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Comparative Evaluation of The Shear and Tensile Bond Strength of Two Denture Reline Materials in Conventional And 3D Printing Denture Bases

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ABSTRACT

Aim: Edentulous ridge resorption results in failure of dentures. The aim of this study was to compare the shear and tensile bond strength of reline materials to conventional and 3D printed denture bases.
Methods: In this experimental study which was done in 2022, samples(N= 72) devided eight groups.A tensive vertical force was exerted to the end of the samples at 1 mm/min until the tested materials were debonded. For the shear bonding strength, a shear force was exerted to the interface of base and reline material at 1 mm/min using a one-sided shear blade. The force required for detachment of material was recorded .
Results: Data showed mean shear bonding strength in conventional groups with TDV reline material and Riviver relining material were obtained 2.22 and 1.89 MPa, while in the 3D printer group, they were 1.34 and 0.81 MPa, respectively. Also tensile bonding strength in the conventional groups with TDV reline material and Riviver reline material were obtained 1.4 and 1.01 MPa, while in the 3D printer group, were obtained 0.64 and 0.45 MPa. Based on paired comparison of groups, they were significantly different (P-value<0.001).
Conclusions: The mean tensile and shear bonding strength was higher in all groups fabricated via conventional method as compared to 3D printer method.

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INTRODUCTION

The main goal of prosthetic treatment for lost teeth is restoring the function of the lost teeth as well as improving aesthetics (1). Various studies have shown that tooth loss increases with age (2). Full denture treatment is widely used for restoring oral function in fully edentulous patients (3), which is one of the most popular and typical prosthetic therapeutic options for patients who have systemic, anatomical, or economic constraints (4). One of the newest methods of denture fabrication for fully edentulous patients is used for 3D printers (5). These printers use additive technology for denture fabrication via digital design. Residual ridge resorption is a complication, showing the constant remodeling process of alveolar ridge after tooth extraction (6). With gradual resorption of the residual ridge beneath the denture, stability and retention decrease, while reduction of vertical dimension may also occur (7,8) .There are two options for treating this problem: i) creating a new denture, and ii) adapting the current denture to reline treatment (9,10).

Relining refers to resurfacing the tissue part of denture, and creates a base and foundation for denture bearing site (2). The reline resolves the need for fabricating a new denture, and some clinicians consider it as an advantage in terms of economy and time(10,11). Liners are used as heat polymerized and as chair-side by the dentist him/herself (auto polymerized) (12). Chairside relining allows the dentist to perform relining process directly in the patient's mouth(13). Its usage is becoming more popular due to greater speed it offers compared to heat polymerized relining (14). Chair side relining is done using hard layer and soft layer materials. Hard ones are as heat cure, self-cure, and light cure. The soft liners are categorized into four groups based on their chemical structure: 1) Plasticized acrylic resins, which include various heat cured and chemical cured types, 2) Vinyl resins, 3) rubbers, which include polyurethane and polyphosphazene, and 4) silicon rubbers (13). Further, sot liners are classified into sort-term and long-term in terms of time (15).

Successful relining and propre denture functioning depend on the bonding strength between denture and liner (16). Lack of success in the bonding of relining material to the denture base results in reline debonding and decreased denture lifespan, which can be due to insufficient bonding with low cohesive strength (17).

Weak bonding can cause accumulation of bacterial, increased calculus, and layering of the liner material (18). Further, bonding strength between the relining material and denture base can affect the mechanical strength of the denture base (19). Adhesion of liner to the denture base depends on the chemical composition of the materials, and is affected by heat cycle as well as surface treatments (20,21). Currently, there are two types of relining material available including those with silicon base and liners with resin acryl bases, which are classified into auto-polymerized and direct heat polymerized groups (22). The liners with acryl resin base have a similar chemical composition to the resin acryl present in the denture base, and need to adhesive or primer(16). On the other hand, silicon-based liners, which have a different chemical structure, need adhesives, whereby debonding of the denture base occurs in this type of liners more frequently (22).

Various studies have been done on examining the bonding strength of resin materials to the denture base; give the different materials used and varying study conditions, different results have been obtained (10, 13, 22-24).

Given the differing and contradictory results, as well as lack of any study to explore the bonding strength of resin materials to the denture base created by 3D printers, this study was conducted to address this issue.

MATERIALS AND METHODS

This experimental study was approved by the research and ethics committee of Hamadan University of Medical Sciences with the ethics code of IR.UMSHA.REC.1400.526 in 2022.

