ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)
IJDSIR : Dental Publication Service
Available Online at: www.ijdsir.com
Volume – 4, Issue – 2, April - 2021, Page No. : 411 - 418

Comparative evaluation of fracture strength of polymethylmethacrylate(pmma) provisional restorative material using different reinforcements-an in vitro study

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Citation of this Article: Dr Sherin Cherian, Dr Rupal J. Shah, Dr Sanjay B. Lagdive, Dr Abhay Machchhar, Dr Rachana Gaonkar, "Comparative evaluation of fracture strength of polymethylmethacrylate(pmma) provisional restorative material using different reinforcements-an in vitro study", IJDSIR- April - 2021, Vol. – 4, Issue - 2, P. No. 411 – 418.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Statement of problem: Auto polymerizing polymethyl methacrylate resin (PMMA) had been a popular material for the direct and indirect fabrication of provisional fixed restorations essentially due to its versatility. Its use is limited due to their relatively poor strength.

Purpose: This study compares the fracture strength of unreinforced self-cure polymethylmethacrylate (PMMA) provisional restorative material with those reinforced with stainless steel wire (SS) and unidirectional glass fibre

Materials & Method: Sixty standardized PMMA resin specimens resembling three unit fixed partial denture were prepared and divided into two equal groups viz Group 1(n=30) with connector width of 3mm and Group 2 (n=30) with connector width of 4mm. Each major group was subdivided into three groups of unreinforced specimens (n= 10), reinforced with stainless steel (SS) wire (n= 10) and reinforced with unidirectional glass fibre (n= 10). These specimens were subjected to three point bending test for fracture strength under a universal testing machine, loaded with a 5 mm diameter steel rod placed in the central fossa of the pontic with a crosshead speed of 5mm/min. The value at fracture was recorded in Newtons. Data was analysed with Kruskal Wallis test and Mann Whitney U test. ($p< 0.05$)

Result: Fracture strength with reinforcement was significantly higher than the control group. The maximum fracture strength was achieved with SS wire reinforced group. Samples with 4mm connector width dimension showed significant increase in fracture strength compared to 3mm connector width dimension

Conclusion: The most effective reinforcement for autopolymerising polymethylmethacrylate resin is at a connector width dimension of 4mm using stainless steel wire.

Keywords: Auto polymerizing polymethylmethacrylate resin, fracture strength, glass fibers, stainless steel

Introduction

Provisional restorations are imperative for treatment in fixed prosthodontics. Factors to be considered when choosing provisional materials are physical properties, handling characteristics, patient response to the appearance of the provisional restoration, durability of the restoration, and the cost of the material[1]. Practitioners should, therefore, base their choice on the clinical needs for each situation.

Contemporary materials for the fabrication of single and multiple unit provisional restorations are for the most part resin based. They include auto-polymerizing and dual curing resins, such as poly (methylmethacrylate) (PMMA), polyethyl methacrylate (PEMA), polyvinyl (ethylmethacrylate) (PVEMA), bis-GMA resins, bis-acryl resin composites, and visible light cured (VLC) urethane dimethacrylate resins[2].

In selecting a material for a provisional restoration, consideration should be given to the physical properties of the material which include strength, rigidity, reparability, exothermic reaction, polymerization shrinkage, marginal integrity, and color stability. The strength of polymethylmethacrylate (PMMA) is only one- twentieth than that of metal ceramic alloys[3], making fracture of the provisional restorations much more likely, especially in long span provisional restorations, high stress areas , cases with bruxism and long term uses.

Only few research interests have been focused on the correlation between the design parameters and the reinforcement of the connectors with respect to provisional fixed partial dentures. Factors like the span length of the edentulous space, the number of pontics, the height of connectors, radius of curvature of the connectors have been studied in the past[4].The width of the connectors and its influence on the various reinforcements have not been studied.

However the effect of connector width dimensions and its influence on reinforcements like stainless steel wire and glass fibers have not been a topic of research in the past.

