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ORIGINAL RESEARCH

Comparison of flexural strength and surface roughness of temporary crowns made by conventional and digital methods

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Abstract

Background: Assessment of dental materials do by different methods. The aim of this study was to compare the flexural strength and surface roughness of temporary crowns manufactured through conventional and digital methods.

Materials and method: An experimental laboratory study was conducted on 60 rod-shaped samples made from three different materials. These materials were ENA high filler flowable composite, CENTRIX self-curing acrylic base composite and 3D printer resin. To create the 3D printer group samples, the original metal model was scanned and the design file was printed using a 3D printer. For the composite samples and acrylic bases, a silicone index was used, which was composed of the original metal model. Ten samples of each material were stored in artificial saliva for 30 days. The samples were then tested for flexural strength and surface roughness. The data collected was analysed using a one-way analysis of variance, Bonferroni's post hoc (α =0.05).

Results: The average flexural strength varied significantly among the three materials after being immersed in artificial saliva for a month (p<0.001). The ENA flow material's average flexural strength was significantly higher than the CENTRIX material and printed resin (p<0.001), and the CENTRIX material's average flexural strength was significantly higher than printed resin (p<0.001). The CENTRIX material also had a significantly higher initial roughness mean (Ra) value compared to the ENA flow material (p=0.010) and printed resin (p=0.009), while there was no significant difference between the ENA flow material and printed resin (p=1.00). One month after immersion in artificial saliva, the CENTRIX material's mean surface roughness (Ra) was significantly higher than the ENA flow material (p=0.005) and printed resin (p=0.040).

Conclusion: Flowable composite resin presents better mechanical properties when compared to acrylic base resin and printed resin. The surface roughness of flowable composite and printed resin is lower than acrylic base composite, but the surface roughness of all materials increases when exposed to saliva.

Keywords: Dental Restoration, Temporary; Flexural Strength; Composite Resins

Introduction

A well-made temporary crown is crucial to achieve a good quality definitive prosthesis. A temporary crown should maintain the tooth's position and periodontal relationship protect the pulp and provide both function and esthetics (1-4). In long-term temporary restorations for implant treatment or in comprehensive occlusal reconstructions temporary restorative materials should have good physical and mechanical properties to prevent failure under long-term loadings. (5, 6). Therefore, it is essential for temporary materials to have optimal mechanical properties, colour stability, and marginal integrity (7).

There are two types of temporary restoration materials: polymethyl methacrylate (PMMA) or polyethyl methacrylate (PEMA) and bis-acrylic

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or di methacrylate resins, based on their composition (8)

PMMA was initially used as a temporary material, but with the advancement of material science newer materials such as bis-acrylics were introduced to achieve better clinical results (8, 9). These materials can be used directly or indirectly, or sometimes through a combination of both methods using conventional techniques The flexural strength of temporary materials is crucial , particularly when the patient has to use the temporary restoration for an extended period (10).Temporary restorations have rougher surfaces and less marginal compliance which leads to greater biofilm attachment...Although these rough surfaces can enhance the initial attachment of bacteria by shielding them from saliva and biting forces (11, 12).

The introduction of digital technology (computer-aided design and computer-aided manufacturing (CAD/CAM)) in the field of dental prosthetics has revolutionized the way patients are treated (13, 14). Computer-Aided Design/Computer-Aided Machining (CAD/CAM) enables the milling of 3D-designed components from blocks with high accuracy, better colour stability, and more accurate marginal quality than resins.

Multiple studies have indicated that temporary resins fabricated by computer-aided design and computer-aided manufacturing (CAD/CAM) technology exhibit superior physical and mechanical properties compared to conventional temporary resins (1, 4, 15, 16).The inherent problems of conventional PMMA-based temporary materials such as high polymerization shrinkage ,and high residual monomer have been minimized using reductive fabrication techniques (17, 18).

Today, further research is needed to explore various aspects of 3D Printing and CAD-CAM technology. And of course one of the crucial areas of these investigations is flexural strength and surface roughness of temporary coating materials produced using different methods.

Rayyan et al. (4) conducted a comparison of temporary restorations produced through two different methods: CAD/CAM and manual techniques, and showed that CAD/CAM temporary veneers possess higher physical and mechanical properties making it more preferable for long-term temporary restorations. Due to optimal production conditions the industrially polymerization of CAD/CAM PMMA blocks results in temporary restorations with better mechanical properties than manual types.

