Original Study

FRACTURE FORCE EVALUATION, DEFLECTION, AND TOUGHNESS ON THREE REPAIRED INJECTION MOLDED PMMA DENTURE BASE RESINS

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ABSTRACT

To date, the management of fractured dentures made from high-impact acrylic polymers is challenging. Hence this study is aimed to evaluate fracture force, toughness, and deflection on three types of repaired injection-molded polymethyl methacrylate thermoplastic denture base resins.

In this in-vitro study, the sample size was estimated to 20 samples per group (group A, B, and C) using G*power 3.0.10 software with power 80% and alpha error of 5%. So, a total of 60 high-impact injection-molded acrylic resin samples (39mm x 4mm x 8mm) were prepared and a pre-crack was made with a diamond disc to a depth of (3.0 ± 0.2) mm along the marked centreline. Repair of the fractured segments was done with Probase cold, Triplex SR cold, and Lukafix light cure resin. A three-point bending test was carried out to test the repaired site, and the obtained values were statically analyzed with one-way ANOVA and Tukey's post hoc test ($\alpha \leq 0.05$).

The statistical analysis has shown significant differences in flexural force, deflection, and fracture toughness between groups. The increase in fracture toughness was observed in group A, which was 245.06N, the deflection was 0.14cm and flexural strength was 24.0 Mpa

The fracture force, deflection, and toughness were found to be significant in samples repaired with auto polymerizing PMMA resin. Hence the study concludes that auto polymerizing resin can be better used in repair auto polymerizing PMMA resin when compared to other resins.

Key words: Injection molded acrylic resin, Denture fracture, Denture repair, Deflection, Toughness.

Introduction

The construction of dentures can be done by compression molding, injection molding the acrylic resin, or microwave processing [1-3]. PMMA is extensively processed by compression molding method for fabrication of denture for its desirable properties [4]. However, a dimensional change attributed to this technique can be inevitable. According to ISO standard (1567:19881), the denture base acrylic resin should possess Kmax (maximum factor of the loading intensity), fracture work Wf of 1.90 MPam1/2 and 900 J/m2 respectively to resist fracture. However, fractures and the formation of cracks are common complications to both compression molded and injection molded removable prostheses. The most common of which is midline fractures and cracks at the posterior cantilever area, as a result of fatigue failure, extreme thin area, thin flange near frenum [5, 6]. So, Pryor in 1942 developed an injection molding system of plastics for dentures [7]. The continuous injection process under constant hydraulic pressure in the closed mold compensates for excessive shrinkage and produces a dense strong plastic-free from porosity. Studies had shown that this injection-molded PMMA system had better dimensional stability, wear strength, better deflection, and water sorption [8-10]. However, fractures and the formation of cracks are common complications to both compression molded and injection molded removable prostheses. The denture base repair was previously done with auto polymerizing resin glass fiber reinforcement, woven metal, visible light polymerized reline material, salinized glass fibers, wires reinforced with Co-Cr or San-cobalt palatal bars which showed significant results on conventional compression-molded PMMA dentures [11-14]. The main aim of denture repair is to reimpose the denture to its initial strength. Final strength after repair depends on certain factors like the width of the fracture gap, fracture surface bevelling, and properties of repair resin. So the resistance to fracture of the repaired denture base material is affected by fracture strength and fracture toughness [15]. Dentures made with injection-molded PMMA thermoplastic resin can also fracture but it is not feasible to repair with the same material. So it is mandatory to determine the flexural properties like toughness, deflection, and strength after the fractured denture base was repaired with other auto polymerizing and light cure resins. However, no studies have been previously done to analyze the fracture toughness of repaired Injection-molded polymethyl methacrylate denture base resins. Hence this study is aimed to evaluate fracture force, toughness, and deflection of injection-molded polymethyl methacrylate thermoplastic denture base resins repaired with two different auto polymerizing resins and one light-curing resin. The null hypothesis of this study stated that there is no difference in fracture force, deflection, and toughness between the three repair materials tested.

Materials and Methods

This in-vitro study was conducted in SRM Dental College from March 2018 to December 2019 and was approved by the institutional review board with the IRB number SRMDC/IRB/2017/MDS/NO.202 The sample size was estimated to 20 samples per group, using G*power 3.0.10 software with power 80% and alpha error 5% the sample size was calculated.

A master brass die was prepared according to ISO 20795.1.2013 with dimensions of 65mm x 40mm x 5mm in brass. The master die was duplicated with an additional silicone impression material (Aquasil soft putty, Dentsply, Germany) to prepare the mold. The wax blocks were prepared from the mold **(Figure 1)** and processing was done using injection-molded PMMA resin (SR Ivocap High Impact, Ivoclar Vivadent, Liechtenstein) based on the manufacturer's instruction. The acrylic specimens were retrieved after the curing cycle is completed and checked for any irregularities. Then the specimens were trimmed and finished using acrylic stone trimmers and 600 grit sandpaper. Each specimen was cut into six equal samples measuring 39mm length, 4mm width, and 8mm height using a milling machine .

