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THE EFFECT OF ADDING HARD & SOFT LINERS ON SHEAR BOND OF CAD-CAM 3D PRINTED & CONVECTIONAL HEAT CURED DENTURE BASE MATERIALS BEFORE & AFTER THERMAL-CYCLING

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Purpose: An in vitro study to compare the shear bond of denture bases fabricated with 2 different techniques (CAD-CAM 3D Printed & Conventional Heat-Cured), After Relining with Hard & Soft liners & After Thermal-Cycling.

Material and Methods: The minimum sample size was calculated by using a software program (3D Builder, Microsoft, U.S.A). The denture base resin was designed as a cylindrical shape with a diameter of 20.0 mm and a height of 14.0 mm as a standard tessellation language (STL) file, connected to another cylindrical shape with a diameter of 4 mm and a height of 4 mm cylinder and then an SLA type 3D-printer (Asiga, Australia) was used to print the specimens of 3D. The layer thickness (100 µm) was set, supports were placed opposite to the testing side, and printed in 0°. After the supports were removed, the specimens were post-polymerized in glycerin at 80°C for 20 minutes to follow the manufacturer's instructions. The underside of the specimens was reversed and light-cured in a post-curing machine for 20 minutes in the same manner. To make the bottom surfaces parallel and flat to each other, they were polished with an automatic polishing device (LaboPol-5; Struers, Copenhagen, Denmark). Then, the specimens were cleaned using an ultrasonic cleaner (SD-120H; Mujigae Co., Seoul, Korea) with distilled water for 20 minutes. For following ISO 10139-2, The specimens were stored in distilled water at 37°C for 24 hours. The models of the 3D printed denture base materials of shear bond test were used to produce the conventional heat cured specimens, The two parts of the flask were tightened to each other, they were pressed under a compression force of 13.8 kPa. (TISSIDental, Italy), The flask was kept in water at room temperature for 1 hour and the temperature is raised to 74°C (165F) and maintained for 9 hours in the curing machine (Zung, China) The total specimens of shear bond test were 80 specimens, 20 of them were 3D printed denture base materials (Saremco Denture Base, Germany), 20 of them were conventional heat cured denture base materials (Procryla, Germany), 20 specimens of 3D printed were relined, Specimens from (1-10) were relined with hard relining material (PMMA), while specimens from (11-20) were relined with soft resilient denture liner (Super Soft, USA). 20 specimens of conventional denture base were relined. Specimens from (1-10) were relined with hard relining material (PMMA), while specimens from (11-20) were relined with soft resilient denture liner (Super Soft, USA), then shear bond strength test was calculated after relining, then additional number of samples 40 were relined, they were thermal cycled, The specimens were kept for 24 hours in an incubator at 37°C and not thermocycled, then they were thermocycled for a total of 5000 cycles between 5 °C and 55 °C with a dwell time of 60 seconds and a transfer time of 30 seconds. subjected to 5,000

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cycles of thermocycling (SD Mechatronik Thermocycler; SD Mechatronik GmbH, Westerham, Germany) & the shear bond strength test was calculated another time using A universal testing machine (TERCO, MT 3037, Sweeden).

Results: (⸸): t-test (Two independent sample), (¥): Z=Mann-Whitney U were used when the specimens of CAD-CAM (3D printed) were relined with hard liner (PMMA) & then thermal cycled, there was a significant increase in shear bond strength ($p<0.05$). While when the specimens of 3D printed were relined with soft liner (SUPER SOFT) & then thermal cycled, there was no significant change ($p>0.05$). When the specimens of Conventional heat cured were relined with hard liner (PMMA) & then thermal cycled, there was no significant change ($p>0.05$). While when the Conventional heat cured were relined with soft liner (SUPER SOFT) & then thermal cycled, there was significant decrease after thermal cycling ($p<0.05$). £: F-test One Way ANOVA, Ҕ: Kruskal-Wallis H test, [(a),(b),(c)] multiple comparison by Duncan multiple range test for Parametric test, [(1),(2),(3),(4)] Rank for Not Parametric test, were used for Comparison Analysis of shear bond of 3D & conventional Denture Bases between 3DH (3D Hard), 3DS (3D Soft), CH (Conventional Hard), & CS (Conventional Soft) liners at Both Group after relining, there was Significant differences ($p<0.05$). Highest in conventional hard, lowest in 3D soft. While when the specimens of Conventional & CAD-CAM (3D printed) were compared After Thermal Cycling, there was also Significant differences ($p<0.05$). Highest in conventional hard, lowest in conventional soft.

Conclusion: When the CAD-CAM 3D Printed denture Base relined with hard liner there was significant increase After Relining & Thermal-Cycling. But when relined with soft liner & thermal cycled there was no significant changes occurred. shear bond strength was estimated After Relining, (3DH, 3DS, CH &CS) liners from both Group, & Thermal-Cycling, there was significant differences, highest in Conventional hard, lowest in 3D soft.

Key words: Shear Bond, CAD-CAM 3D Printed, Convectional Heat cured, Relining, Soft liner, Hard liner & Thermal-Cycling.