In a study by Batisse and Nicolas (19) CAD/CAM prosthetic base resins demonstrated better physical and mechanical properties when compared to conventional prosthetic base resins. Furthermore, in the study conducted by Alt et al. (1) bridges produced with the CAD/CAM method exhibited higher flexural strength than those created with the manual methods using the same materials.

The application of digital technology in dental prostheses and temporary restorations has advanced significantly with the help of 3D printers. Nevertheless, there is limited research on the flexural strength and surface roughness of temporary veneers made through new methods. Therefore, this study aimed to compare the flexural strength and surface roughness of a base bis acrylic temporary material with printed resin temporary material and high filler flowable composite after one-month immersion in artificial saliva

Materials and Method

These materials were ENA high filler flowable composite, CENTRIX self-curing acrylic base composite and 3D printer resin

A total of 60 rod-shaped samples with dimensions of 2×2×25mm were made with three materials, high filler flowable composite (ENA HRi flow, Micerium), 3D printer resin (DETAX temp, Korea), and CENTRIX self-curing acrylic base composite (Access Crown, Centrix)) in this invitro experimental laboratory study.

To create samples for a 3D printer group, the original metal model was scanned. Using the design file obtained from scanning, a 3D printer (ASIGA MAX, Australia) was utilized to print the samples. Next, composite samples and an acrylic base were prepared. Finally, 20 rod-shaped samples (ten samples for the flexural strength test and ten samples for the surface roughness test) were created for each material with the assistance of a silicon index made from the original metal model.

The 3D printer uses DLP (Digital Light Processing) technology, and the light source in this printer is an LED with a wavelength of 405 nm (100% light intensity). The exposure time for each layer in this printer is 2.5 seconds, and the layer thickness in this printer is 119mm along the X-axis, 67mm along the Y-axis, and 76mm along the Z-axis. DETAX 3D light cure resin was used to make temporary veneers. Based on the manufacturer's instructions, the printed coatings were washed with 99% methanol for 5-10 minutes after the fabrication process and then cured with UV rays in a cold-water chamber for 45 minutes.

All samples were polished using 3M discs, rough, medium, and soft.

Ten samples of each material were stored in artificial saliva (1 L double distilled H2O, 1.6802 g NaHCO3, 0.41397 g NaH2PO4 • H2O, and 0.11099 g CaCl2) for 30 days to perform a flexural strength test (20). After this period, the samples were placed on the bending strength testing machine with a support separation of 10 mm. A 3-point bending test was performed in a universal testing machine (Zwick GmbH and Co, Ulm-Einsingen, Germany) with a weight of 10KN at a crossing speed of 0.7mm/min. The fracture force was recorded and calculated in Newton.

Rectangular samples before and after 30 days of immersion in artificial saliva were used to conduct surface roughness, primary, secondary, and surface roughness tests. Mean surface roughness (Ra [µm]) and arithmetic mean surface characteristics Rz [µm])) of ten samples was measured from each group with a contact profilometer (Rogosurf 20; TESA, Switzerland) with a cutting length of 0.25mm, transverse length of 4mm, resolution of 0.001µm, and pen speed of 1mm/s. Three measurements were taken for each sample, and the mean values were recorded.

The data were analysed by one-way analysis of variance, Bonferroni's post hoc, in SPSS 25 software. In this study a P value of 0.05 was considered significant.

Results

According to the results of one-way analysis of variance, there was a significant difference in the mean flexural strength after one month of immersion in artificial saliva between the three materials CENTRIX, EAN flow, and printed resin (p<0.001). In pairwise comparison according to Bonferroni's post hoc test, the mean bending strength of ENA flow material was significantly higher than CENTRIX and printed resin materials in a pairwise comparison (p<0.001). The mean bending strength of CENTRIX material was significantly higher than the printed resin (p<0.001) (Table 1).

Table1. The mean flexural strength after one month of immersion in artificial saliva between the three materials

Materials	No	Mean ± SD	Minimum	Maximum	P value
CENTRIX	10	56.900 ± 3.578	52.900	64.100	
EAN flow	10	134.750 ± 8.788	125.000	151.200	<0.001
printed resin	10	31.171 ± 6.329	24.040	45.230	

According to the results of one-way analysis of variance, there was a significant difference in the mean roughness (Ra) between the three materials before and one month after immersion in saliva (p=0.002), but the difference significant for artificial saliva (p=0.545) (Table 2).

