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Research Article / Araştırma Makalesi

The Effect of the Toothbrushing and Surface Treatments on the Surface Roughness of Interim Crown Materials Used for Conventional, Subtractive, and Additive Manufacturing Techniques: An *in Vitro* Study

Konvansiyonel, Eksiltmeli ve Eklemeli İmalat Tekniklerinde Kullanılan Geçici Kron Materyallerinin Yüzey Pürüzlülüğüne Diş Fırçalama ve Yüzey İşlemlerinin Etkisi: *in Vitro* Çalışma

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ABSTRACT

Background: This study aimed to compare the effect of the surface treatment and toothbrushing abrasion on the surface roughness of interim crown material specimens manufactured using conventional, subtractive, and additive processing techniques.

Material and methods: 80 disk-shaped specimens were prepared from 4 different interim crown materials; one auto-polymerized polymethyl methacrylate resin (PMMA);(IM) and one bis-acryl composite resin;(AC) for conventional technique, one computer-aided design/computer-aided manufacturing (CAD-CAM) PMMA block;(TC) for subtractive process, one 3-dimensionally (3D) printed resin;(CB) for additive process. Specimens of each interim crown material were divided into two subgroups according to applied surface treatments; conventional polishing or surface sealant agent coupling (n=10). The surface roughness values of specimens before (Ra0) and after 10,000 cycles of toothbrushing (Ra1) were measured with a profilometer. Data were statistically analyzed.

Results: The polished groups of all interim crown materials showed significantly higher Ra0 values compared to the sealant groups before toothbrushing ($p<0.05$). While the polished IM groups exhibited the highest Ra0 value (0.44±0.08), the sealed TC groups exhibited the lowest Ra0 value (0.23±0.06). The Ra values of all material groups increased after simulated 1-year toothbrushing. While the polished IM group exhibited the highest Ra1 value (0.45±0.14), the sealed CB group had the lowest Ra1 value (0.31±0.09).

Conclusion: It was observed that toothbrushing caused an increase in the surface roughness of all interim materials. The application of a surface sealant agent to these materials is more effective than polishing to reduce surface roughness. Sealed 3D printed resin for additive process exhibited the lowest mean roughness value after toothbrushing.

Keywords: Additive Manufactured, Interim Crown Material, Roughness, Subtractive Manufactured, Toothbrushing Abrasion

ÖZ

Amaç: Çalışma konvansiyonel, eksiltmeli ve eklemeli imalat yöntemleri kullanılarak üretilen geçici kron materyali örneklerin yüzey pürüzlülüğüne yüzey işlemi ve diş fırçası aşınmasının etkisini karşılaştırmayı amaçladı.

Gereç ve yöntemler: 4 farklı geçici kron materyalinden toplamada 80 adet disk şeklinde örnek hazırlandı; konvansiyonel üretim için bir oto-polimerizan polimetil metakrilat rezin (PMMA);(IM) ve bis-akrilik kompozit rezin;(AC), eksiltmeli imalat için bilgisayar destekli tasarım-bilgisayar destekli üretim (CAD-CAM) PMMA blok;(TC), eklemeli imalat için 3 boyutlu yazıcı rezini (3D); (CB). Her bir geçici kron materyaline ait örnekler konvansiyonel polisaj veya yüzey örtücü ajan uygulaması için iki alt gruba ayrıldı (n=10). Örneklerin 10.000 diş fırçalama öncesi (Ra0) ve sonrası (Ra1) yüzey pürüzlülük değerleri profilometre ile ölçüldü. Veriler 2 yönlü ANOVA, Bonferroni post hoc ve paired sample t-testi ile istatistiksel olarak analiz edildi.