Materials and Methods

Section1: Fabrication of master die

An aluminium die model (Alum 6 Block) (fig 1) including the mandibular first premolar, second premolar and first molar was milled in lathe machine (VMC machine, Jyothi Machine Tools, Rajkot). Measurements for the abutments were as follows: 7.5*5mm (height *width) for the second premolar, 6*8mm for the second molar ,convergence angle of 2 degrees, 0.5 mm chamfer width, with a chamfer margin around the entire circumference and a pontic space of 8*10mm. The designed die had a rectangular platform (50mm*25mm*14mm) to facilitate holding of the die in the Universal Testing Machine (Tue-C1000, Sno:206l2, Fine Spavy Associates Pvt. Ltd. India) (figure 1)

Section 2: Designing and fabrication of the wax patterns

Two anatomic wax patterns resembling a three unit fixed partial denture was milled out of wax in a CAD CAM machine Ceramill Mind (Amann Girbach, Austria) . The connector width was kept 3mm for one group and 4mm for the other. (Figure 1)

Section 3: Indexing the wax pattern

Indices (fig14) of both the wax patterns were made using Polyvinyl siloxane impression material of putty consistency (Affinis, Coltene , Whaledent, Switzerland) by mixing equal amounts of catalyst and base and adapting it over the wax patterns. (figure 1)

Section 4: Fabrication of the test specimens

The tooth coloured polymethyl methacrylate (PMMA) acrylic resin (DPI, Dental Products of India Ltd, Mumbai, India) and monomer (DPI-RR cold cure monomer, Mumbai, Maharashtra) were used to make the provisional prosthesis samples. The SS wire reinforcement was done by cutting a 1.5mm SS wire and adapting it to the occlusal surfaces of the abutments in the aluminium die (figure 3). Similarly 1.5mm glass fibre (Everstick C&B – fibre reinforcement for composite bridges, GC Corporation, Tokyo) were cut for each sample and adapted on the die and light cured (figure 2). The samples were fabricated with PMMA resin the polymer to monomer ratio was as per manufacturers recommended ratio of 3:1 by volume. A direct method of fabricating provisional restoration was used to simulate intraoral fabrication. A total of 60 specimens were fabricated. The study included the following groups:

Group I - Provisional FPDs made of PMMA resin having buccolingual connector width of 3mm.

Group Ia – Control Group ; Provisional FPDs made of PMMA resin having buccolingual connector width of 3mm without any reinforcement.

Group Ib- Glass Fibre Reinforced Group ; provisional FPDs made of PMMA resin having buccolingual connector width of 3mm, reinforced with glass fibres(Everstick C&B – fibre reinforcement for composite bridges , GC Corporation, Tokyo)

Group Ic- Stainless Steel Wire Reinforced Group : provisional FPDs made of PMMA resin having buccolingual connector width of 3mm, reinforced with 0.9 mm stainless steel wire.

Group II - Provisional FPDs made of PMMA resin having buccolingual connector width of 4mm.

Group IIa - Control Group : Provisional FPDs made of PMMA resin having buccolingual connector width of 4mm. without any reinforcement

Group IIb- Glass Fibre Reinforced Group : Provisional FPDs made of PMMA resin having buccolingual connector width of 4mm, reinforced with glass fibres

Group IIc – Stainless Steel Wire Reinforced Group : Provisional FPDs made of PMMA resin having buccolingual connector width of 4mm, reinforced with 0.9 mm stainless steel wire.

Section 5: Testing of the fracture strength of the specimen

The samples were tested for fracture strength using three point bending test with the help of a Universal Testing Machine (TUE-C1000, SNO:206L20, FINE SPAVY ASSOCIATES PVT. LTD. INDIA) (fig 4). Each interim FPD sample was firmly seated with hand pressure on the aluminium master die and held on the Universal Testing Machine (Tue-c1000, sno: 206l20, fine spavy associates pvt. Ltd. India). (Figure 4). The test samples were loaded with a 5 mm diameter steel rod placed in the specifically demarcated region of the sample, i.e. the central fossa of the pontic with a crosshead speed of 5mm/min till the fracture occurred (figure 4).

Results & Discussion

The data were presented as mean ± standard deviation and the mean values were compared using Kruskal Wallis test (for independent variables) among different groups. The Mann-Whitney U test (for independent variables) was applied after having significant result of Kruskal Wallis test. Statistical Package for Social Science (SPSS, IBM) version 22 was used for the analysis. The level of significance was set at 5%.Table 1 shows mean values of fracture strength of all the sample groups.

