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Shear Bond Strength Comparison Between Heat Cure Acrylic Resin and Other Types of Acrylic Denture Bases

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Abstract

Objective: The study purpose was to examine the shear bonding strength of heat cure acrylic resin to thermoplastic resin and three-dimensional printed resin materials.

Methods: A total of 30 acrylic specimens were fabricated in this study. Each specimen had a basal and top parts. The basal part was rectangular in shape. We had three different groups: 10 specimens of a basal part made of heat cured polymethylmethacrylate, 10 specimens of a basal part made of thermoplastic, and 10 specimens of three dimensionally printed resin. The top part of which is attached to the basal one was formed into a cylindrical shape made of heat cure poly methyl methacrylate in all three groups.

Results: Significant differences were found between the heat cured polymethylmethacrylate and the other two groups (P<.001). Heat cured polymethylmethacrylate showed the highest bond strength (75 MPa), and thermoplastic resins showed the lowest (37 MPa). No significant difference in the shear bond strength was noticed between three dimensionally printed and thermoplastic acrylic.

Conclusion: This study revealed that the shear bond strength of heat cured acrylic denture base to the relining/repairing from the same material was significantly higher than three dimensionally printed and thermoplastic resins with HC relining/repairing material.

Keywords: Dentistry; Denture base materials; Prosthodontics; Repair of acrylic denture base; Shear bond strength, 3D printed acrylic

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Introduction

There are various types of dental resins which are used in the prosthetic dental field. Generally, all types of dental resins are desirable aesthetically and functionally. Despite their advantages, they also have some disadvantages, such as a significant shrinkage and color changes during their serving period in the oral cavity [1]. Using the acrylic resin material in the process of removable prosthesis fabrication remains the most preferable by most patients and dental professionals due to their low cost and availability [2]. Dental acrylic resins can be found either naturally or from a synthetic origin. They are macromolecular compounds of natural or that are composed of multiple repeating structural units (monomer units), forming macromolecules (polymers). Methacrylate monomers composed of single simple molecules with double and triple bonds, and they are linked in polymer chains. The macromolecule is produced by a process called polymerization [1]. (PMMA) are considered as the gold standard of traditional manufacturing [3], in terms of polymerization by compressing, mold injection technique [4,5]. Generally, all types of dentures need to be repaired or relined during their serving period inside the wearer's mouth, and that can be due to fracture results from

Vol 12 No 2 (2024) DOI 10.5195/d3000.2024.756

misusing or ridge resorption as the denture becomes loose and needs to be relined. Repairing and relining materials are used to restore the dentures functions in case the patient does not want to replace it with a new one. Different materials were used for the purpose of relining and repairing, including thermo-polymerized HC, auto-polymerized (cold cured), visible light-polymerized (light cured) and microwave-polymerized acrylic resins [6,7]. The most popular and widely used materials are the chair-side auto and heat polymerized acrylic resins. They are used for quick and simple procedure, but the thermos-polymerized remains the best choice over the auto-polymerized one, because of its proper flowing, high durability, lower porosity and details reproductions [8]. To obtain a desirable result, it is important to make sure that there is consistent bond between the denture base material and reline/repair resin. The good bond is depending on the mechanical properties of the denture and mainly the failure of it can be due bacterial accumulation, and staining [9]. Basically, when the stress applied the failure occurs at the bonding area, this is like the shear [10]. Therefore, the shear bond stress test is used as the force applied directly on the bond region [6]. The bonding strength depends mainly on the material's chemical compositions [11], and there are other affecting factors such as thermal cycling and material surface treatment [12].

Thermoplastic materials were introduced as polyamides (nylon plastic) in 1950s. They were developed into many types; thermoplastic acrylic, thermoplastic polycarbonate, thermoplastic acetal, thermoplastic nylon (resin). It has some advantages over the conventional acrylic such as flexibility, light weight, monomer free and high esthetical properties. While the drawbacks are the adherence of teeth with a base can be achieved mechanically and this would increase the problem of detachment.