Bulgular: Tüm geçici kron materyallerinin konvansiyonel polisaj işlemi uygulanmış gruplarının Ra0 değerleri, yüzey örtücü uygulanmış gruplarına kıyasla anlamlı derecede daha yüksekti ($p<0.05$). Polisajlı IM grupları en yüksek Ra0 değerine sahipken (0,44±0,08), yüzey örtücü uygulanmış TC grubu en düşük Ra0 değeri göstermiştir (0,23±0,06). 1 yıllık diş fırçalaması sonrası tüm materyal gruplarının Ra değerleri artmıştır. Polisajlı IM grubu en yüksek Ra1 değerine sahipken (0,45±0,14), örtücü uygulanan CB grubu en düşük Ra1 değeri göstermiştir (0,31±0,09).

Sonuç: Test edilen materyallere yüzey örtücü uygulaması yüzey pürüzlülüğünü azaltmada konvansiyonel polisaja kıyasla daha etkilidir. Fırçalamanın test edilen tüm geçici kron materyallerinin yüzey pürüzlülüğünde artışa neden olduğu görülmüştür. Fırçalama sonrası tüm materyaller içinde yüzey örtücü uygulanmış 3D yazıcı rezinin yüzey pürüzlülüğü en düşüktür.

Anahtar Kelimeler: Diş Fırçası Abrazyonu, Eklemeli İmalat, Eksiltmeli İmalat, Geçici Kron Materyali, Pürüzlülük

INTRODUCTION

Interim crown restorations are widely used in prosthetic treatments to protect the prepared tooth from external factors, the prevention of tooth movements, and maintain oral function and aesthetics until definitive restorations are placed in dentistry. In the fabrication of interim crown restorations, resin-based materials such as polymethyl methacrylate (PMMA) and bis-acryl composite resin can be used. Auto-polymerized PMMA resin and bis-acryl composite resin have been manually used in the conventional production of interim crowns for many years.[1,2] Thanks to advances in digital dental technologies, computer-aided design/computer-aided manufacturing (CAD/CAM) materials have made possible the use of techniques such as subtractive milling and additive 3-dimensionally (3D) printing in the production of these restorations in recent years.[3]

Interim crown restorations should provide sufficient mechanical strength, abrasion resistance, and color stability to receive biological and aesthetic requirements.[4] In addition, they should be able to maintain these properties long-term in situations requiring more comprehensive prosthetic rehabilitation or interdisciplinary treatment cooperation.[5] Surface roughness, an important parameter to fulfill these requirements, is highly effective on plaque deposition, final aesthetic appearance and color of restorations, gingival health, and secondary caries. Smooth interim crown surfaces are less susceptible to dental plaque accumulation and bacterial colonization, as plaque

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attachment is associated with surface irregularities and roughness.[6,7]

After finishing with burs and abrasive stones, polishing the material surface with a water-pumice mixture, polishing paste, or liquid polishing agents is effective against the surface irregularities of interim crown materials.[8] Surface sealant agents have recently been developed to reduce surface irregularities, achieve smooth surfaces, improve wear resistance, and prevent discoloration and staining of the resin.[9] However, there is not enough investigation about the long-term performance of these agents applied to interim restorative materials in the presence of thermal and mechanical variables.

Due to the abrasive effect of toothbrushing that is used to maintain oral hygiene, the increased surface roughness of restorative materials can cause aesthetic and biological disadvantages resulting in plaque accumulation, discoloration, and decreased gloss.[10] Therefore, it is significant to understand how brushing with a toothbrush affects the surface of restorative crown material and in this context artificial brushing, one of the abrasion tests, can be used to determine the longevity of restorative materials.[11] Furthermore, the authors are unaware of studies that evaluated the effect of different surface treatments and toothbrushing abrasion on the surface and integrity of conventionally, additively, and subtractively manufactured interim crown material. Therefore, this study aimed to compare the change in surface roughness of the interim crown materials with different surface treatments manufactured using different production methods; conventional, subtractive, and additive methods, before and after toothbrush abrasion. The first null hypothesis was that the surface roughness of interim crown materials would not be affected by the type of interim crown materials (conventionally, subtractively, and additively manufactured) and surface treatment. The second null hypothesis was that toothbrushing would not affect the surface roughness of different interim crown materials with different surface treatments.