Table 2. Surface roughness (Ra) between the three materials before and after one month after immersion in artificial saliva

Time	Materials	No	Mean ± SD	Minimum	Maximum
Before	CENTRIX	10	0.455 ± 0.197	0.167	0.805
	EAN flow	10	0.246 ± 0.094	0.129	0.401
	printed resin	10	0.243 ±0.123	0.110	0.529
after	CENTRIX	10	0.608± 0.147	0.410	0.891
	EAN flow	10	0.353± 0.170	0.152	0.638
	printed resin	10	0.417 ±0.166	0.176	0.690

After conducting a pairwise comparison using Bonferroni's post hoc test, it was found that the initial mean roughness (Ra) of CENTRIX material was significantly higher than that of ENA flow material (p=0.010) and printed resin (p=0.009) in a binary comparison. However, there was no significant difference in the mean surface roughness between the two ENA flow materials and printed resin (p=1.00). One month after being immersed in artificial saliva, the mean surface roughness (Ra) of CENTRIX material was significantly higher than that of ENA flow material (p=0.005) and printed resin (p=0.040). On the other hand, there was no significant difference in the mean surface roughness between the materials, ENA flow, and printed resin (p=1.00) as shown in Figure 1.

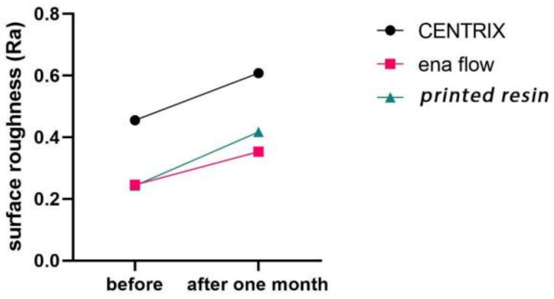

Figure1. Changes of initial surface roughness (Ra) and after one month immersion in artificial saliva in different materials

Based on the results of the one-way analysis of variance, the mean surface roughness (Rz) was not significantly different between the three materials (p=0.138) and before and one month after immersion in artificial saliva (Table 3). There was no significant difference in the mean surface roughness (Rz) of CENTRIX material with ENA flow material (p=1.00) and printed resin (p=0.123) one month after immersion in artificial saliva. Further, the initial mean roughness between the ENA flow and printed resin materials was not significantly different (p=0.060).

Table3. Surface roughness (Rz) of different materials before and after one month after immersion in artificial saliva

Time	Materials	No	Mean ± SD	Minimum	Maximum
Before	CENTRIX	10	6.999 ± 3.304	2.880	14.896
	EAN flow	10	6.572 ± 2.718	3.274	12.999
	printed resin	10	7.424 ± 4.306	1.741	13.446
After	CENTRIX	10	9.017± 3.896	4.881	15.252
	EAN flow	10	8.387± 3.673	3.729	15.316
	printed resin	10	13.177± 5.269	4.092	23.416

According to Figure 2, there was no significant difference in CENTRIX materials (p=0.165), ENA flow (p=0.210), initial mean roughness (Rz), and one month after immersion in artificial saliva. However, the mean roughness (Rz) in the printed resin one month after immersion in artificial saliva was significantly higher than the initial value (p<0.001).

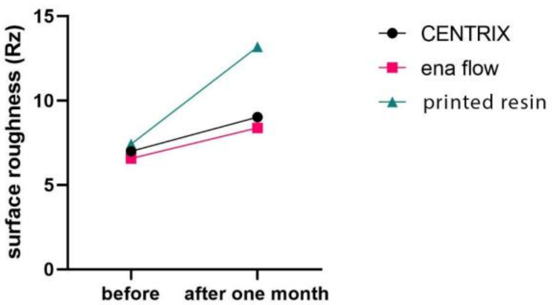

Figure 2. Changes of surface roughness (Rz) initially and after one month immersion in artificial saliva in different materials

Discussion

Results of present study showed that the primary and secondary mean roughness (Ra) of CENTRIX material was significantly higher than ENA flow material and printed resin. Nevertheless the mean initial and secondary surface roughness between ENA flow material and printed resin was not significantly different. In addition, the mean roughness (Ra) of CENTRIX, ENA flow, and printed resin materials were significantly higher than the initial value one month after immersion in artificial saliva, indicating the effect of saliva in increasing the surface roughness. Surface roughness is one of the most important criteria that affect biofilm accumulation on dental materials (21, 22). This study evaluated both Ra and Rz values because lower Rz values mean a smoother surface when Ra values are equal (23). Although all surface roughness values were above the threshold (0.2 µm) that could eliminate the role of surface roughness in plaque adhesion (24), they were below the clinically undetectable roughness limit (10µm) (12).

