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Original article

Various methods affect the flexural strength of repairing the denture base

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ABSTRACT

Background: *The assembly of replacement teeth to mimic natural ones remains a challenge for dentists, particularly regarding the surface characteristics of prosthetic teeth.* ***Purpose:*** *To evaluate various surface mechanical techniques that affect the flexural stress of a repaired denture base.* ***Methods:*** *Six sets (n = 10) of sixty heat-polymerized acrylic resin bar-shaped samples have been produced. Samples were divided into halves to give a 1-mm clearance, with the exception of the group under positive control (group PC). Also taken into account was a negative control group (group NC) that received no skin treatment. Other groups received a variety of surface treatments, including group Er:YAG laser therapy, group abrasion by airborne particles (APA), group APA + Laser, and group Bur grinding. All sectioned samples were repaired by auto-polymerizing acrylic resin, which was then thermocycled after surface roughness was measured with a profilometer. A global testing device conducted a three-point bending test.* ***Results:*** *The mean surface roughness of all study groups was considerably greater than group NC's (P<0.05). With the exception of group Bur, group PC's flexural strength was considerably greater than that of all other groups (P=0.999). The bending strength of groups Bur and Laser among all surface-treated groups was significantly greater than that of group NC (P=0.001 and P=0.015, respectively).* ***Conclusion:*** *All surface treatments enhanced surface roughness in comparison to the untreated group, but bur grinding and Er:YAG laser exposure also significantly raised the flexural strength of the sectioned groups. Sectioned polymethyl methacrylate's flexural strength was significantly increased by bur grinding.*

Keywords: *acrylic resins; dental air abrasions; denture repairing; erbium-doped yttrium aluminum garnet lasers; polymethyl methacrylate*

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INTRODUCTION

The best way to treat edentulous patients is with a complete prosthesis.[1–3] Traditional complete dentures are still a popular treatment option due to budgetary considerations.[2] Due to its low cost, simplicity of use, pleasing aesthetic, and dimensional stability, polymethyl methacrylate (PMMA) is a popular choice for manufacturing denture bases.[4–6] Nevertheless, poor long-term mechanical strength linked to inherent stress accumulation, high load application, ridge resorption, or teeth erosion can result from poor design or production procedures.[7] Repair is frequently chosen over replacement since fabricating a new denture is costly and requires multiple visits.[7–9] The method for making the repair must be simple, affordable, and able to match the original denture's color while giving it sufficient strength and dimensional stability. The technique of preference is acrylic resin auto-polymerizing,[8–11] as it is readily accessible, does not need to be processed in a lab, and can be prepared in front of the patient, thus reducing the amount of time they are without a denture.[10] There are limitations when it comes to fixing a broken denture foundation, and it is common for dentures that have been repaired to refracture at the patch site.[8,12,13]

In addition to the inconvenience and expense incurred, the patient frequently lacks faith in the dentist. To address this issue, many studies have been undertaken to search for solutions. Mechanics such as bur grinding and airborne-particle abrasion (APA) could widen the contact region between the prosthesis and the repair substance[8,14]

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and lasers.[15] Laser surface treatment of materials is a comparatively simple and secure technique.[15] Numerous studies have looked into the use of lasers to treat the surfaces of denture bases for a number of factors, such as strengthening the connection between acrylic teeth or soft-liner liners and the denture foundation.[4, 5, 16–18] To the best of the authors' understanding, just one research study has looked at the effect of erbium-yttrium-aluminum-garnet (Er:YAG) laser therapy on the capacity to repair cracked conventional denture bases.[14] Surface roughness may improve mechanical retention or bonding areas although research using different surface treatments to repair shattered conventional dentures has not statistically evaluated this effect. It has not yet been determined how improved surface roughness following surface treatments affects the bond strength needed to fix broken traditional dentures. Therefore, the purpose of this research was to assess the impact of various mechanical surface treatments on the flexural strength of a traditional denture base that had been repaired. In this study, there were two null hypotheses: first, that various surface treatments have no impact on the flexural strength of repaired denture bases, and second, that those treatments do not impact the surface roughness of denture bases that have undergone treatment.

MATERIALS AND METHODS

An in vitro comparative repair of old dentures with acetone, thinner, and monomer materials was carried out, and a total of 60 heat-cured PMMA bars measuring 80 mm in length, 10 mm in width, and 4 mm in thickness were created. The test examples were made by fabricating bar-shaped metal patterns, coating them with a separating medium, and investing them into a plaster and stone mixture in the bottom section of a metallic flask. To avoid air trapping, a mechanical vibrator was employed.[19] Immediately after setting, a layer of separating medium was applied to the stone and the designs. All specimens were tested in the Department of Physics/Al-Anbar University in Anbar, Iraq.