MATERIALS AND METHODS

This in vitro study evaluated the surface roughness of conventional polished or surface sealant agent applied 4 different interim crown materials before and after toothbrush abrasion: a conventional auto-polymerized PMMA (Imident; Imicryl, Konya, Turkey) (IM), an auto-polymerized bis-acryl composite resin (Acrytemp; Zhermack, Bovazecchino, Italy) (AC), a CAD/CAM PMMA block (Telio CAD; Ivoclar Vivadent Schaan, Liechtenstein) (TC), and a 3D-printed polymer-based resin (Temporary C&B; Formlabs, Somerville MA, USA) (CB). The interim materials and the surface sealant agent used are shown in **Table 1**. Based on the findings of previous research examining the surface roughness of interim crown materials that reported significant differences, the number of specimens in each group was determined.[12,13]

Table 1. Materials used in the study

Materials (Code)	Type	Components	Manufacturer
Imident (IM)	Conventional auto-polymerized PMMA	Polymethyl methacrylate powder (cadmium free), methyl methacrylate monomer	Imicryl
Acrytemp (AC)	Auto-polymerized bis-acryl composite resin	Mixture of polyfunctional acrylates and methacrylates, unsaturated esters and malonyl urea derivates.	Zhermack
Telio CAD (TC)	CAD/CAM PMMA-based polymers	Polymethyl methacrylate	Ivoclar Vivadent,
Temporary C&B resin (CB)	3D printed polymer-based resin	Esterification products of 4,40-isopropylidenediphenol, ethoxylated and 2-methylprop-2-enoic acid	Formlabs,
Optiglaze Color	Surface sealant agent	Methyl methacrylate, polymethyl methacrylate, silica filler, photo inhibitor	GC Corp.

PMMA: Polymethyl methacrylate

Preparations of the specimens

Twenty disk-shaped specimens (10×2) were prepared from each interim crown material. A stainless-steel mold was used to fabricate IM and AC specimens (**Fig.1**).

Figure 1. Stainless-steel mold for conventional PMMA and bis-acryl composite resin materials

Mixing and polymerization processes were carried out according to the manufacturer's instructions and a constant load was applied with a glass slide to remove excess material, flatten the surface and reduce surface voids until they chemically polymerized. A disk-shaped 3D model (2 mm thickness, 10 mm diameter) was designed in the Fusion 360 CAD software program (Autodesk, Mill Valley, CA, USA) for CAD-CAM and 3D specimens (**Fig.2**).

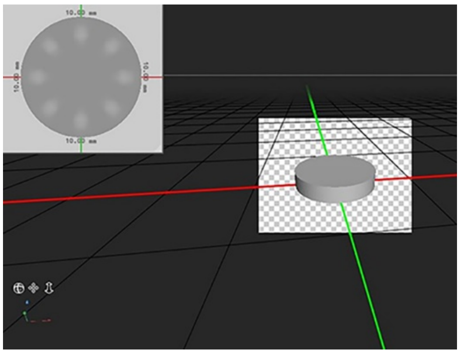

Figure 2. 3D model designed in Fusion 360 CAD software program

This digital design was exported to produce the specimens in a Standard Tessellation Language (STL) file. The TC specimens were produced by using a 5-axis milling machine (HinriMill 5, Goslar, Germany) from pre-polymerized PMMA resin blocks. The CB specimens were produced by using Stereolithography (SLA) 3D printing technology (Form 3B, FormLabs, Somerville, MA, USA). The layer thickness of each specimen was set to 50 µm and the build orientation was 0 degrees. The printed specimens were washed with 90% isopropyl alcohol using ultrasonic cleaning (Form Wash, Formlabs, Somerville, MA, USA) and then subjected to a post-polymerization process in a polymerization unit (PCA 100; EnvisionTEC, MI, USA).