In the 1990s, computer aided design/computer aided manufacture (CAD/CAM) technologies were revealed to the dental field, and it was considered as the great change in the fabrication techniques of dentures [13]. The interest in the advances of CAD/CAM and materials science have been flourished, as the digital process offers a wide range of facilities such as reducing the chair-time, number of visits, saving case data, and more desirable clinical and laboratory results [14]. The digital object fabrication requires obtaining the virtual design on the computer software (CAD) followed by manufacturing process (CAM). This can be achieved either by subtractive milling of prefabricated acrylic resin blocks or an additive rapid prototype process. Additive manufacturing techniques using the photopolymerizable acrylate material and a lithographic machine. While the resin liquid accomplishes a layer-by-layer curing until the complete object is achieved [15]. The additive manufacturing technique offers several advantages compared to the subtractive methods such as reducing the waste material for about 40%, big object size and complex geometry can be produced unlike the subtractive method which Its work is limited by the material's block, milling burs diameter and the milling axes of the machine. On the other hand, there is no force exerted on the object like in the subtractive method that causing surface cracks during the milling process. As a new technology there is a widely range of usage in the dental office [16].

Therefore, the aim of this study was to investigate the shear bond strength of HC acrylic resin to both thermoplastic resin and three-dimensional printed resin (3D printed resin) materials.

Vol 12 No 2 (2024) DOI 10.5195/d3000.2024.756

Material and Methods

The single specimen consists of two parts: the basal part made from HC acrylic (Rodex dental product, Barmstedt/Hamburg), thermoplastic (Deflex, United Kingdom), and 3D printed acrylic (ArmaResin, Turkye), while the repairing/relining parts were made of HC acrylic resin. A total of 30 basal part specimens were fabricated in the shape of rectangle with dimensions of (10 mm × 10 mm× 20 mm3), and they were attached to another 30 HC acrylic resin (Rodex dental product, Barmstedt/Hamburg) specimens with a cylindrical shape and dimensions of 10 mm and a diameter of 6 mm [17].

Specimen preparation

For the preparation of basal part of the specimens, wax pattern with dimensions of 10 × 10 × 20 mm3 [17]. It is noteworthy that the wax pattern was used for preparing both the PMMA and the thermoplastic specimens. For the PMMA specimens the wax patterns were constructed and placed in the dental flask for creating the mold to pack the acrylic material and obtaining the specimens. The thermoplastic wax patterns were also flasked and the flexible acrylic material was injected carefully using the injection device (Shang Hange, China). All the specimens were finished and polished to remove any access material using the grinder/polisher device and aluminum oxide abrasive papers under water cooling and then cleaned with distilled water. The 3D-printed specimens were virtually designed and then printed horizontally with a DLP 3D-printer (ASIGA MAX™, Germany). To remove fluid resin remnants from the test specimens, they were placed in ultrasonic cleaning device (IMPRIMO® Clean; Germany) for 3 minutes with a water-based cleansing agent. The specimens were rinsed properly in a separate device (Form Wash®; Form labs, Berlin, Germany) with isopropanol for an additional 3 minutes, following the manufacturer's instructions. The specimens were finished using silicon carbide grinding papers (800, 1500, and 2000 grit FEPA) and washed with water. Then the specimens from each group were stored in water [18].

Thirty specimens for the extension parts were prepared with a wax pattern in a cylindrical shape, with dimensions of 10mm and a diameter of 6mm [17].

The basal part of the specimens was scratched from one surface in all specimens to stick the wax extension to it prior to the flacking process. After the wax patterns were flasked and eliminated, the mold created, and the basal part still fixed in place and ready for packing of the resin material into the mold to produce the specimens with both the basal and the extensional parts (Figure 1). The polishing process of the resin extension part is the same as mentioned before. This was followed by immersing the specimens in a distilled water for 24 hours to eliminate residual monomers [19].