Introduction

There were many disadvantages in the production of dentures, such as frequent visits from patients who would follow the usual and traditional methods, the multi-stage porosity process, and the consequent increase in the use of dentures. In addition, in the event of fracture or loss of dentures, the reproduction of new dentures has become difficult and takes a long time. However, in recent years, the development of 3D printing technology in the field of dentistry has gradually developed and has begun to expand its scope to denture manufacturing, and it was expected to be a new method that can compensate for the shortcomings of the existing denture manufacturing method.[4,6,11]

Residual alveolar preparations below the denture inevitably undergo physiological absorption over resulting in poor suitability of existing dentures and clinically resulting in changes in the occlusal plane, decrease in vertical occlusal height, loss of oral function due to loss of denture retention and stability,

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and aesthetic damage due to loss of support. In such a situation, for the maintenance of the patient, the alignment of the denture between the denture and the residual gymnastics is an essential treatment in terms of the maintenance of the denture, and the patient's oral structure and the correct fit of the denture are important factors in determining the success or failure of the treatment.[8,13]

In the maintenance of ordinary dentures, there are two types of denture enhancement methods: the direct method that is performed directly in the doctor's office and the indirect method that is performed in the laboratory. The direct method has the advantage of being simple and easy to perform because it is performed directly in the patient's mouth, but it has the disadvantage that it can be affected by the bond strength between the existing denture resin and the denture cusp material. If the bond strength between the existing denture resin and the denture cusp material is weak during the direct method denture reproduction, separation and falling out of the material may occur at the interface, and it may also cause pigmentation and odor. Therefore, the shear bond strength between the existing denture and the denture apex material can be a very important factor in denture implantation, and the shear bond strength with the denture additive material used in the clinic becomes a very important factor in order for 3D printed dentures to become an excellent treatment method in clinical practice.[8,12]

To ensure a satisfactory outcome, a reliable bond between the denture base material and reline resin is important. A weak bond is associated with reduced mechanical properties of the denture, bacteria accumulation, staining or complete delamination of both the denture base resin and reline material.[14]

Clinically, the stresses applied to the interface of the two materials, leading to bond failure, are most closely related to shear and tear. Therefore, shear bond strength test, which exerts the load directly to the interface of denture base and liner, has been extensively used to investigate bond strength of reline materials It has been shown that bond strength depends on the chemical compositions of both the reline/repair material and the denture base polymer. [3,15] Other factors affecting the bond strength are surface treatment and thermal cycling Thermocycling in an aqueous environment has been widely used to replicate temperature changes in the wet oral environment and to simulate the effects of aging on the properties of materials including bond strength.[23]

After examining the shear bond strength between different denture relining materials and different 3D printed and conventional denture foundation resins. In comparison to other denture additive materials, the denture additive material including PMMA as its primary component demonstrated a high shear bond strength value across all denture resins utilized in the trial. The aforementioned findings suggest that, when doing denture augmentation on 3D-printed dentures, it would be beneficial to use denture additive materials using PMMA. However, there are drawbacks to doing so directly in the mouth cavity, such as thermogenesis. It is believed that when direct denture augmentation occurs in the oral cavity, using isobutyl.[8]

The compression of shear bond strength between the 3D-printed denture base and the chairside relining material, according to the surface treatment. The shear bond strength between the 3D-printed denture base and the chairside relining material exhibited significant differences according to the surface

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treatment methods. It is believed that excellent adhesive strength will be obtained when the Rocatec system is applied to 3D-printed dentures in clinical practice.[18]

After investigating the shear bond strength of CAD/CAM and conventional heat polymerized acrylic resin denture bases bonded to self-cured and heat-cured acrylic resins after aging. Within the limitations of this study, it was concluded that heat polymerizing acrylic denture liners have greater shear bond strength, compared to auto polymerizing acrylic denture liners, when bonded to both conventional and CAD/CAM denture bases, with no significant difference between the two denture base resins. However, there is a significant difference between auto polymerizing acrylic resin bond strength to CAD/CAM and conventional denture base. Auto polymerizing reline material seems to produce stronger bond with CAD/CAM denture base.[23]

Comparing the shear bond strength of relined milled CAD-CAM & 3D printed complete removable dental prosthesis (CRDP) resins with conventional heat-polymerized polymethylmethacrylate (PMMA) it was concluded that the shear bond strength of the 3D-printed resins used for fabricating CRDPs was inferior to the shear bond strength of resins employed for manufacturing CRDPs using CAD-CAM milling and conventional heat-polymerization techniques.[16]

Analyzing the shear bond strength of relined milled CAD-CAM & 3D printed complete removable dental prosthesis (CRDP) resins with conventional heat-polymerized polymethylmethacrylate (PMMA) it was concluded that the shear bond strength of the 3D-printed resins used for fabricating CRDPs was inferior to the shear bond strength of resins employed for manufacturing CRDPs using CAD-CAM milling and conventional heat-polymerization techniques.[16]

Materials and Methods

The total specimens of shear bond test were 80 specimens, 20 of them were 3D printed denture base materials (Saremco Denture Base, Germany), 20 of them were conventional heat cured denture base materials (Procryla, Germany), 20 specimens of 3D printed were relined, Specimens from (1-10) were relined with hard relining material (PMMA), while specimens from (11-20) were relined with soft resilient denture liner (Super Soft, USA). 20 specimens of conventional denture base were relined. Specimens from (1-10) were relined wit hard relining material (PMMA), while specimens from (11-20) were relined with soft resilient denture liner (Super Soft, USA), then shear bond strength test was calculated after relining, then additional number of samples 40 were relined, they were thermal cycled & the shear bond strength test was calculated another time Figure (1).