Surface Treatment Procedure

All of the specimens were then finished with a carbide bur and were wetly grounded with 400-grit silicon carbide paper. Specimens of each interim crown material were divided into two subgroups for conventional polishing or a surface sealant agent (n=10). The conventional polishing group specimens of each interim material were first polished using a mixture of pumice and water. Finally, fine polishing was carried out by using a polishing paste (Universal Polishing Paste, Ivoclar Vivadent, Liechtenstein). In the other test group, the surfaces of the specimens were coated with a surface sealant agent (Optiglaze Color, GC, Tokyo, Japan) using a bristle brush. Twenty seconds later, the specimens were polymerized with an LED unit for 90 seconds (Labolight Duo, GC, Leuven, Belgium). One operator completed all of the procedures.

Measuring the Surface Roughness and Toothbrushing Procedure

Initial surface roughness (R_a0) values of all specimens were measured with a contact profilometer (SJ-210, Mitutoyo, Tokyo, Japan) with a diamond needle. Profilometer's stylus speed was 0.5 mm/sec, and the cutoff length was 0.80 mm. For each specimen, the measurement was repeated 3 times from different points of the specimen13 and the Ra0 value was obtained by calculating the mean values of the measurements. The specimens were then subjected to the artificial toothbrushing procedure by using a simulation device (DentArge TB-6.1; Analytical Medical, Gaziantep, Turkey). The simulation was carried out in back and forth direction for 10,000 brushing cycles, which corresponds to 1 year of toothbrushing14,15 with a toothbrush and a slurry of toothpaste-water (1:1 weight ratio) (**Fig. 3**). The toothbrush and a fresh slurry of toothpaste were changed for each specimen. After brushing, the specimens were washed under water for 1 minute and dried for 24 hours. The surface roughness measurements of the specimens were repeated with the same procedure and R_a1 values were obtained.

Figure 3. Toothbrushing simulation device used in the study

Scanning Electron Microscopy (SEM)

The surfaces of one extra specimen prepared from each group were observed using a SEM (Zeiss EVO LS 10, Oberkochen, Germany) at ×1000 magnification. An operating voltage of 15 kV was used for the SEM investigation.

Statistical Analysis

Statistical analyses were performed using a software program (SPSS 23.0, IBM, Armonk, NY, USA). The distribution of the variables was evaluated with the Kolmogorov-Smirnov test of homogeneity. A 2-way analysis of variance (ANOVA) was performed to analyze the Ra results because the normal distribution was observed. Mean R_a values were compared with the Bonferroni test and the paired sample t-test was used to compare pairwise comparisons of the R_a0 and R_a1 values of each group (α=0.05).

RESULTS

The results of the 2-way ANOVA test showed that the evaluated type of interim crown materials (conventionally, subtractively and additively manufactured), surface treatment technique, and their interaction were statistically significant on R_a0 values ($p<0.05$) (**Table 2**).

Table 2. Results of two-way ANOVA for R_a0 values

	SS	df	MS	F	p
Interim material (A)	0.057	3	0.019	3.928	0.012
Surface treatment (B)	0.220	1	0.220	45.758	0.001
A×B	0.045	3	0.015	3.110	0.032
Error	0.346	72	0.005		
Total	8.159	80			

SS, sum of squares; df, degrees of freedom; MS, mean square; F, F value (variation between sample means/variation within the samples).
***Significantly different at p<0.05*

For Ra1 values, only the surface treatment technique was statistically significant ($p<0.05$) (**Table 3**). The mean R_a0, R_a1 and standard deviation (SD) values of test groups, the multiple comparisons of these values according to Bonferroni post hoc tests, and the pairwise comparisons according to the paired sample t-tests are shown in **Table 4**.