Shear bond strength test

Shear bond strength (SBS) test for 30 specimens was performed through a Universal testing machine (LARYEE, 50kn, 1202001, China, 2012) at a crosshead speed of 1mm/min until fracture occurred (Figure 2). The shear bond force was exerted vertically to the bonding interface between the edge of the heat acrylic, 3D printer and flexible acrylic basal part and the extension HC acrylic with a stainless-steel chisel rod [17] until fracture (Figures 3 and 4). The maximum force that caused failure was recorded in Newtons for each specimen and the SBS in MPa was calculated by dividing the force (N) value at which the bond failure occurred by the sample bonding area and expressed in MPa according to the following formula:

Shear bond strength (MPa) = Maximum force (N)/ bonding surface area (2mm) [20].

Data were revised, coded, and analyzed using the "Statistical Package of Social Science (SPSS) version 26.0. Analysis of data done by using independent sample t-test and simple linear regression.

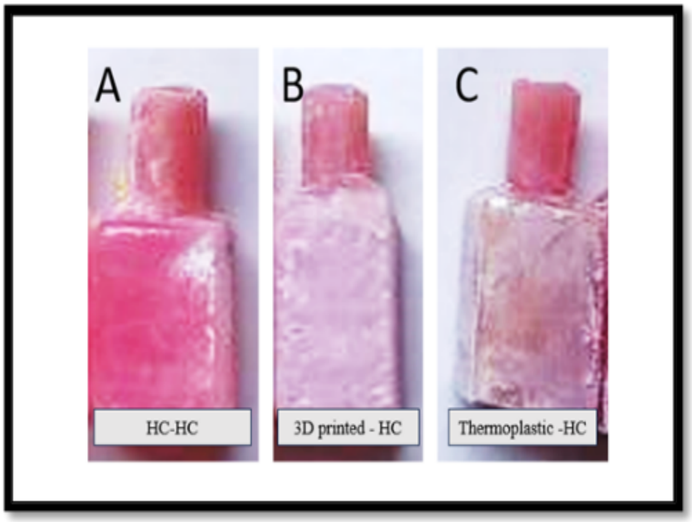

Figure 1. A: Full heat cured acrylic specimen, B: 3D printed acrylic to heat cured acrylic specimen, C: Thermoplastic acrylic to heat cured acrylic.

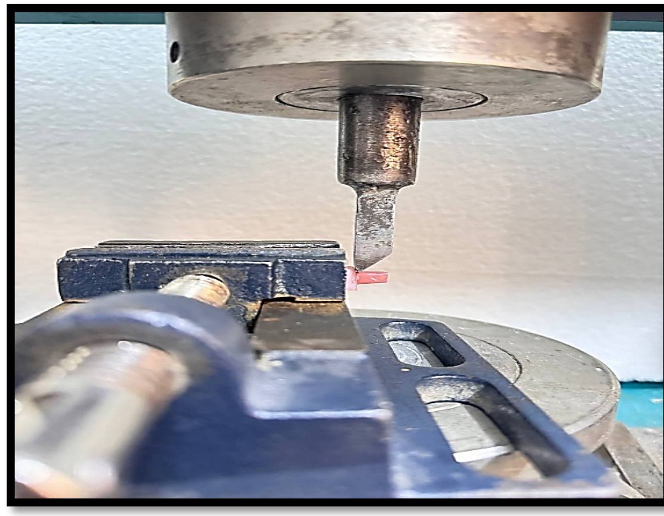

Figure 2. Universal testing machine for shear bond strength.