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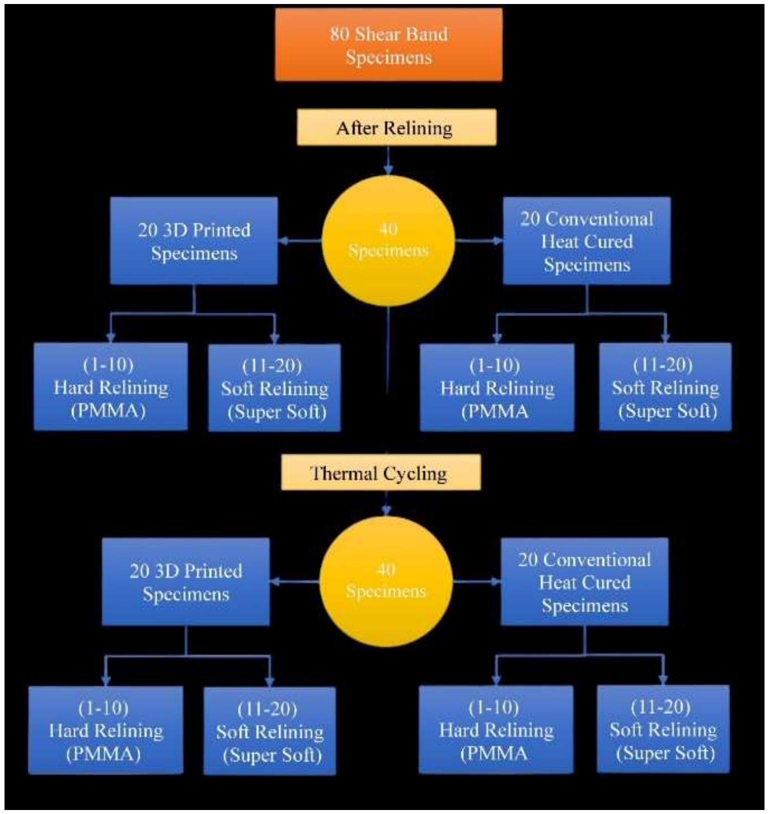

Figure 1: Denture base shear bond protocol

The minimum sample size was calculated by using a software program (3D Builder, Microsoft, U.S.A) & data from previous studies. The denture base resin was designed as a cylindrical shape with a diameter of 20.0 mm and a height of 14.0 mm as a standard tessellation language (STL) file, connected to another cylindrical shape with a diameter of 4 mm and a height of 4 mm cylinder and then an SLA type 3D-printer (Asiga, Australia) was used Figure (2). The layer thickness (100 µm) was set, supports were placed opposite to the testing side, and printed in 0°. After the supports were removed, the specimens were post-polymerized in glycerin at 80°C for 20 minutes to follow the manufacturer's instructions. The underside of the specimens was reversed and light-cured in a post-curing machine for 20 minutes in the same manner. To make the bottom surfaces parallel and flat to each other, they were polished with an automatic polishing device (LaboPol-5; Struers, Copenhagen, Denmark). Then, the specimens were cleaned using an ultrasonic cleaner (SD-120H; Mujigae Co., Seoul, Korea) with distilled water for 20 minutes. For following ISO 10139-2, The specimens were stored in distilled water at 37°C for 24 hours. Figure (3).[5,18,24]

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Figure 2: Saremco Materials used for 3D printing the specimens of shear bond

Figure 3: Asiga printer used for 3D printing specimens of shear bond

The models of the 3D printed denture base materials of shear bond test were covered with separating medium then they were placed in the first pour of stone into the flask, they were positioned so that the upper land area of the models was leveled with the edge of the flask, making sure that the upper plane of the models was parallel to the base of the flask. The stone around the models was brimmed up so that no undercut was present around the models. The stone layer around the edge of the flask was removed so that to ensure that the two halves of the flask were still meet properly when the stone was set after 45 minutes. Layer of silicon rubber base impression material (R&S, Turboflex, France) was applied around the 3D models, the other half of the flask was positioned on its place and it was placed on the vibrator, second layer of stone was applied, the upper lid of the flask was positioned and the two halves of the flask was tightened Figure (4).

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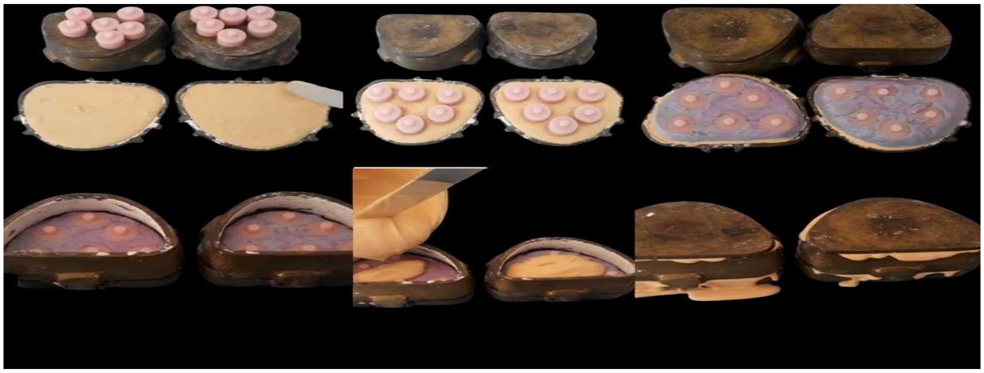