Table 3. Results of two-way ANOVA for R_a1 values

	SS	df	MS	F	p
Interim material (A)	0.016	3	0.005	0.399	0.754
Surface treatment (B)	0.143	1	0.143	10.786	0.002
A×B	0.045	3	0.015	1.125	0.345
Error	0.957	72	0.013		
Total	12.151	80			

SS, sum of squares; df, degrees of freedom; MS, mean square; F, F value (variation between sample means/variation within the samples).
***Significantly different at p<0.05.*

Table 4. The mean R_a0 and R_a1 values (µm) and standard deviations (±SD) of test groups with Bonferroni multiple and paired sample t-test comparisons

Surface treatment	Interim material	R_a0	Bonferroni	R_aI	Bonferroni	t-test
Conventional Polishing	TC	0.35 ± 0.04	Aa	0.39 ± 0.13	Aa	0.364
	IM	0.44 ± 0.08	Ba	0.45 ± 0.14	Ba	0.748
	AC	0.31 ± 0.03	Aa	0.37 ± 0.11	Aa	0.142
	CB	0.34 ± 0.06	Aa	0.44 ± 0.12	Ba	0.023
Sealant application	TC	0.23 ± 0.06	Ab	0.35 ± 0.16	Aa	0.048
	IM	0.27 ± 0.12	Ab	0.32 ± 0.08	Ab	0.239
	AC	0.27 ± 0.05	Ab	0.33 ± 0.06	Aa	0.031
	CB	0.24 ± 0.07	Ab	0.31 ± 0.09	Ab	0.046

**TC; CAD/CAM PMMA-based polymers, IM; conventional auto-polymerized PMMA AC; auto-polymerized bis-acryl composite resin, CB; 3D printed polymer-based resin*
***Means followed by different superscript letters differ significantly, at the 0.05 confidence level. While uppercase letters show differences between different interim restorative materials for same surface treatment, lowercase letters show differences between different surface treatments groups for same interim restorative material,*
****Pairwise comparison results of R_a0 and R_a1 values with paired sample t-test (p<0.05 indicates statistical significance).*

The polished IM group had the highest R_a0 value (0.44±0.08), while the sealed TC group had the lowest R_a0 value (0.23±0.06). For all interim material groups, surface sealant agent coupled specimens revealed statistically significantly lower R_a0 values compared with the conventional polished ones ($p<0.05$). When the R_a0 values of the same surface treatment applied interim material groups were compared, the R_a0 values of the polished IM group were statistically significantly higher than the other interim material groups ($p<0.05$). No significant differences were observed among the other groups ($p>0.05$)

While the polished IM group had the highest R_a1 value (0.45±0.14), the sealed CB group had the lowest R_a1 value (0.31±0.09). When the difference between the R_a1 values of the conventional polishing and surface sealant agent groups of the same interim material were compared, significant differences were detected for the IM and CB groups ($p<0.05$). For all interim materials, there was no statistically significant difference among the surface sealant agent groups ($p>0.05$). When the R_a1 values of conventional polished interim materials were compared, the highest values were obtained for the IM and CB groups which were significantly higher than those of AC and TC ($p<0.05$).

According to the pairwise comparisons of R_a0 and R_a1 values, R_a1 values were significantly higher for polished CB and sealed TC, AC, and CB groups ($p<0.05$). SEM images of the material groups with different surface treatments before and after toothbrushing are shown in **Fig. 4** and **Fig. 5**. In **Fig. 4**, it is observed that there are more intense superficial lines and irregularities in conventionally polished interim materials compared to its sealant groups. Supporting the results of the study, most surface irregularities are observed in the IM group specimens before the toothbrushing procedure. In Fig. 5, supporting the results of the study, it is observed that there is an increase in surface irregularities and scratches in both surface treatments after the toothbrushing procedure but less in sealed groups than in the polished groups.