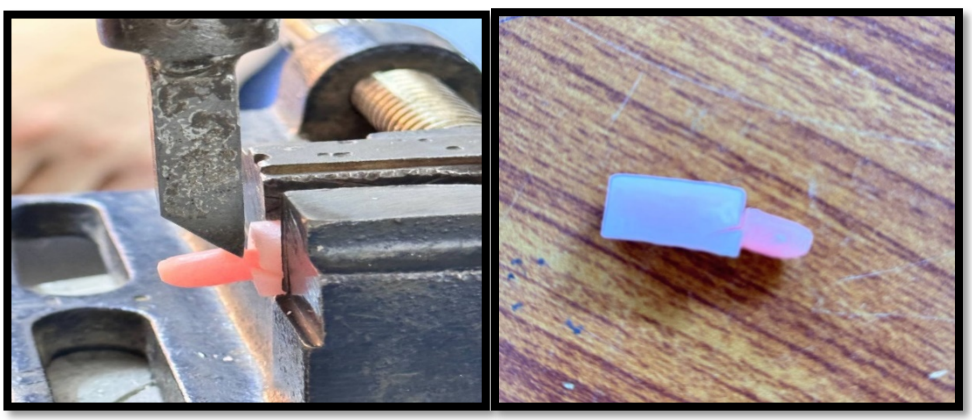

Figure 3. Specimen fracture after force application.

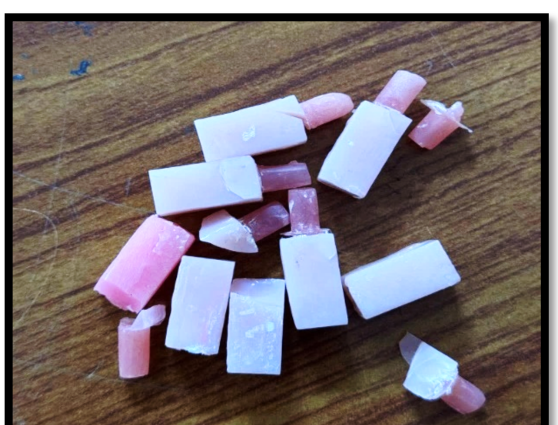

Figure 4. Tested specimen after fracture.

Results

The mean and standard deviation (SD) of the SBS values were listed and illustrated in Table 1 and Figure 5, and P-value after the T-test in Table 2. Showed a significant difference between the SBS of the HC acrylic reline/repair material bonded to both 3D printed resin and thermoplastic one.

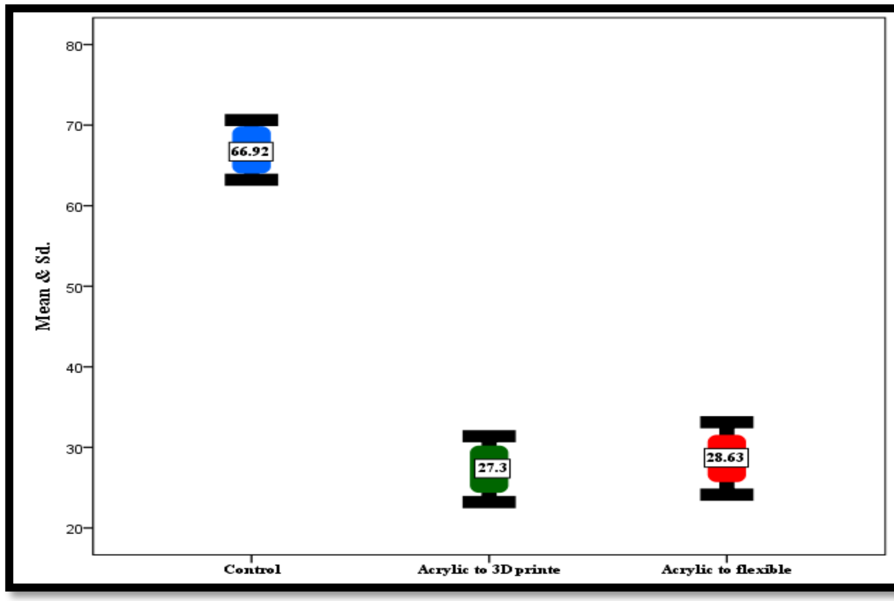

Figure 5. Mean and standard deviation (Sd.) values of shear bond strength test for the studied groups. Heat cured polymethylmethacrylate = control.