The null hypothesis was that the two kinds of reinforcements would not significantly alter the fracture strength of the three unit fixed partial denture made of autopolymerising pmma resin.

Valittu P K (1992)[5] found that reinforcement fibers like glass fibers also had a positive effect on fracture resistance of the resin but none of the fibres studied had as favourable an effect on fracture resistance as metal wires. The results of this study are in agreement with this finding. The reinforcement-wise comparison of fracture strength of 4 mm bucco-lingual connector for PMMA resin group was statistically analysed (graph 1). It is clear that for samples with 4mm connector, the fracture strength improved for the reinforced samples as compared to unreinforced samples. The differences between their means were statistically significant.($p< 0.05$)(table 2)

Geerts GA et al (2008)[6] reported that wire reinforced pmma had significantly higher fracture toughness ($P<.001$) when compared to the control as did the glass fibers ($P<.01$). The wire group exhibited highest fracture strength. However, the differences between glass fiber and wire reinforcement were not significant. In this study, the mean differences in fracture strength between the wire reinforced group and glass fiber reinforced group, when compared individually with the control group, was statistically significant ($p<0.01$). The mean value difference between the glass fibres and wire group was statistically significant, as was the difference between glass fibre reinforced and unreinforced group and wire and unreinforced group ($p<0.01$)(table 3).

In group II, with 3mm connector width, the wire reinforced group exhibited the largest mean, standard deviation values (graph 2). However, the difference between the mean values were not statistically significant ($p>0.05$).This is in partial agreement with the study conducted by **Geerts GA et al**[6].

The connector-width wise comparison between the two groups were statistically analyzed to evaluate if it influences the material strength of the pmma resin material (graph 3). No statistical significance was found between any of the groups. Highest fracture strength was found in the stainless steel wire samples in both group I and II. Although the difference was not statistically significant.

In group I, all the differences were statistically significant (graph 1). This may imply that for reinforcement to be effective in a three-unit provisional fixed partial denture made of pmma resin, 4mm bucco-lingual connector width is the minimum requirement. However more evidence will be imperative to support this finding.

Thus the null hypothesis was rejected and alternative hypothesis was accepted which stated that reinforcement of three unit provisional fixed partial dentures made of autopolymerising pmma resin significantly increased the fracture strength of pmma resin at a buccolingual connector width of 4mm.

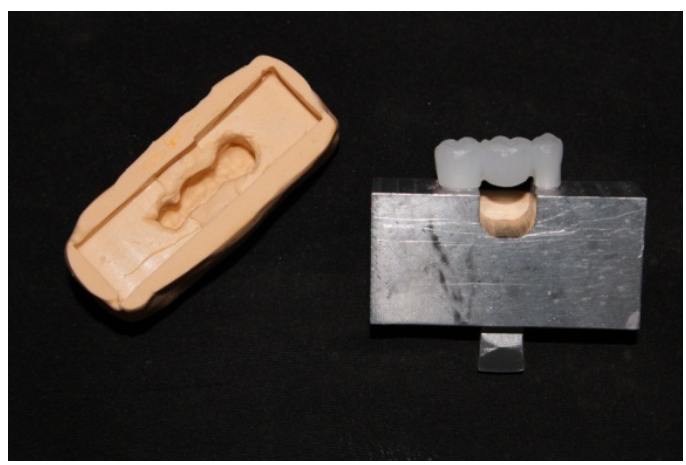

Figure 1: A polyvinylsiloxane putty index of the wax pattern to fabricate the samples

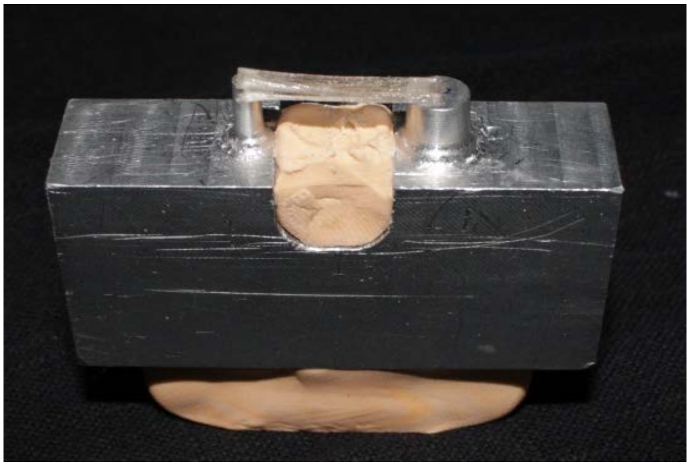

Figure 2: Everstick glass fibre of 1.5cm length stabilised on the occlusal third of the simulated abutment teeth