A similar mixture (plaster ratio P/L 100 g to 50 ml, and stone with ratio P/L 100 g to 30 ml) that filled the upper part of the flask was set on top of the lower portion and allowed to solidify after the flask was covered in stone. The metal designs were subsequently removed after separating the flask halves. After cleaning the stone mold thoroughly, a separating material was applied twice over. As per the manufacturer's instructions, 23.4 g of powder to 10 ml of liquid was mixed with the heat-polymerized denture base resin (Heat Cure, Est. Sinco 1982). The resin was allowed to reach the dough stage prior to packaging. After the upper part of the flask was placed over the lower part, the flask was placed under a hydraulic press unit (under a 3000psi hydraulic press) to create a gradual pressure that allowed the acrylic dough to flow uniformly. The experiments were opened and any extra material was removed and polymerized in a processing facility using the standard protocols for making conventional dentures.

Samples were given one hour to settle at room temperature prior to deflasking.[2,19] They were then submerged in water at 37°C for 50±2 hours to remove any remaining monomers. To eliminate sample lights and entrances, an acrylic bur was used. All examples were then polished with pumice after being completed with 80, 320, 400, and 1000-grit silicone papers, respectively, under water coolant To confirm the length, breadth, and thickness of 19 specimens, a digital gauge, manufactured by Mitutoyo Corp. in Kawasaki, Japan, was used. The specimens were then split into six groups (n = 10): APA, bur grinding, YAG laser therapy treatment of the surfaces (Laser), repaired samples without surface treatment (NC), and untouched samples as the positive control (PC) and negative control (NC), respectively. (Bur, Ruixin Tungsten Carbide Acrylic Trimming Bur HP 060 Cross Cut Garima Dental Suppliers).

A diamond disk (Zweiling Diamant, Berlin, Germany) was used to divide each sample into halves, with the exception of group PC, allowing for a 1-mm space. While the sample's halves aligned with one another after sectioning, there was a 6-mm gap between their top margins. Each half's junction surface had a 45-degree chamfer. On the top and bottom of each example, a guideline was set to normalize repair gap breadth and joint surface contour. A costume-made gadget with the same interior measurements and bevel was also used, with the same technician carrying out each operation. In group Laser, an Er:YAG laser (Florence, Italy, DEKA, Smart 2940D Plus) (2940 nm, 1.5 W, 150 mJ, 119.42 J/cm^2) was used to manage objects' bonding surfaces. Using a hand piece with a 4-mm diameter point (spot size: 4 mm) and a pulse mode (10 Hz) with a 700-s pulse length for 20 seconds, a laser was irradiated at a distance of 10 mm, while being sprayed with water at a rate of 5 ml per minute.[20,21] In group APA, the beveled specimens were exposed to 250-mm aluminum oxide particulates in a sandblaster at a 10-mm spacing and 0.2 MPa pressure for 10 seconds.[14]

As outlined for groups Laser and APA, respectively, the samples in group APA + Laser underwent laser therapy as well as APA. A tungsten carbide bur with a slow motion (Dia-Tessin, Vanetti SA, Gordevio, Switzerland) was used to roughen the cut examples in group Bur, with the same technician carrying out each operation. The samples were then air-dried after being cleansed for 10 seconds in an ultrasonic tank filled with deionized water. Before fixing broken specimens, the surface roughness (Ra value) of each side of sectioned specimens was determined three times using a profilometer (TR200, Time Group Inc., Beijing, China) with a 0.25 mm cutoff at 0.1 mm/second speed and an accuracy of 0.001 m. A total of six surface roughness readings for each of the samples was determined and noted. Acrylic resin auto-polymerizing was used to cover the spaces. (Ivoclar Vivadent, Schaan, Liechtenstein, Pro Base- Cold).

The samples were then submerged for 15 minutes in 400°C water in a two-bar compressed container (Mestra R-030425, Spain). As shrinking after polymerization was taken into account, specimens were slightly over repaired. The samples were then cleaned. To prevent any potential changes in the sample measurements that might result from polishing, the length, breadth, and thickness of each specimen were measured once more with a digital caliper. Following the healing process, the samples were stored in an aqueous solution for 24 hours at 37°C. They were then thermocycled for 5000 cycles between 5° and 55°C with a 20-second dwell period. Finally, a universal testing machine (STM-20) was used to measure the load at fracture in Newtons (N) and compute the values of flexural strength in Megapascals (MP). At a crosshead pace of 5 mm/min, the load was given to the patch area's center until fracture. The following algorithm was then applied: $S=\frac{3wl}{2bd^2}$ where, [s] is the flexural strength or fracture strength in N/mm^2, [w] is the force used to induce fracture in Newton (N), [l] is the length of the gap between the two perpendicular rods (50 mm), [b] is the breadth of the sample (10 mm), and [d] is the thickness of the sample (4 mm).