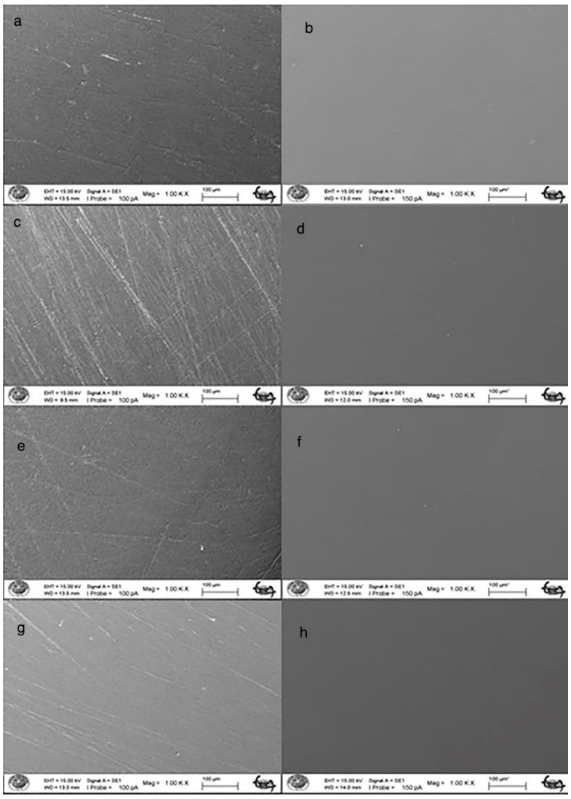

Figure 4. SEM images of tested material groups before toothbrushing (×1000 magnification): **a.** Polished TC group, **b.** Sealed TC group, **c.** Polished IM group, **d.** Sealaed IM group, **e.** Polished AC group, **f.** Sealed AC group, **g.** Polished CB group, **h.** Sealed CB group

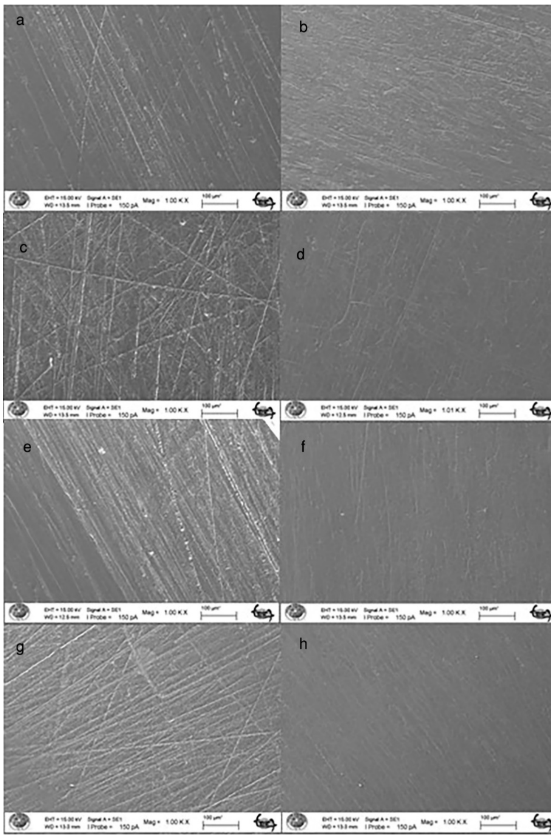

Figure 5. SEM images of tested material groups after toothbrushing (×1000 magnification): **a.** Polished TC group, **b.** Sealed TC group, **c.** Polished IM group, **d.** Sealaed IM group, **e.** Polished AC group, **f.** Sealed AC group, **g.** Polished CB group, **h.** Sealed CB group

DISCUSSION

The first null hypothesis was rejected because both surface treatment and type of interim crown material had statistically significantly different results on the surface roughness of the tested interim crown materials ($p<0.05$). The second null hypothesis was rejected since the effect of toothbrush abrasion was significant on the surface roughness of different interim crown materials with different surface treatments ($p<0.05$).