Table 1. Mean and standard deviation (SD) for SBS values

Studied groups	n	Mean ± Sd.
Heat cured polymethylmethacrylate	10	66.92 ± 5.17
3D printed acrylic to HC acrylic	10	27.30 ± 5.71
Thermoplastic acrylic to HC acrylic	10	28.63 ± 6.28

Table 2. T-test for shear bond strength.

Studied groups	t-test	P-Value
Heat cured polymethylmethacrylate vs. HC acrylic to 3D printed acrylic	16.262	P= .000
Heat cured polymethylmethacrylate vs. HC acrylic to Thermoplastic acrylic	14.885	P= .000
HC acrylic to 3D printed acrylic vs. HC acrylic to Thermoplastic acrylic	0.495	P= .626

Discussion

The present study investigated the shear bond strength between different types of denture base resins which are heat cured, 3D printed and thermoplastic acrylic resin with HC acrylic resin as a relining/repairing material. Shear bond strength can be defined as the material's component's strength against the type of yield or structural failure when the material component fails by shear force [21]. Since the additional material can be detached from a denture base for many reasons, it is important to ensure that the shear bond strength is as high as possible.

Vol 12 No 2 (2024) DOI 10.5195/d3000.2024.756

As the results shown, the highest SBS strength has been recorded in the control group, this can be referred to the bonding between specimen's parts from the same material. This finding agrees with previous work [22]. It has been stated that using a material with a matching chemical composition for relining or repairing of the denture base, the results will be achieving the highest potential values of SBS, fracture resistance and flexural strength [21,23], as it is carried out by means of a chemical reaction between the individual components [24]. The successful bonding between the new material and the base depends on the effective penetration of polymerized monomer particles from the reline/repair material into the denture base network. The high SBS of the control group might be due to high monomers diffusion rates into the denture base resin which was led by processed polymer under a high temperature and a long polymerization time [17]. Generally, new denture resins have monomers with larger molecules (molecular weight larger than 100) which act slower with respect to swelling PMMA and penetrating the PMMA surface [25]. While, in regard to the 3D printed ones the relined/repaired printed resins showed significantly lower values than the relined conventional heat-polymerized resins. This agreed with previous work [26]. Moreover, similar outcomes have been revealed in terms of comparisons in SBS for relined 3D-printed denture resins and relined heat-polymerized denture resins made by Cho et al. (2021) and Mert et al. (2023) [21,23]. They used a few different relining materials, and the results for the SBS with all relining materials were significantly lower in the 3D-printed group compared to the relined heat-polymerized resin group. The reason after that may be due to the conventional cross-linking of methyl methacrylate that occurs between PMMA interfaces may not be occurring in this group. This plays an important role in the low SBS of 3D printed resin. There are a lot of surface treatments for relining the resins. The surface treatment in this current study was creating scratches with sandblast before applying relining/repairing material. It has been shown that regardless of the material, the SBS was increased after sandblasting [26]. Polyamide thermoplastic resin group has recorded the lowest SBS results, this is referred to the nature of the material as it is produced by a reaction between a diamine and a dibasic acid called the condensation reaction. Polyamide has a high degree of crystallinity which cause polymers chemical resistance and prevent the penetration of monomer molecules and other resin primers into the polymers [27]. Therefore, the SBS is not sufficient in this type of resin and does not support any relining or repairing procedure.

Conclusion

In the light of the current study, the shear bond strength showed higher values for heat cured polymethylmethacrylate, whereas 3D printed and thermoplastic resins showed lower bonding results.

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Conflict of Interest

The authors of the manuscript declare that there are no conflicts of interest.

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Vol 12 No 2 (2024) DOI 10.5195/d3000.2024.756

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Vol 12 No 2 (2024) DOI 10.5195/d3000.2024.756

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