Figure 4: Samples Preparation for PMMA Denture Base Materials

The models of 3D printed denture base material were removed gently from the stone mold so that copy of these 3D printed models was taken, another layer of separating medium was applied on the inner surface of the mold and on the surface of the first layer of the stone, conventional heat cured (Procryla, Germany) was applied on the molds. The two parts of the flask were tightened to each other, they were pressed under a compression force of 13.8 kPa. (TISSIDental, Italy), The flask was kept in water at room temperature for 1 hour and the temperature is raised to 74℃ (165F) and maintained for 9 hours in the curing machine (Zung, China) Figure (5).

Figure 5: Curing the conventional heat cured specimens of shear bond test

20 specimens of 3D printed were relined, specimens from (1-10) were relined with hard liner PMMA, while specimens from (11-20) were relined with soft liner Super Soft. 20 specimens of conventional were relined, specimens from (1-10) were relined with hard liner PMMA, while specimens from (11-20) were relined with soft liner Super Soft Figure (6).

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Figure 6: Relining process of specimens of shear bond test

Both parts of the flask were pressed under a compression force of 13.8 kPa. (TISSIDental, Italy). The flask is kept in water at room temperature and the temperature is raised to 74℃ (165F) and maintained for 9 hours for PMMA and 6 hours for Super Soft liner. the flask should be cooled slowly to room temperature before the denture was deflasked. This process may lead to the setting up of internal stress within the denture base since the coefficient of thermal expansion of acrylic resin is about 10 times greater than that of the gypsum mould material Figure (7).[19]

Figure 7: Curing the specimens of shear bond test after relining

The specimens were stored in distilled water at 37°C for 24 hours. Figure (3.40). A universal testing machine (TERCO, MT 3037, Sweeden) was used to evaluate the shear bond strengths. Special jig was manufactured to accommodate the size of the specimens Figure (8). The crosshead speed was set at 0.5 mm/min, and the maximum load until fracture of the specimens was recorded in Newton (N) Figure (3.42) The shear bond strength was calculated using the equation: Shear bond strength (MPa) = N/A, N = maximum load (N), A = Relining area (mm2) = 12.56 mm^2 ($A = \pi r^2$)=3.14*$(2)^2$. [18]

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Figure 8: A universal testing machine (TERCO, MT 3037, Sweeden)

The shear bond specimens were kept for 24 hours in an incubator at 37°C and not thermocycled.[21] Specimens for each of the tests were thermocycled for a total of 5000 cycles between 5 °Cand 55 °C with a dwell time of 60 seconds and a transfer time of 30 seconds.[20] subjected to 5,000 cycles of thermocycling (SD Mechatronik Thermocycler; SD Mechatronik GmbH, Westerham, Germany). The thermo-cycling machine was consisted of two baths, for the hot bath; there was a boiler, provided with a thermostat to regulate the temperature to be in 55±2 ºC, for the cold bath there was a refrigerator compressor, provided with a thermostat to regulate the temperature to be in 5 ±2 ºC. The samples were placed inside a basket connected to a handle to transfer the basket automatically between the baths; 30 seconds in each bath and 5 seconds interval between each bath. A thermocouple (HT-9815 Thermocouple Thermometer) was used for monitoring the temperature of the baths by inserting the one probe in the hot bath and one probe in the cold bath Figure (9).[1,2,7,10]

Figure 9: Thermocycling device

Statistical Analysis

(ϯ:) t-test (Paired), (£:) Wilcoxon Signed Ranks Test were used to compare the mean values of 3D Denture Bases before & after relining with Hard & soft liners & after thermal cycling. £: F-test One Way ANOVA, Ᵹ: Kruskal-Wallis H test, $^{(a),(b),(c)}$ multiple comparison by Duncan multiple range test for Parametric test, $^{(1),(2),(3),(4)}$ Rank for Not Parametric test, were used for Comparison Analysis of Shear Bond of 3D & conventional Denture Bases between 3DH (3D Hard), 3DS (3D Soft), CH (Conventional

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Hard), & CS (Conventional Soft) liners at Both Group after relining & After Thermal Cycling. When (p>0.05) no significant difference was reported, (p<0.05), statistical significance differences was reported for all comparisons, (p<0.01) highly significancy was reported.