A total of 60 samples were made and their dimensions were verified using a digital micrometer (Digimatic Micrometer, Japan). The test samples were stored at 37 °C in water for 24 hrs before testing. The samples thus obtained were fixed lengthwise in the holding device and a mark was set exactly on the centreline of the sample. A pre-crack was cut with a diamond disc according to ISO 20795.1.2013 to a depth of (3.0 ± 0.2) mm along the marked centreline. Then the pre-crack was wet with a drop of glycerol and a sharp notch was made with a Double-sided 0.25*22mm NTI Flex disc (Val Lab diamond disk, US) **(Figure 2)**. The notched samples were stored in a container with water at (37 ± 1) °C for 7 days before testing.

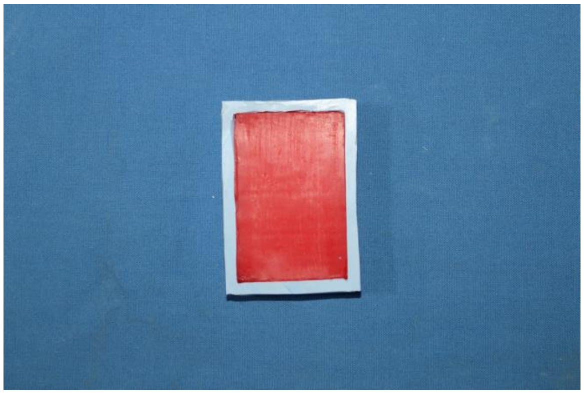

Figure 1. Wax pattern

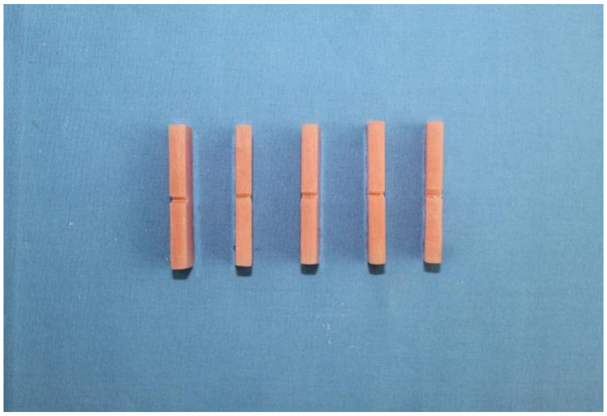

Figure 2. Repaired samples with butt joint

The samples were staged on the Universal Testing Machine (Autograph universal testing machine, Shimadzu Corp, Japan) for fracture toughness with the notch facing exactly opposite the load plunger. The load was applied at the mid-point of the sample until the crack has almost reached the opposite side of the specimen. The maximal load before fracture was measured. After fracture tests, the samples were randomly divided into three groups (n=20) for repairing and described as:

Group A- Repaired with Probase Cold, auto polymerizing resin (n=20)

Group B- Repaired with Triplex SR cold, auto polymerizing resin (n=20)

Group C- Repaired with Lukafix, light-curable resin (n=20)

Group A samples were repaired with Probase Cold (SR Triplex Cold Pink –V (541433AN), Ivoclar Vivadent, Liechtenstein) Group B samples were repaired with Triplex SR auto polymerizing resin (ProBase Cold Trial Kit pink-V (531487AN) Ivoclar Vivadent, Liechtenstein) and Group C samples were repaired with LukaFix light-curable resin (LUKAFix-Kit, color pink, Indenco Dental products, USA). Group C samples were cured using a halogen lamp light-curing unit (BlueLuxcer, Taiwan) with the voltage of 50/60 Hz and wavelength of 360-480 nm for 10 mins. The butt joint surface was first treated with the monomer liquid of each acrylic resin for 3 minutes, and the gap was filled with group A, group B, and group C acrylic resin. After polymerization, the surfaces of each repaired sample were finished and polished using 600-grit sandpaper. The repaired samples were segregated and stored at 37◦ Cunder distilled water for 7 days and evaluated for fracture toughness. Three-point bending was used to test the repaired site, and the values obtained were statically analyzed with one-way ANOVA and Tukey's post hoc test ($\alpha \leq 0.05$). Statistical analysis was done with G*power 3.0.10 software.

Results and Discussion

The standard deviation and standard error of each group were listed in **Table 1** and the mean value of group A was 2.013, group B was 1.915 and group C was 1.753, and the standard deviation of group A, B, C were 3.5581595, 7.7922529, and 9.7700762 respectively. The standard error values were 79, 1.74, and 2.18 respectively. Whereas, 95% confidence interval for mean was higher for group A with the lower bound value of 1.818730 and upper bound value of 2.549270 and was lower for Group C with the lower bound value of 1.479964 and higher bound value of 2.125036.