Figure 3: 0.9 mm stainless steel wire stabilised on the occlusal third of the simulated abutment teeth

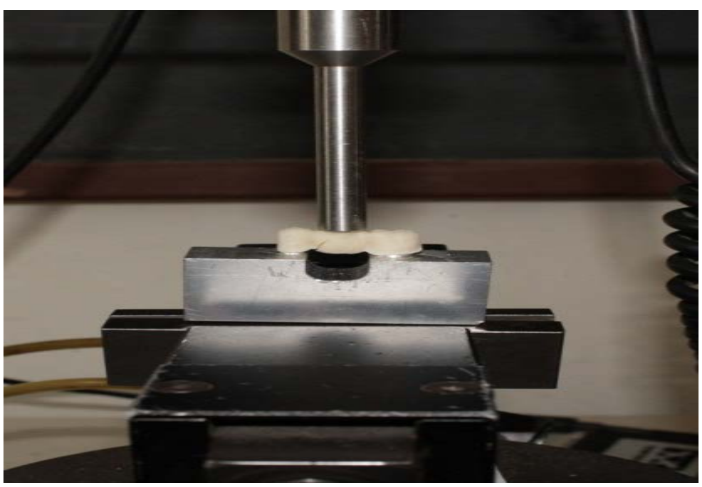

Figure 4: Samples loaded on the UTM at 5mm/min crosshead speed

Table 1: Mean Fracture Strength of All the Groups

Groups	n	Mean	SD
Group I a	10	1281.016	125.43
Group I b	10	1439	67.31
Group I c	10	1593.21	343.94
Group II a	10	1241.84	301.55
Group II b	10	1464.92	290.55
Group II c	10	1573.62	501.67

Table 2: Reinforcement-wise comparison of fracture strength of 4 mm bucco-lingual connector for PMMA resin group

Parameters	Unreinforced (n=10)	Glass reinforced (n=10)	Metal reinforced (n=10)
Minimum	1120.17	1327.41	1039.98
Mean ± SD	1281.02 ± 125.44	1439.23 ± 67.31	1593.21 ± 343.94
95% CI	1191.28 -1370.75	1391.07 -1487.38	1347.17 -1839.25
Maximum	1436.80	1494.16	1944.49
P Value	0.01*	0.01*	0.01*

Table 3:Intergroup comparison of fracture strength of 4 mm bucco-lingual connector for PMMA resin group

Reinforcement	Mean Difference	P Value
Unreinforced vs Glass reinforcement	-158.21	0.01*
Unreinforced vs Metal reinforcement	-312.19	0.02*
Glass reinforcement vs Metal reinforcement	-153.98	0.02*

Conclusion

Respecting the limitations of the study, following conclusions were drawn

- Reinforcement with 0.9mm stainless steel wire provides the highest fracture strength for pmma resin when compared to unreinforced three unit fixed partial dentures, but esthetics and availability of space may restrict its use.

- Glass fiber reinforcements produce significantly higher fracture strength in provisional fixed partial dentures made of autopolymerising pmma resin when compared with unreinforced three unit provisional fixed partial dentures.
- Reinforcement with stainless steel wire at the connector region of a provisional three unit fixed partial denture yields the greatest strength when compared to glass fibre reinforced or unreinforced provisional fixed partial dentures.
- The buccolingual connector width influences the fracture strength of three unit fixed partial denture made of autopolymerising pmma resin reinforced with stainless steel wire and glass fibres. Reinforcement is effective at a buccolingual dimension of at least 4mm.

The results of this study revealed that reinforcement of provisional fixed partial dentures made of autopolymerising polymethylmethacrylate resin designed with an optimum connector dimension reinforced with glass fibers or stainless steel wires may be a useful approach to strengthen provisional fixed partial dentures beyond their normal limits.

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