Results

(ǂ): t-test (Two independent sample), (¥): Z=Mann-Whitney U were used when the specimens of CAD-CAM 3D printed were relined with hard liner (PMMA) & then thermal cycled, there was a significant increase in shear bond strength (p<0.05). While when the specimens of 3D printed were relined with soft liner (SUPER SOFT) & then thermal cycled, there was no significant change (p>0.05) Figure (10) Table (1), Table (1), Table (2)

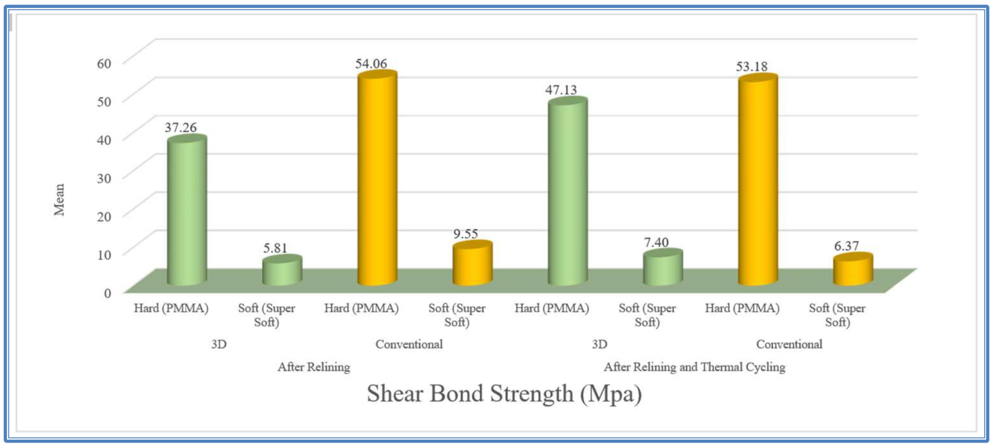

Figure 10: Bar chart illustrate the mean values of Shear Bond of 3D & Conventional Denture Bases after relining & after relining & Thermal cycling.

Table 1: Comparison of Shear Bond of 3D Denture Base Material before & After Relining with hard liner and after Thermal Cycling.

	Dimensionality -PMMA_SS			Mean	N	Std. Deviation	Test Value	d.f.	P-Value	Sig.
1-3	3D - Hard (PMMA)	Impact Strength	Control	2.370	10	0.589	0.630ǂ	9	0.544	NS
			After Relining	2.210	10	0.624				
1-7		Impact Strength	Control	2.370	10	0.589	1.899ǂ	9	0.090	NS
			After Relining and Thermal Cycling	1.750	10	0.979				
1-3		Flexural Strength	Control	83.333	10	9.980	-2.499£	9	0.012	S
			After Relining	138.430	10	39.155				
1-7		Flexural Strength	Control	83.333	10	9.980	-6.716ǂ	9	0.000	HS
			After Relining and Thermal Cycling	139.119	10	20.990				
1-3		Adaptation	Control	0.718	10	0.132	5.812ǂ	9	0.000	HS
			After Relining	0.386	10	0.124				
1-7		Adaptation	Control	0.718	10	0.132	5.175ǂ	9	0.001	HS
			After Relining and Thermal Cycling	0.450	10	0.114				
3-7		Shear Bond Strength (Mpa)	After Relining	37.261	10	11.997	-2.729ǂ	9	0.023	S
			After Relining and Thermal Cycling	47.134	10	6.585				
3-7		Impact Strength	After Relining	2.210	10	0.624	1.288ǂ	9	0.230	NS
			After Relining and Thermal Cycling	1.750	10	0.979				
3-7		Flexural Strength	After Relining	138.430	10	39.155	-0.057ǂ	9	0.955	NS
			After Relining and Thermal Cycling	139.119	10	20.990				
3-7		Denture Base (Mean)	After Relining	0.386	10	0.124	-3.287ǂ	9	0.009	HS
			After Relining and Thermal Cycling	0.450	10	0.114				

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Table 2: Comparison of Shear Bond of 3D Denture Base Material before & After Relining with soft liner and after Thermal Cycling.

Dimensionality	Dimensionality -PMMA_SS			Mean	N	Std. Deviation	Test Value	d.f.	P-Value	Sig.
1-4	3D - Soft (Super Soft)	Impact Strength	Control	2.370	10	0.589	-10.444†	9	0.000	HS
			After Relining	4.900	10	0.699				
1-8		Impact Strength	Control	2.370	10	0.589	0.352†	9	0.733	NS
			After Relining and Thermal Cycling	2.240	10	0.857				
1-4		Flexural Strength	Control	83.333	10	9.980	2.673£	9	0.008	HS
			After Relining	59.917	10	11.728				
1-8		Flexural Strength	Control	83.333	10	9.980	0.751†	9	0.472	NS
			After Relining and Thermal Cycling	78.512	10	14.592				
1-4		Adaptation	Control	0.718	10	0.132	2.803£	9	0.005	HS
			After Relining	0.285	10	0.126				
1-8		Adaptation	Control	0.718	10	0.132	8.196†	9	0.000	HS
			After Relining and Thermal Cycling	0.331	10	0.146				
4-8		Shear Bond Strength (Mpa)	After Relining	5.812	10	1.762	-1.519†	9	0.163	NS
			After Relining and Thermal Cycling	7.405	10	2.057				
4-8		Impact Strength	After Relining	4.900	10	0.699	11.735†	9	0.000	HS
			After Relining and Thermal Cycling	2.240	10	0.857				
4-8		Flexural Strength	After Relining	59.917	10	11.728	-2.827†	9	0.020	S
			After Relining and Thermal Cycling	78.512	10	14.592				
4-8		Denture Base (Mean)	After Relining	0.285	10	0.126	-0.764£	9	0.445	NS
			After Relining and Thermal Cycling	0.331	10	0.146				

When the specimens of Conventional heat cured were relined with hard liner (PMMA) & then thermal cycled, there was no significant change ($p>0.05$). While when the Conventional heat cured were relined with soft liner (SUPER SOFT) & then thermal cycled, there was significant decrease after thermal cycling ($p<0.05$) Figure (10), Table (3), Table (4).