In **Table 2**, the values were analyzed using ANOVA and the values for Sum of squares between the group were 4510.614. The mean square between each group was 1127.653 and the F value was 20.904. Post hoc Tuckey HSD showed statistically significant value towards group A. Fracture force was maximum in group A repaired with auto polymerizing resin Probase Cold, 245.06N and minimum in group C 181.90N.

In **Table 3** the mean fracture force values for groups A, B, C were 245.06, 229.55,181.90 respectively. So group A samples had higher mean fracture force vales when compared to group B and C. Whereas in **Table 4** the deflection values for Group C was higher when compared to group B and A. The deflection was maximum for group C samples which were 0.38cm and minimum for group A samples 0.14cm.

Table 1. The standard deviation and standard error of each group- Descriptive Fracture toughness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Group A	20	2.013	3.5581595	.7956286	1.818730	2.549270
Group B	20	1.915	7.7922529	1.7424007	1.738613	2.232387
Group C	20	1.753	9.7700762	2.1846554	1.479964	2.125036
Total	60	5.681	9.8654739	1.5742283	1.679102	2.302231

Table 2. One-way analysis of variance (ANOVA) for fracture toughness

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	4510.614	4	1127.653	20.904	.000

Table 3. Mean fracture force of different repair resin incorporated into injection-molded PMMA

S/No	**Group**	**Mean fracture force (N)**
1.	**Group A**	**245.06**
2.	**Group B**	**229.55**
3.	**Group C**	**181.90**

Table 4. Mean deflection of different repair resin incorporated into injection-molded PMMA

S/No	**Group**	**Deflection (cm)**
1.	**Group A**	**0.14**
2.	**Group B**	**0.24**
3.	**Group C**	**0.38**

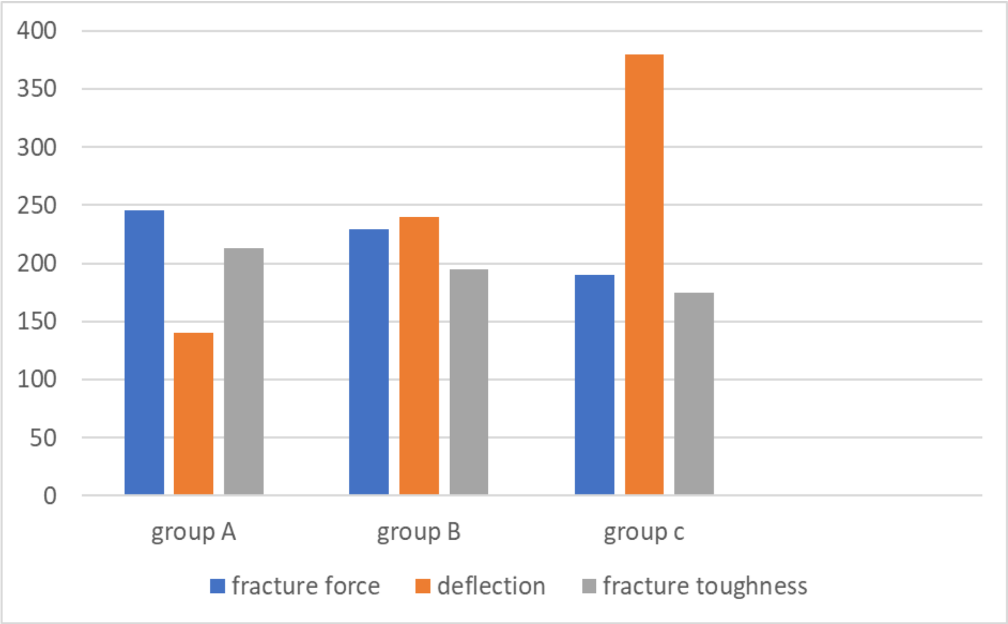

Figure 3. Graphical representation of fracture force, deflection, and fracture toughness plotted against the groups.

The **figure 3** shows the mean and standard deviation plotted against the groups for fracture force, deflection, and fracture toughness. Group C samples showed the highest deflection whereas group A samples showed the least deflection. Group A samples had maximum fracture toughness and fracture fore and minimum deflection when compared to group B and C samples.

Pryor in 1942 introduced an injection molding technique to overcome the shortcomings of conventional heat polymerized PMMA resin [7]. He found that continuous injection process on a closed mold compensates for shrinkage and produced dense stronger prosthesis. The advantage of using the injection-molded technique is better dimensional stability, less polymerization shrinkage, and increased mechanical properties. The normal biting force for any edentulous patients ranges from 100-150 N beyond which the fracture of the prosthesis occurs.

