod-shaped test specimens (n=20) were subjected to a 3-point bending test after being kept in artificial saliva for 10 days. They stated that the average flexural strength of PMMA was significantly higher than UDMA. The authors discussed that polymerization shrinkage was much less than that of PMMAs in UDMA, that the material contracted in the middle of the mass during shrinkage, and this could make a difference in flexural strength. They suggested the use of PMMA material for long-term treatments. In our study, we found results similar to the results of Sharma et al.

The flexural strength of provisional restoration materials is an important mechanical property. If a restoration needs to be used for a prolonged time, patient has parafunctional habits and multi-member bridges are required, the importance of material properties increases. Although tests performed in the laboratory cannot mimic exact clinical conditions, these tests that are conducted in a controlled environment allow us to compare materials. It has been shown in the literature that flexural strength is not only related to resin type but also to the chemical composition of a material.[13,17,18] In our study, PMMA material Imident showed the highest flexural strength with an average value of 143.14 MPa. Protemp 4, a bis-acryl material, exhibited very close flexural strength to Imident with an average value of 139.65 MPa. Telio-CAD, which is the other PMMA material and prepared in factory conditions, ranked third with 116.79 MPa. Polyethyl methacrylate (PEMA) material Dentalon Plus had the lowest value with 64.49 MPa. The different results between the methacrylate materials support the thesis that flexural strength depends on material composition and not the type of resin.[13,17,18]

In many studies, it has been found that the mechanical properties of polymer resins depend on the degree of conversion of monomer to polymer.[19-22] In this context, some researchers have shown that the hardness of a material is a simple and effective method for measuring the degree of its conversion. Stawarczyk et al[23] examined wear of CAD/CAM resin blocks and found that hardness and surface properties of restorations are important factors affecting wear on antagonist tooth.[23] Hardness of resin materials gives us information about the degree of transformation.[24,25] Resins that have low conversion rates can release monomers to the environment they are in, and they also have a negative effect on wear resistance. Residual monomer affects the amount of water absorption.[25]

Studies show that water absorption affects fatigue strength, flexural strength, and stiffness of UDMA, bis-acryl, and acrylic provisional restoration materials.[9,26-28]

In our study, the lowest microhardness value was found in Protemp 4 which is a bis-acryl material. Diaz-Arnold et al[29] found the hardest material as bis-acrylic, but the results of Yap et al.[30] showed similar values to our study. The bis-GMA used in bis-acrylic resins has a rigid central structure and has limited participation in polymerization process. Resins made of this structure have low polymerization degrees.[24] This may be the reason why bis-acrylics exhibit low hardness values compared to other resins, although they have inorganic fillers in their structures.[30]

Haselton et al[5] investigated the color stability of 12 different provisional restoration materials consisting of methacrylates and bis-acrylates. For 1, 2, and 4 weeks, the samples were kept in artificial saliva and coffee solution. They measured color values before and after staining, while coffee produced the highest coloration in all groups, the highest ΔE values were found in Provipont from the bis-acryl group. The least color change was observed in the Zeta CC of the methacrylate group. Similar to the results of Haselton et al.[5] the highest ΔE value was found in Protemp 4 which was bis-acryl in our study.

Similar to other studies in literature, bis-acryl material (Protemp 4) was found to be worse in color stability than PMMA and PEMA materials. Discoloring of bisphenol A-glycidyl methacrylate (bis-GMA) may be due to polar OH– groups in monomer structure. This feature of bis-GMA causes more water absorption.[31] Protemp 4 contains bis-GMA, UDMA, triethylene glycol dimethacrylate (TEGDMA), and bis-EMA. When TEGDMA in bis-GMA increases from 0% to 1%, water absorption increases from 3% to 6%.[32] Most dimethacrylates are more polar than monomethacrylates such as PMMA and therefore have higher affinity to water.[5] Revotek LC is composed of urethane dimethacrylate structurally. In our study, Revotek LC showed the highest ΔE values after Protemp 4 in accordance with this information. In the literature, it is stated that highly cross-linked resins show less water absorption.[33,34] The Vita Cad-Temp material used in the study was also composed of cross-linked acrylate polymer. The Cad-Temp material showed the lowest ΔE values and was found to be the best in terms of color stability.

Surface roughness in composite resin materials depends on size, hardness, and quantity of filler particles.[35,36] In provisional restoration materials, resistance to coloration can be affected by the presence of filler particles or the chemical

properties of the material.[37,38] Other factors affecting roughness are abrasive particles used in polishing methods, pressure applied to the surface, polishing time, and direction of abrasion.[39,40]

Sen et al[41] compared the surface roughness of 6 different provisional restoration materials, 3 of which were bis-acryl resins and 3 of which were methacrylate resins. The samples were polished with aluminum oxide paste and diamond paste. As a result of the profilometer analysis, bis-acryl groups were found to show more surface roughness than the methacrylate-based resin groups in both polishing methods. It was concluded that methacrylate materials could be better polished. In accordance with the results of Sen et al.[41] the lowest R_a values were recorded in PMMA materials which are Imident and Telio-CAD in our study.

The reason why methacrylate resins have smoother surfaces than bis-acryls may be the more homogeneous structure of acrylic material and the heterogeneous structure of composite materials.[42] Bis-acrylic composite resins have organic polymer matrix and inorganic filler particles. The presence of filler particles, their size, and their density can affect their polishability.[43] In the study of Sen et al.[41] it was observed that in the scanning electron microscope (SEM) image of bis-acryls, fillers were protruding on the surface. This is explained by the fact that the resin matrix, which is softer than the fillers, is removed during polishing.

Based on the results of our study, it was concluded that heat-polymerized PMMA material is more advantageous than the other groups. The PMMA has been found to be better polishable than other groups and has the highest color stability. The PMMA also showed superior mechanical properties and high bending strength. While discoloration of the CAD/CAM blocks is very low, flexural strengths are not satisfactory. Therefore, the null hypothesis was rejected. In order for CAD/CAM resin blocks to give good results in long-term clinical use, the material needs to be improved and further studies are needed.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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