Table 3: Comparison of Shear Bond of Conventional heat cured Material before & After Relining with hard liner and after Thermal Cycling.

Dimensionality	Dimensionality -PMMA_SS			Mean	N	Std. Deviation	Test Value	d.f.	P-Value	Sig.
2-5	Conventional - Hard (PMMA)	Impact Strength	Control	2.850	10	1.001	-0.960£	9	0.337	NS
			After Relining	3.050	10	0.550				
2-9		Impact Strength	Control	2.850	10	1.001	3.760†	9	0.004	HS
			After Relining and Thermal Cycling	1.590	10	0.401				
2-5		Flexural Strength	Control	76.446	10	15.383	-7.417†	9	0.000	HS
			After Relining	146.006	10	23.140				
2-9		Flexural Strength	Control	76.446	10	15.383	-6.716†	9	0.000	HS
			After Relining and Thermal Cycling	146.694	10	28.865				
2-5		Adaptation	Control	0.341	10	0.134	-2.932†	9	0.017	S
			After Relining	0.477	10	0.100				
2-9		Adaptation	Control	0.341	10	0.134	-2.908†	9	0.017	S
			After Relining and Thermal Cycling	0.527	10	0.135				
5-9		Shear Bond Strength (Mpa)	After Relining	54.061	10	10.796	0.257†	9	0.803	NS
			After Relining and Thermal Cycling	53.185	10	7.708				
5-9		Impact Strength	After Relining	3.050	10	0.550	8.331†	9	0.000	HS
			After Relining and Thermal Cycling	1.590	10	0.401				
5-9		Flexural Strength	After Relining	146.006	10	23.140	-0.058†	9	0.955	NS
			After Relining and Thermal Cycling	146.694	10	28.865				
5-9		Denture Base (Mean)	After Relining	0.477	10	0.100	-1.266†	9	0.237	NS
			After Relining and Thermal Cycling	0.527	10	0.135				

Table 4: Comparison of Shear Bond of Conventional Heat Cured before & After Relining with soft liner and after Thermal Cycling.

Dimensionality	Dimensionality -PMMA_SS			Mean	N	Std. Deviation	Test Value	d.f.	P-Value	Sig.
2-6	Conventional- Soft (Super Soft)	Impact Strength	Control	2.850	10	1.001	-1.190£	9	0.234	NS
			After Relining	3.750	10	1.603				
2-10		Impact Strength	Control	2.850	10	1.001	1.606†	9	0.143	NS
			After Relining and Thermal Cycling	2.240	10	0.721				
2-6		Flexural Strength	Control	76.446	10	15.383	4.106†	9	0.003	HS
			After Relining	56.474	10	6.329				
2-10		Flexural Strength	Control	76.446	10	15.383	4.221†	9	0.002	HS
			After Relining and Thermal Cycling	57.163	10	11.270				
2-6		Adaptation	Control	0.341	10	0.134	-1.586†	9	0.147	NS
			After Relining	0.441	10	0.144				
2-10		Adaptation	Control	0.341	10	0.134	-0.706†	9	0.498	NS
			After Relining and Thermal Cycling	0.393	10	0.174				
6-10		Shear Bond Strength (Mpa)	After Relining	9.554	10	1.914	2.524£	9	0.012	S
			After Relining and Thermal Cycling	6.369	10	1.547				
6-10		Impact Strength	After Relining	3.750	10	1.603	0.035£	9	0.036	S
			After Relining and Thermal Cycling	2.240	10	0.721				
6-10		Flexural Strength	After Relining	56.474	10	6.329	-0.176†	9	0.864	NS
			After Relining and Thermal Cycling	57.163	10	11.270				
6-10		Denture Base (Mean)	After Relining	0.441	10	0.144	1.567†	9	0.152	NS
			After Relining and Thermal Cycling	0.393	10	0.174				

£: F-test One Way ANOVA, Ҕ: Kruskal-Wallis H test, (a),(b),(c) multiple comparison by Duncan multiple

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range test for Parametric test, $^{(1),(2),(3),(4)}$ Rank for Not Parametric test, were used for Comparison Analysis of shear bond of 3D & conventional Denture Bases between 3DH (3D Hard), 3DS (3D Soft), CH (Conventional Hard), & CS (Conventional Soft) liners at Both Group after relining, there was Significant differences ($p<0.05$). Highest in conventional hard, lowest in 3D soft. While when the specimens of Conventional & CAD-CAM (3D printed) were compared After Thermal Cycling, there was also Significant differences ($p<0.05$). Highest in conventional hard, lowest in conventional soft Figure (10), Table (5), Table (6).

Table 5: Comparison Analysis of Shear Bond of 3D & conventional Denture Bases between (3DH, 3DS, CH &CS) liner at Both Group after relining.