Based on information obtained from previous studies (13,25), and using pwr software package in R 3.6.1 Software, and considering significance level 0.05, test power 80%, and f statistic 0.25, the sample sized required in this study was obtained 72; it included eight groups of nine.

In this study, two types of acryl denture bases were prepared via conventional method (Acropars, Tehran, Iran) of heat curing, and 3D printing (Detax GmbH, Ettlingen, Germany). All of these materials were prepared according to the manufacturer's instructions, and as cylinders with 8*20 mm dimensions (13). To prepare the samples, in the 3D printing group, first using Solid Works software, (Dassault Systemes Americas Crop.Waltham MA,United States), a cylinder sample was designed with 8 * 20 mm dimensions, and then changed into STL file format. Next, this STL file, for fabrication of samples in the 3D printing group, was transferred to Asiga , the freeform pro,Sydney, Australia device via Digital light processing technology, whereby the samples were prepared. For fabrication of samples via conventional method, wax samples were muffled cylindrically in 8*20 mm dimensions. For this purpose, plaster type 2 and dentistry acetone type 4 were mixed with 1:1 ratio with each other; when the cast was solidified, the muffle was opened and the waxed samples were withdrawn.

Thermoset acrylic resins (Acropars, Tehran, Iran) were mixed according to the manufacturer's instructions with 4:1 ratio, then packed inside muffles, and pressed under 1.5 bar pressure. This was replicated twice, whereby the extra acryl was removed in each stage. The muffles were first compressed again for 10 min, and then placed inside cold water automatic curing machine (KAVO EWL type 5518, Warthausen, Germany). The device was adjusted such that it remained at 74˚C for 90 min and at 95% for 60 min. Once the device became off automatically and muffles cooled down slowly along the night, the samples were withdrawn from the muffles and cured.

Thereafter, all samples in each group were placed inside a generator made of compressed silicon (spedex , Colten,Whaledent,Altstatten, Switzerland), which had upper and lower parts to encompass the samples. Four millimeters of the middle part of the samples was marked for placement of reline materials and cut using a disk (Softy-longlife crown cutter , 15' – 25.000 rpm , Riedenburg, Germany)(Fig. 1).

Fig 1: Marking of samples

To place the relining material in the space created on the samples available in each group, the denture base was divided into two groups: in half of the samples the relining material (soft relining silicone –super bond reviver (Medicept dental . United kingdom) and in the other relining material TDV Soft Provisional (Brazil) were mixed according to the manufacturer's instructions, then packed in a predetermined 4-mm space. To create a relatively smooth and uniform surface, the upper half of the generator was placed on the lower half until complete setting of the relining material. Once the reline materials were set completely, the samples were withdrawn from inside the samples, whereby the extra material was removed using blade and bur. Before doing the tensile and shear strength tests on the samples, all samples were placed inside thermocycling device in 50 heat cycles at 5 ˚ until 55 ˚ C [26].

Thereafter, each of these samples was tested separately for tensile and shear strength using Universal testing machine (Instorn , canton , massachu srHs ,USA)(Fig.2 a and b).

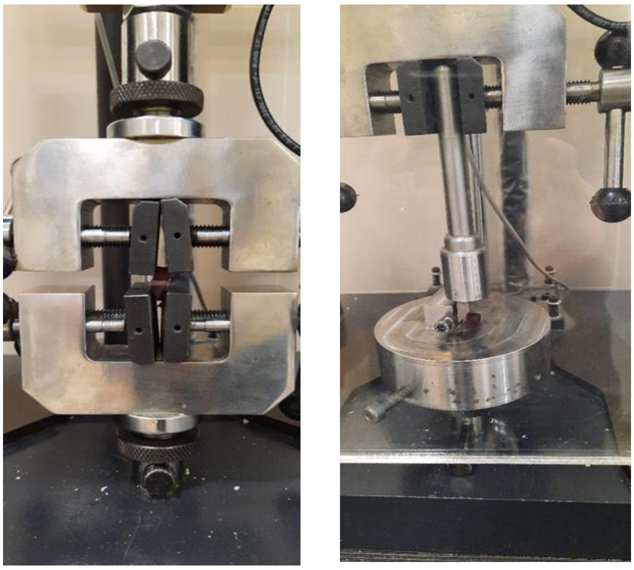

Figure 2: (**a**)Tensile bonding strength test;(**b**)Shear bonding strength test

To conduct the tensile strength test, a tensile perpendicular force was exerted to the end of the sample at 1 mm/min until debonding of the tested material from our base.