The denture base can undergo fracture when it is loaded under flexural fatigue and when it exceeds its maximum mechanical capacity [16, 17]. It was said that when a fractured denture base was repaired its flexural strength can reduce to 22- 65% of its original strength and also stated that the maximum required repair strength could be 75-85% of the original strength. In the present study, the repaired strength was more than 7.9-72.1% of the strength required. After fracture usually repair of conventional heat polymerizing PMMA resin was done using different materials such as; heat polymerized, microwave or light polymerized resins. However, fracture at the site of repair was most common [18, 19]. An acceptable repair should own good strength, cost-effective, shade matching, ease in application, quick, biocompatible, and should be dimensionally stable. Rached RN et. al., did a study on repair strength on conventional heat polymerizing resin and found that auto polymerizing PMMA resin produced better repair strength [20]. So the repaired prosthesis must have sufficient fracture toughness to withstand the masticatory load. Previously studies were done to evaluate fracture toughness of repaired conventional heat polymerized PMMA resin [21]. However, no repair studies have been done on injection-molded PMMA. Hence in the present study fracture toughness of repaired injection-molded PMMA resin was done.

Hamanaka et. al., evaluated the presence of good bond strength between auto polymerizing resin and injection-molded thermoplastic denture base resins [8]. Similarly in this study, two groups of auto polymerizing resins and one group of light polymerizing resin were used as a repair material. Ban S and Anusavice KJ studied the influence of the test method on the stress of brittle dental materials and suggested a three-point bending test, and so it is adapted in the present study [22]. Ward JE et al conducted a study on the effect of repaired surface on both self-cure and heat cure PMMA acrylic resin with three repair joints- butt, round, and 45-degree bevel, using auto polymerizing and heat cure repair material, and with three different methods of processing. They found that there was a difference in the strength of repairing made with butt joint [23]. So in this study, the butt joint was used as a repair joint for the groups. Testing was done taking three parameters namely fracture force, toughness, and deflection of repaired injection molding resin. In the present study fracture force of the repaired resin was found to be maximum in Group A samples and least at Group C samples, which is in accordance with the study done by Kostoulas et al where he evaluated fracture force, deflection, and toughness on repaired conventional heat polymerized polymethyl methacrylate denture base resins and had similar results [24]. This is attributed to the increased bond strength between auto polymerizing resin and injection-molded thermoplastic denture base resins. So the flexural strength of the samples repaired with auto polymerizing resin was applicable for clinical purposes.

Fracture toughness will describe the ability of the denture base material to resist the propagation of crack due to the flaws seen in the denture surface or due to notches.

The international standard for measuring flexural properties of denture base resins is a 3-point bent test and this has been advocated to examine fracture force, deflection, and fracture toughness. So this study's Fracture toughness was evaluated to determine the mechanical performance of repaired high-impact denture bases. Faot et. al. had reported that when the repair of denture base was done with auto polymerizing resin they had less flexural strength but this contradicts with the present study [25]. A survey of denture repair was conducted in the year 1997 which stated that auto polymerized PMMA resin was an acceptable repair material of 86% of the repliers. The result of the present study correlates with the survey concerning the toughness and it suggests auto polymerizing resin to be used as a repair material for fractured high impact denture bases [26]. However deflection was maximum in group C and least at group A and fracture toughness was calculated, suggesting the increased flexibility in group C. Polysois et al did a study on the fracture toughness of conventional heat-cured PMMA and repaired it with auto polymerizing resin and had increased mean value, this is in coherence to the present study [11]. The deflection was low on the samples repaired with group A signifying the better rigidity in samples treated with group A.

Specimens repaired with light polymerizing resin (Group C) exhibited very poor mechanical properties when compared with specimens repaired with auto polymerizing resin which is following the study done by Andreopoulos [27]. The light cure resin could not be a suitable repair material for high-impact denture bases. It may be because of its low flow rate, high stiffness, more viscosity, and reduced wettability of the repair area [28-30]. The findings of this current vitro study demonstrate that auto polymerizing acrylic repair resin enhances the fracture toughness of high-impact injection molding resin. The limitation of this in-vitro study is that the ability to determine the success of the repair material in clinical situations is restricted. So more clinical studies in the future could be beneficial to evaluate the mechanical properties, durability, and excellence of the repaired high impact injection molded PMMA dentures

Conclusion

The conclusion drawn within the limitations of the study was that the fracture force, deflection, and toughness were found to be significant in Group A samples repaired with auto polymerizing PMMA resin. Hence, from the present study, it was concluded that auto polymerizing PMMA resin can be better used in the repair of fractured high-impact injection-molded PMMA resin.

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Conflict of interest: None

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Ethics statement: The study was apporoved and completed as per the research protocol approved by the Institutional Review Board with the approval number SRMDC/IRB/2017/MDS/NO.202.

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