For the purpose of determining the type of failure (cohesive or sticky), fragmented specimens were examined using a video measuring device (C-Class Vision Measurement Machine; Easson Optoelectronica Technology Co., Suzhou, China). The cohesive failure group was assigned to samples that had a full coating of an auto-polymerized acrylic resin on both repaired sides. An SPSS program, version (26), was used to evaluate the data (IBM Corp., Armonk, NY, USA), and Kolmogorov-Smirnov and Levene tests were used to evaluate the data's normal distribution and the uniformity of variances, respectively. The surface roughness data in all groups had a normal distribution in the findings, and the premise of uniformity of variances was also satisfied. The mean surface roughness of the research groups was compared using an ANOVA, followed by a Tukey's test. Additionally, it was discovered through the study of the flexural strength values that the data were not regularly disseminated. To evaluate the mean flexural strengths of the research groups, the Kruskal-Wallis test was employed. We used the Mann-Whitney test with Bonferroni correction for pairwise tests. A 0.05 level of significance was used.

RESULTS

Table 1 displays the means and standard deviations of the research groups' surface roughness and bending strength measurements. Group Bur had the greatest mean surface roughness among the research groups (94±19 µm), while group NC had the smallest value (56±13µm). Based on the findings, the ANOVA test revealed a substantial variation in surface roughness between the research groups (P<0.001). All surface-treated groups had a mean surface roughness considerably greater than NC (P<0.05). Surface irregularity was considerably higher in group Bur compared to group APA (P<0.047). Regarding surface irregularity, there was not a significant variance between the other surface-treated groups (P>0.05, Table 2).

Group Bur had the greatest mean flexural strength of the surface-treated groups (36.21 ±1.97MPa), but Group APA + Laser had the lowest value (28.98±1.87MPa). According to the Kruskal-Wallis findings, there was a substantial variation in flexural strength between the research groups (P<0.001). Except for group Bur (P=0.999), all groups' mean bending strengths were significantly less than those of group PC. The mean bending strength of groups Bur and Laser among all surface-treated groups was significantly greater than that

Table 1. The flexural strength (MPa) and surface roughness (µm) of the studied groups

Groups	Surface roughness	Flexural strength
	Mean±SD	Mean±SD
PC	-	68.28±5.23
NC	56±13	30.05±2.16
Bur	94±19	36.21±1.97
Laser	80±11	33.04±1.31
APA	77±74	29.99±1.88
APA + Laser	81±12	28.98±1.87

Data expressed as mean±SD.

APA, treated with airborne-particle abrasion; APA + Laser, treated with a combination of laser and APA; Bur, treated with bur grinding; Laser, treated with Er:YAG laser; NC, negative control; PC, positive control; SD, standard deviation.

Table 2. Comparisons of surface roughness of the studied groups using Tukey's test

Group	NC	Bur	Laser	APA	APA + Laser
NC	-				
Bur	0.001*	-			
Laser	0.025*	0.09	-		
APA	0.051*	0.048*	0.989	-	
APA + Laser	0.008*	0.195	0.989	0.959	-

*Indicates a significant difference between groups (P<.05).

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Table 3. Comparisons of flexural strength of the studied groups using Mann-Whitney test and Bonferroni adjustment

Group	PC	NC	Bur	Laser	APA	APA + Laser
PC	-					
NC	0.001*	-				
Bur	0.999	0.001*	-			
Laser	0.046*	0.015*	0.999	-		
APA	0.001*	0.487	0.145	0.999	-	
APA + Laser	0.001*	0.897	0.067	0.999	0.999	-

*Indicates a significant difference between groups (P<.05).

of group NC (P<0.001 and P=0.015, respectively). Flexural strength, however, did not significantly vary between the surface-treated groups (P>0.05). The noted fractures in the categories Laser, APA, APA + Laser, Bur, and NC were cohesive in approximately 50%, 60%, 70%, and 30% of the cases, respectively (Table 3).

DISCUSSION

Surface roughness and tensile strength varied significantly between research groups. The null prediction that there would be no discernible impact of surface treatment on the flexural strength of the restored denture base and the surface roughness of the treated denture was thus disproved. A 1.5–3 mm space between the repaired areas had been taken into consideration in earlier research.[8,11,14] In this research, a 1-mm gap was taken into consideration since spaces larger than that could make it more difficult to fix the denture base.[22] Additionally, the effectiveness of the restored denture depends greatly on the joint surface's shape.[9] The shape of a 45-degree chamfer raises the bonding area between surfaces, shifts the distribution of interfacial stress from more damaging forces to shear forces, and raises the likelihood of cohesive failure in general.[8] Therefore, in this research, a 45-degree chamfer was created.