To perform the shear test, a shear force was exerted from a single-sided cutting blade to the interface of the base and reline material used at 1 mm/min. The force required for debonding of the relining material from the denture base was recorded electronically, and measured as Newton. The obtained values were then converted to MPa unit using the following equation. For data analysis, analysis of variance and LSD post hoc tests were used. Note that first the data normality assumption was examined using Shapiro-Wilk test. All calculations were done using SPSS 24. The significance level was considered 0.05.

Bond strength (tensile/shear) = force / surface area

RESULTS

For each of the obtained results, the mean shear bonding strength, standard deviation, and confidence interval in groups were measured together, and shown in Table 1 in terms of MPa.

Table 1: The descriptive information related to the shear bonding strength in different groups

		Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bond	Upper Bond
Mega. Pascal	3D/reviver	0.8101	0.07022	0.7561	0.8641
	3D/ TDV	1.3416	0.12754	1.2435	1.4396
	Conventional/ reviver	1.8929	0.15363	1.7748	2.0110
	Conventional/ TDV	2.2244	0.22057	2.0549	2.3940

As seen in Table 1, the mean shear bonding strength in the 3D printer groups have been lower than in conventional groups, and smaller in Reviver compared to TDV reline material.

For each of the obtained results, the mean tensile bonding strength, standard deviation, and confidence interval in groups were measured together, and revealed in Table 2 in terms of Newton and MPa.

Table 2: The descriptive information related to the tensile bonding strength in different groups

		Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Mega.pascal	3D/ reviver	0.4543	0.03903	0.4243	0.4843
	3D /TDV	0.6411	0.06054	0.5946	0.6877
	Conventional/reviver	1.0123	0.08095	0.9500	1.0745
	Conventional/ TDV	1.4006	0.18017	1.2621	1.5391

As outlined in Table 2, the mean tensile bonding strength in the 3D printer groups have been lower than in conventional groups, and smaller in Reviver compared to TDV reline material.

Considering the difference in the tensile and shear bonding strength among various groups, to measure the significance or lack of significance of this difference, one-way analysis of variance was used. The main assumption behind this test is normality of data, which was examined through Shapiro-Wilks test. Based on this test, the observations of all groups were normal. According to the results related to the ANOVA, the mean tensile and shear bonding strength were significantly different (P-value<0.001). Considering the significance of this test, for pairwise comparison of the groups, LSD post hoc test was employed (Tables 3 and 4).

Table 3: Pairwise comparison of the tensile bonding strength among groups

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Mega. Pascal	Tensile 3D/reviver	3D/ TDV	-0.18688*	.04955	0.001	-0.2878	-0.0859
		Conventional/ reviver	-0.55799*	.04955	0.000	-0.6589	-0.4570
		Conventional/ TDV	-0.94635*	0.04955	0.000	-1.0473	-0.8454
	Tensile 3D/TDV	Conventional/ reviver	-0.37111*	0.04955	0.000	-0.4720	-0.2702
		Conventional/ TDV	-0.75947*	0.04955	0.000	-0.8604	-0.6585
	Tensile Conventional/reviver	Conventional/ TDV	-0.38836*	0.04955	0.000	-0.4893	-0.2874

*. The mean difference is significant at the 0.05 level.

With pairwise comparison of the groups, it was found that the obtained numbers have been significantly different (Pvalue<0.001).

Table 4: Pairwise comparison of the shear bonding strength among groups

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Mega. Pascal	Shear 3D/reviver	3D/ TDV	-0.53145*	0.07205	0.000	-0.6782	-0.3847
		Conventional /reviver	-1.08280*	0.07205	0.000	-1.2296	-0.9360
		Conventional/TDV	-1.41432*	0.07205	0.000	-1.5611	-1.2676
	Shear 3D/ TDV	Conventional /reviver	-0.55135*	0.07205	0.000	-0.6981	-0.4046
		Conventional/TDV	-0.88287*	0.07205	0.000	-1.0296	-0.7361
	Shear Conventional/reviver	Convectional/ TDV	-0.33152*	0.07205	0.000	-0.4783	-0.1848

*. The mean difference is significant at the 0.05 level.

With pairwise comparison of the groups, it was found that the obtained numbers have been significantly different (Pvalue<0.001).

DISCUSSION

Soft liners are used in removable partial and total prostheses for distributing the functional loads homogeneously on the prosthesis bearing tissues. By absorbing some masticating forces, liners help in homogeneous distribution of mastication forces in underlying tissues (27). Dentistry digital technology is changing into a mainstream for dental prosthetics worldwide. In comparison to traditional fabrication method, 3D printing prostheses have a shorter manufacturing cycle and higher accuracy, and maximize patient convenience with denture (28).