The chemical composition of the temporary material affects its mechanical properties (25). The ENA flowable composite showed the highest values for flexural strength, which can be due to its higher filler content and increased polymerization, which is consistent with the results of Scotti et al. (26).

Contrary to results of previous research, Centrix base acrylic resin exhibited higher flexural strength than the printed resin (26-28). Tahayeri et al. (29) reported similar flexural strength of bis-acrylic and a 3D-printed resin.

Scotti et al. (26) investigated the mechanical and surface properties of three different composite materials and concluded that Z350 composite, printed resin, and acrylic base???? had the highest bending strength, respectively. The surface roughness of Z350 was similar to base acrylic but less than printed resin.

The printed resin showed similar surface roughness compared to the acrylic base.

Conventional temporary materials are divided into monomethacrylate or acrylic resins and dimethacrylates or composite bis-acrylic resins (BIS-GMA and UDMA). In addition, the temporary 3D printer materials seem to follow the same classification (30).

The manufacturing technique strongly influences the restoration made by the 3D printer. Factors including manufacturing parameters, the addition of reinforcing materials to printed resins, layer thickness, and printing direction can affect the mechanical properties of printed materials (31).

Alharbi et al. (32) investigated the impact of print direction on the mechanical properties and compressive strength of 3D-printed temporary restorations and showed that temporary restorations printed in the horizontal direction had significantly lower compressive strength than those printed vertically. In the samples printed for that study, the junction between the layers was positioned horizontally in relation to the direction of load application. Furthermore, the layered nature of printed materials in additive manufacturing technology can cause crack propagation and lead to additional structural damage.

In the current study, the samples were printed horizontally with layers parallel to the loading direction. This orientation can reduce their bending strength because the connections between layers are weaker than the connections within each layer. Alharbi found that the thickness of the print layer is critical in determining the mechanical properties of the printed resins. A lower layer thickness increases the number of interfaces between layers, which raises the probability of crack propagation from these interfaces (32).

Tahayeri et al (29) found no significant difference in the mechanical properties of printed samples with layer thicknesses of 25, 50, and 100µ. Interestingly, layer thicknesses of 25µ and 100µ produced higher stress peaks than a layer thickness of 50µ. These researchers have suggested that other printer settings can also affect the studied mechanical properties. In addition, the mechanical performance of printed materials increases significantly after polymerization and post-polymerization processes.

Based on the results, ENA flowable nanofiller composite and printed resin had the smoothest surfaces, compared to acrylic base resin which showed the most uneven surfaces. This suggests that larger particles cause surface irregularities and a higher filler particle content results in increased surface roughness (25,33). Moreover, different brands of printable resins and acrylic base materials have varying chemical compositions and conversion degrees, which may affect their mechanical and biological properties. The quality and accuracy of the printer used also played a significant role in determining the mechanical properties of the printed restorations.

Surface roughness and mechanical properties are crucial in ensuring the health and stability of the prepared tooth, particularly when temporary restorations are being considered. Additionally, the recommended light polymerization protocol can improve the mechanical and surface properties of the material and should be studied.

Temporary restorations have a short lifespan, so there is no need for high-filler composite resin. Although such materials offer superior physical and mechanical properties, their additional costs, time-consuming fabrication, and higher elastic modulus make them less practical for temporary restorations.

Conclusion

Based on the results, ENA flowable composite resin showed better mechanical properties than CENTRIX acrylic base resin and DETAX printed resin. The flexural strength depended more on the chemical properties of the material used than on the manufacturing method. The surface roughness of flowable composite and printed resin was lower than acrylic base composite, and the surface roughness of all materials increased by immersion in saliva

Conflict of Interests: The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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