R_a value, which is the roughness average, is the universally accepted and the most used roughness parameter. Recent studies have specified R_a=0.2 µm as the threshold value of surface roughness for bacterial retention and plaque accumulation.[16] In the current study, each interim crown material group's mean surface roughness values were above the plaque accumulation threshold, however, none of the groups' mean surface roughness values reached the clinically unacceptable level of 10 µm.[17] Although conventional PMMA interim crown materials are frequently used in dental clinics, they have poor mechanical properties due to increased polymerization shrinkage, porosity, and void as a result of being hand-mixed.[1,18] Taşın et al.[13] investigated the surface roughness of 3D printed, conventionally fabricated, and CAD-CAM milled interim materials. They found that polished conventional PMMA interim material had the highest Ra values. Simonetti et al.[19] compared surface roughness between interim single crowns obtained by 3D printing and conventional methods (bis-acryl resin and PMMA acrylic resin). They found that 3D printing and bis-acryl resin had lower surface roughness than conventional acrylic resin. In the present study, similar to the results of these studies, the conventional polished IM group exhibited higher R_a0 values than TC, CB and AC groups with the same surface treatment. This may be attributed to the unreacted monomer and penetration of air bubbles into the material during the hand mixing of the powder and liquid and filling them in the mold[18] and also attributed to the parameters and differences in the composition, procedure and production method of different interim crown materials. Although CAD-CAM PMMA-based polymers have a similar chemical structure to conventional PMMA materials, they have a more homogeneous structure due to the industrial polymerization of resin blocks. This situation provides improved mechanical properties such as lower water absorption and increased wear resistance compared to conventional PMMA resin materials.[20] In the process of 3D printing, various parameters such as printed layer thickness, printing angle, and the layering direction influence the surface roughness of the interim material.[21] Khanlar et al.[22] evaluated the surface roughness of additively manufactured interim restorative material with different printing orientations (0 degree, 45 degrees, and 90 degrees). The 0-degree group showed low surface roughness in this study. Revilla-Leon et al.[23] also examined the surface roughness of the silicone indices manufactured by a 3D printer with different printing orientations (0 degree, 25 degrees, 45 degrees, 75 degrees, and 90 degrees) and found that the 0-degree oriented specimens had the least surface roughness. Gad et al.[24] evaluated the surface properties of 3D printed resins and reported that the low surface roughness of the 3D printed resin may be related to the thickness of the printed layers being in the 50µm/layer range. In the present study, 3D printed interim specimens were printed at 50 µm layer thickness and at a 0-degree built orientation. The low R_a0 values of 3D printed specimens may be attributed to these print parameters due to the layers being closely packed resulting in a smoother surface after polishing at 50 µm layer thickness[24] and the creation of one layer in the horizontal plane at 0-degree built orientation.[25] It was reported that bis-acryl composite resins which exhibit lower R_a0 values in the present study have a more homogeneous and less porous structure due to low air entrapment since they are auto-mixed[26] and are more durable than conventional PMMA interim materials due to their viscous, high volume monomers and a cross-linked polymer structure.[27]

Sealant agents are an alternative to conventional polishing methods.[28] In addition, sealant agents are recommended for restorations to improve the smoothness of restorations by filling in defects and irregularities that occur after the finishing/polishing procedure. Taşın et al.[13] compared the effect of conventional polishing and surface sealant application on the surface roughness of interim dental materials and reported that the use of a surface sealant significantly decreased the surface roughness of interim material. Topcu et al.[29] examined the surface roughness and streptococcus mutans adhesion on surface sealant agent coupleded interim crown materials after dynamic loading and surface sealant agent application significantly decreased the surface roughness compared with conventionally polished groups. In the present study, similar to these studies,[13,29] surface sealant application onto the interim materials provided smoother surfaces compared to conventional polishing surfaces and this can be attributed to the ability of surface sealant agents to fill micro defects, irregularities, and imperfections.[30]

Tooth brushing is an important factor that increases the surface roughness of dental materials.[31] Decreased restoration gloss due to surface roughness, an increase in discoloration, and plaque accumulation lead to aesthetic and biological disadvantages.[32] Therefore, it is important to evaluate the effect of toothbrush abrasion on interim restorations with different surface treatments that are expected to meet aesthetic and biological needs for a long time. In the present study, the tested interim materials were subjected to 10,000 cycles of artificial toothbrush abrasion, equivalent to 1 year of use[17] and results indicated that surface roughness values of all material groups increased after this procedure.