(3-4-5-6)		N	Mean	Std. Deviation	Test Value	P-Value
Y1 Shear Bond Strength (Mpa)	3 After Relining 3D Hard (PMMA)	10	$37.261^{(b)}$	11.997	79.342£	0.000 (HS)
	4 After Relining 3D Soft (Super Soft)	10	$5.812^{(a)}$	1.762		
	5 After Relining Conventional Hard (PMMA)	10	$54.061^{(c)}$	10.796		
	6 After Relining Conventional Soft (Super Soft)	10	$9.554^{(a)}$	1.914		
	Total	40	26.672	21.667		
Y2 Impact Strength	3 After Relining 3D Hard (PMMA)	10	$2.210^{(a)}$	0.624	13.817£	0.000 (HS)
	4 After Relining 3D Soft (Super Soft)	10	$4.900^{(c)}$	0.699		
	5 After Relining Conventional Hard (PMMA)	10	$3.050^{(ab)}$	0.550		
	6 After Relining Conventional Soft (Super Soft)	10	$3.750^{(b)}$	1.603		
	Total	40	3.478	1.365		
Y3 Flexural Strength	3 After Relining 3D Hard (PMMA)	10	$138.430^{(b)}$	39.155	42.113£	0.000 (HS)
	4 After Relining 3D Soft (Super Soft)	10	$59.917^{(a)}$	11.728		
	5 After Relining Conventional Hard (PMMA)	10	$146.006^{(b)}$	23.140		
	6 After Relining Conventional Soft (Super Soft)	10	$56.474^{(a)}$	6.329		
	Total	40	100.207	48.347		
Y4 Adaptation (Mean)	3 After Relining 3D Hard (PMMA)	10	$0.386^{(2)}$	0.124	13.073 Ђ	0.004 (HS)
	4 After Relining 3D Soft (Super Soft)	10	$0.285^{(1)}$	0.126		
	5 After Relining Conventional Hard (PMMA)	10	$0.477^{(4)}$	0.100		
	6 After Relining Conventional Soft (Super Soft)	10	$0.441^{(3)}$	0.144		
	Total	40	0.397	0.140		

Table 6: Comparison Analysis of Shear Bond of 3D & conventional Denture Bases between (3DH, 3DS, CH &CS) liner at Both Group after Thermal cycling.

(7-8-9-10)		N	Mean	Std. Deviation	Test Value	P-Value
Y1 Shear Bond Strength (Mpa)	7 After Relining and Thermal Cycling 3D Hard (PMMA)	10	$47.134^{(3)}$	6.585	30.493 Ђ	0.000 (HS)
	8 After Relining and Thermal Cycling 3D Soft (Super Soft)	10	$7.404^{(2)}$	2.057		
	9 After Relining and Thermal Cycling Conventional Hard (PMMA)	10	$53.185^{(4)}$	7.708		
	10 After Relining and Thermal Cycling Conventional Soft (Super Soft)	10	$6.369^{(1)}$	1.547		
	Total	40	28.523	22.588		
Y2 Impact Strength	7 After Relining and Thermal Cycling 3D Hard (PMMA)	10	$1.750^{(2)}$	0.979	6.248 Ђ	0.100 (NS)
	8 After Relining and Thermal Cycling 3D Soft (Super Soft)	10	$2.240^{(3)}$	0.857		
	9 After Relining and Thermal Cycling Conventional Hard (PMMA)	10	$1.590^{(1)}$	0.401		
	10 After Relining and Thermal Cycling Conventional Soft (Super Soft)	10	$2.240^{(3)}$	0.721		
	Total	40	1.955	0.796		
Y3 Flexural Strength	7 After Relining and Thermal Cycling 3D Hard (PMMA)	10	$139.118^{(c)}$	20.990	48.682£	0.000 (HS)
	8 After Relining and Thermal Cycling 3D Soft (Super Soft)	10	$78.512^{(b)}$	14.592		
	9 After Relining and Thermal Cycling Conventional Hard (PMMA)	10	$146.694^{(c)}$	28.865		
	10 After Relining and Thermal Cycling Conventional Soft (Super Soft)	10	$57.163^{(a)}$	11.270		
	Total	40	105.372	43.395		
Y4 Adaptation (Mean)	7 After Relining and Thermal Cycling 3D Hard (PMMA)	10	$0.450^{(3)}$	0.114	9.301 Ђ	0.026 (S)
	8 After Relining and Thermal Cycling 3D Soft (Super Soft)	10	$0.331^{(1)}$	0.146		
	9 After Relining and Thermal Cycling Conventional Hard (PMMA)	10	$0.527^{(4)}$	0.135		
	10 After Relining and Thermal Cycling Conventional Soft (Super Soft)	10	$0.393^{(2)}$	0.174		
	Total	40	0.425	0.156		

Discussion

In this study, the shear bond strength of conventional heat-polymerized, and CAD-CAM 3D-printed resins were examined after relining & thermal cycling. The primary null hypothesis set for this in vitro experiment was that there would be no differences in the shear bond strength of Conventional heat polymerized and CAD-CAM 3D-Printed resins after conventional relining procedures & thermal