Various studies have been conducted on bonding strength of various reline materials; however, comparison of the tensile and shear bonding strength of reline materials to the bases that have been fabricated via 3D printing method is an issue addressed in the present study. Currently, there is no international standard for bonding strength between prosthesis base and liner resins, and there is only ISO1039-2; 2016 international standard for tensile bonding strength between the prosthesis base and soft lining materials (29).

In this study, the tensile and shear bonding strengths of TDV and Riviver soft liners were examined with dentures based made through conventional and 3D printing methods. For this purpose, first cylinder-shaped materials with 20*8 dimensions were prepared via conventional and 3D printing methods. Next, the middle part of the samples were cut in 4 mm to place the relining material and separated. The utilized relining materials ere placed inside the intended space, and each sample was tested separately for tensile and shear bonding strengths.

The mean tensile bonding strength in the conventional groups with the TDV and Riviver relining materials was 1.4 and 1.01 MPa, while in the 3D printing groups they were 0.64 and 0.45 MPa, respectively. Further, the mean shear bonding strength in the conventional groups with the TDV and Riviver relining materials was obtained 2.22 and 1.89 MPa, while in the 3D printing groups they were 1.34 and 0.81 MPa, respectively. The significance level was considered 0.05 here; with pairwise comparison of the groups, it was found that the obtained numbers have bee significantly different (P-value<0.001).

The bonding strength of relining materials to the denture base depends on factors including similarity of the materials' constituent structure, extent of diffusion of monomer or solvent inside the polymer, as well as mechanical and chemical superficial treatments (29).

Dohiem (2022) conducted a study to compare the shear bonding strength of Acrostone Dental & Medial Supplies soft liner to two types of denture made via 3D printing and conventional methods. The shear bonding strength in the conventional heat cured denture base was higher in comparison to the 3D printer denture base group, and showed a significant difference (P-value 0.000) (30). In our study also the samples prepared via 3D printing and conventional methods showed similar and concurring results with the above study; it was found that the tensile and shear bonding strength were lower in the 3D printed samples compared to their conventionally made counterparts.

Zanatta R et al. (2016) did a study to explore the bonding strength of various direct relining materials to acrylic resin as the denture base. They found that the bonding strength of the acrylic denture base to the acrylic relining materials was higher than to other relining materials (24). In our study, conducted with TDV and Reviver relining materials, the results have been congruent with the above study. It showed that TDV acrylic-based relining material had a better bonding in all tests compared to the relining with silicon base. As a justification, it can be stated that materials with the similar base establish a greater crosslink with each other (10).

Choi et al. (2018) examined the tensile strength of three types of soft silicon liners to denture bases made via heat polymerized, auto-polymerized, and CAD-CAM methods. They concluded that the tensile bonding strength of the silicon layers to the CAD-CAM bases was lower than in heat-polymerized and auto-polymerized groups (22). The results of this study can be compared to some extent with the current study findings, since the bases made by CAD-CAM method and 3D printers are materials with higher density and fewer possible crosslinking regions. This can justify the weaker bonding of relining materials to the bases made by these methods in comparison to the conventional bases.

Seong et al. (2020) investigated the tensile strength of chair side relining materials to denture bases fabricated via additive, subtractive, and conventional methods. They concluded that the tensile bonding strength of the relining materials to the denture bases made via additive method was considerably lower than in the two other groups (29), which concurs with the present study findings.

CONCLUSIONS

The mean tensile bonding strength in all groups made via conventional method was higher than in the groups fabricated through 3D printing method. Further, the obtained values showed better bonding of TDV relining materials over Reviver.Regarding the shear bonding strength, similar results were also obtained, where the conventional methods indicated a better performance over 3D printer, and again TDV showed higher bonding strength over Riviver.

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Ethical approval

This experimental study was approved by the research and ethics committee of Hamadan University of Medical Sciences with the ethics code of IR.UMSHA.REC.1400.526.

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CONFLICT OF INTEREST

By Arash Shishehian, Farnoush Fotovat, Fariborz Vafaee, Behnaz Alafchi, Mahmoud Liyaghati Delshad to be considered in the " Journal of complementary medicine research ". We confirm that the material is original and we declare that the manuscript represents honest work and has not been considered for publication elsewhere. The article has been read and approved by all named authors. There is no conflict of interest

Informed Consent

No need.This study is an in vitro study.

Authors' contributions

Farnoush Fotovat, Arash Shishehian: Manuscript preparation, editing, review Fariborz Vafaee, Farnoush Fotovat: Study concept, literature review Mahmoud Liaghati Delshad, Behnaz Alafchi: Experimental procedures, statistical analysis

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