Thermocycling, according to the evidence, is an effective method for simulating temperature changes in the oral environment and can forecast the long-term clinical performance of restorations. 5000 thermal cycles, approximately four to five years of therapeutic employment, were used in this research.[23] It should be mentioned that due to thermal stress and water uptake, thermocycling may cause denture base resins to lose some of their power.[2] In reality, heat stress may lengthen polymer chains, which could promote further water uptake.[24] The ability of resins to capture water during thermocycling depends on the quantity of cross-linking molecules present.[24] Less than 5% of butanediol is present in Probase Cold, the cross-linking substance used in this research to repair divided samples, which could increase its susceptibility to water absorption.[25] In theory, it is acknowledged that mechanical surface processes can make PMMA irregular and consequently strengthen the binding[21].

The present findings show that surface roughness was substantially enhanced by all mechanical preparation techniques. Only bur grinding and Er:YAG laser illumination produced a noticeably higher bending strength than the control group. The tensile strength of the sectioned PMMA was increased by bur grinding to match that of the entire group. Research on the benefits of turban cutting has generated controversy[4,12,18,21,26]. There is, however, little information available on milling PMMA to increase the stability of restored denture bases[12,21,26].

For this reason, some contend that chemical surface treatment is superior to mechanical surface treatment[26]. Furthermore, according to Li et al.[12], grinding is helpful when mending aged fractured 3D-printed dentures but not essential for restoring non-aged fractured ones. This variation can be attributed to various manufacturing processes and the use of silicon carbide abrasive paper to simulate bur sharpening. It has been proposed that the increased surface area and modified surface roughness that result from laser irradiation may prevent acrylic glue from auto-polymerizing and penetrating the formed porosities[4].

In fact, auto-polymerizing acrylic glue can enter the laser-created porosities. In this trial research, laser surface treatment greatly increased the flexural strength for repairing denture bases compared to the control group. This result was consistent with what we had previously discovered[21]. Both Akin et al.[18] and Alkurt et al.[14] reported benefits from Er:YAG laser irradiation, including improved denture base and plastic tooth binding strength and increased denture base repair strength. Aziz et al.[15], however, revealed that diode laser surface treatment had no discernible impact on bending strength.

The use of a distinct kind of laser, which can result in various morphological changes in the surface, can be the source of this variation. In addition, it assesses flexural strength rather than the replacement of the prosthesis base. According to this research, APA and APA + Laser irradiation resulted in significantly increased surface roughness, but none of these therapies significantly boosted bending power. In accordance with this research, other studies have noted the tension that may develop at the interface as well as the inadequate amount of irregularities caused by airborne particulates[16,27]. Nakhaei et al.[28] found that these surface treatments had a beneficial impact on changing the surface of plastic denture bases. This variation might be explained by the use of different materials, such as silicone inner material, and various research designs. The groups Bur and Laser exhibited coherent fracture more than ever according to the analysis of the objects' modes of failure. Li et al.[12] found a prevalent cohesive failure mode in the group that included bur grinding. The findings of this research, however, were at odds with those of studies that focused on the use of lasers[4,14,18]. This variation may be attributed to a different laser type[4], a different exposure time[14], or a different laser output strength[18].

Therefore, in addition to conducting research, it is necessary to examine the mode of action of the laser and its characteristics more thoroughly, as the use of the Er:YAG laser for preparing the denture base for repair has produced positive results. The research's in vitro setup might not exactly replicate a real environment, and bar-shaped examples are not a reliable representation of a real prosthesis[28–31]. Furthermore, fatigue-induced failure could result in tooth base breakage. Therefore, it is advised that future research should use repetitive loading. Additional in vitro research and clinical experiments will be necessary, especially on digitally manufactured dentures and various Er:YAG laser parameters.

In light of the research's constraints, it can be said that all mechanical surface treatment techniques produced surfaces with greater surface roughness than the unaffected group. Nevertheless, the tensile strength of a broken tooth might only be improved by bur grinding and Er:YAG laser irradiation. Of all the groups, Group Bur produced the most bending strength, which is equivalent to an unbroken denture base. Denture failures have always been a serious problem for patients since improper fitting or even broken dentures will require the fabrication of a new denture at additional cost. Repairing the broken denture with suitable materials will save time, cost less, and save the old denture. Some dental technicians still use thinner and acetone to repair it. This study highlighted that using a monomer to repair the acrylic denture showed better impact bond stress compared to those repaired by using thinner or acetone. Thus, clinicians and dental technicians can repair the old denture perfectly with suitable material.

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