Halis et al.[30] evaluated the effect of simulated toothbrushing on the surface roughness of sealed composite resins compared to polished ones. They reported that, in general, the surfaces of sealant applied composite resins exhibited smoother surfaces after the simulated toothbrushing procedure. In the present study, although the surface sealant agent applied all interim material groups showed lower R_a1 values than the conventional polished ones, the toothbrushing procedure caused a statistically significant increase in the R_a1 values of all sealant applied material groups compared to the R_a0 values, except for the IM group. While there are studies suggesting that the surface sealant agents increase the resistance of dental materials to which they are applied,[33,34] there are also studies confirming the current study findings claiming that these agents may cause problems such as the inability to provide proper adherence to materials which they are applied, insufficient resistance to abrasion, and poor surface quality due to viscosity.[35,36] The solubility and water absorption of the material may also be the cause of the reduction in abrasion resistance.[37] Therefore, even if sealant agents have adequate initial performance, they may not give longer-lasting results.[12] The toothbrushing procedure is equivalent to 1 year in the present study. Future studies are needed to investigate the effect of longer-term toothbrush abrasion on the sealant agent.

Since the bristles of the toothbrush used, brushing force, brushing time, and also toothpaste used may influence the surface roughness of the dental restorative materials, all these parameters were standardized during the toothbrushing procedure for each test group.[18]

In the current study, the surface roughness of the conventional polished CB group exhibited a significant increase after the toothbrushing procedure. 3D printing technology is an additive manufacturing method that produces objects consisting of multiple layers, and the inter-layer bonding may be weaker than the intra-layer bonding.[38] Therefore, in this study, the significant amount of wear in the CB group after toothbrushing may have been attributed to separations in the bond between the interlayers. In this context, more work is needed to produce a 3D restoration with optimum surface topography.

This in vitro study has some limitations. Some variables that interim materials will be exposed to in the oral environment, such as thermocycling, occlusal forces, saliva that contains some proteins and enzymes, and mouth rising did not reflect in the present study. In addition, the specimens' flat surfaces and lack of anatomical pits and grooves did not fully mimic clinical polishing. Additionally, a single type of sealant agent was tested in the current study. The effects of sealant agents with different ingredients and longer periods of brushing should be considered in future studies.

CONCLUSION

Based on the in vitro results from the present study, the following conclusions were drawn;

1. The manufacturing technique of the interim crown material and surface treatment had a significant effect on the Ra0 values of the materials.
2. The polished groups of all materials tested showed higher surface roughness values compared to their sealant groups before and after toothbrushing.
3. The polished conventional auto-polymerized PMMA had significantly the highest mean Ra0 value. While no significant difference in the mean Ra0 values was observed among all other sealed and polished groups, the sealed CAD-CAM PMMA material for the subtractive technique exhibited the lowest mean Ra0 value.
4. Simulate one-year toothbrushing abrasion increased the surface roughness of all material groups tested. After toothbrushing abrasion, the polished conventional auto-polymerized PMMA exhibited the highest surface roughness among all groups tested. The sealed 3D-printed resin had the lowest Ra1 value.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: HNB (%60), AK(%20), OŞ(%20)
Veri Toplanması | Data Acquisition: HNB (%50), AK (%30), OŞ (%10), Bİ(%10)
Veri Analizi | Data Analysis: HNB (%50), AK (%25), OŞ (%25)
Makalenin Yazımı | Writing up: HNB (%50), AK (%30), OŞ (%10), Bİ (%10)
Makale Gönderimi ve Revizyonu | Submission and Revision: HNB (%60), AK (%40)

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