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cycling. The null hypothesis was rejected as the results demonstrated that the shear bond strength was significantly different among Conventional Heat polymerized and CAD-CAM 3D-Printed resins after conventional relining procedures & Thermal- Cycling**.** In this study two different relining materials were used, namely hard (PMMA) reline and soft (SUPER-SOFT) reline, to reline CAD-CAM 3D Printed & Conventional heat-polymerized acrylic resin denture bases. In terms of Shear Bond Strength, when the specimens of CAD-CAM 3D printed were relined with hard liner (PMMA) & then thermal cycled, there was a significant increase in shear bond strength. While when the specimens of 3D printed were relined with soft liner (SUPER SOFT) & then thermal cycled, there was no significant change. Shear bond strength was estimated After Relining, **(3**DH, 3DS, CH &CS**)** liner from both Group, there was Significant differences, highest in conventional hard, lowest in 3D soft. The partially different outcome may be due to the use of different relining materials and to the different pre-treatment with sandblasting.[16]

It has been shown in this study that the shear bond strength of CAD-CAM 3D Printed had significant differences than the conventional heat-polymerized resins. Furthermore, comparisons in terms of shear bond strength for relined 3D-printed denture resins and relined heat-polymerized denture resins made by Cho et al. (2021) revealed similar outcomes as the same as in this study. They used a few different relining materials, and the results were for the shear bond strength with all relining materials significant lower in the 3D-printed group compared to the relined heat polymerized resin group.[8]

An important aspect to be considered is that the resin used for 3D printing in this study is primarily composed of bisphenol-A dimethacrylate and therefore the conventional cross linking of methyl methacrylate that occurs between PMMA and PMMA interfaces may not be occurring as with the other groups. This is an important factor that might have affected the low shear bond strength. Nevertheless, this point was known even before the start of the experiment and still no extra measures were taken to improve the bonding because in real life, when a denture needs to be relined or repaired, the information on the resin type is not always known.[16]

Situations may arise that the dentist/laboratory which originally manufactured the CRDP (Complete Removable Denture Prosthesis) may not be the ones who might reline or repair the CRDP should the patient migrates or was unable to access his/her original professional. Therefore, it was important to understand the reline capabilities if such a situation arises. More so, it is now evident that in a clinical context it was important to deliver the information about the resin employed for fabrication along with the denture itself, so that the patient can convey this information to the treating dentist or the laboratory for any required emergency repair or relines.[16]

When the specimens of Conventional Heat-Cured & CAD-CAM 3D printed were compared After Thermal Cycling, **(3**DH, 3DS, CH &CS**)** liners from both Group, there was significant differences, highest in conventional hard, lowest in conventional soft. Thermocycling was also something to consider which may affect the shear bond strength. Denture prostheses are exposed to various thermal situations in the oral cavity due to the intake of cold and hot drinks and food. In a wet environment can

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thermal cycling cause a degradation of the denture polymers, and the water sorption may be raised because of the extension of the distance between the polymer chains due to heat stress.[22]

The water absorption is thus directly related with the dimensional stability of dental material.[9] Absorbed water can reduce the mechanical properties of the denture, because the water can act as a plasticizer, soften the denture and enhance the elasticity this consequences with decreasing the bond strength.[23] Otherwise, further polymerization reactions can be enhanced due to heating the acrylic resins which improves the mechanical properties, So, it can be assumed that the thermal cycling has an effect on the mechanical properties of the acrylic resins, which may influence the performance of the relined removable prostheses. [22] Studies with soft reliner showed that thermocycling can improve or impair the shear, bond strength, but it mostly resulted in a significant reduction of the shear bond strength.[17]

The chemical composition of the different resins used may have an impact on thermocycling. However, the Conventional Heat-Cured denture resins show lower porosities and voids and have a stronger cross linkage between polymer chains. This induces to reduced water absorption.[23] A previous published study showed that thermocycling lowered the microhardness of three different CAD-CAM denture base materials which may lead to reduced shear bond strength. However, the effect may have occurred in the 3D printed resin group, as its chemical composition is different from the conventional Heat-Cured resin groups.[2]

Furthermore, different thermal expansion coefficients (CTE) of materials, as the possible differences in CTE between the denture base resin and the reline material, lead to different degrees of shrinkage and expansion. This results in a cyclic stress at the interface and enhances the fatigue of bond during thermocycling.[2,23]

A limitation of this study was that no special pre-treatment or bonding procedures were applied to the 3D resin group samples. Therefore, this could have affected the shear bond strength of the samples from this group, since the chemical composition is different from the Conventional Heat-Cured. It is therefore evident that conventional relining procedures may not be employed for relining 3D-printed dentures, unless employed with special surface pre-treatment of the resins or with a special bonding technique that will enhance the bonding of the 3D-printed resin with conventional resins used for relining. This aspect was not tested in the current study as it was beyond the scope of this study. It is recommended that this factor should be addressed in a future purpose-built study with this aim as a primary objective, but still the PMMA was considered as material of choice for relining the CAD-CAM 3D Printed & for Conventional Heat- cured denture bases.

Conclusion

When the CAD-CAM 3D Printed denture Base relined with hard liner there was significant increase of shear bond After Relining & Thermal-Cycling. But when relined with soft liner & thermal cycled there was no significant changes occurred. shear bond strength was estimated After Relining, (3DH, 3DS, CH &CS) liners from both Group, & Thermal-Cycling, there was significant differences, highest in

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Conventional hard, lowest in 3D soft.

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