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Comparitive mechanical testing of three different resins used for fabrication of provisional restoration before and after storage in artificial saliva: An in vitro study

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Abstract

Fracture of provisional restorations is of concern, as they are subject to flexure and compress under function. Choice of the suitable material for their fabrication is difficult given the limited evidence-based information on the flexural strength and compressive strength of provisional resins.

Aim: This study compared the flexural strength and compressive strength of self-cure and heat cure methacrylate-based resins and Bis acryl resins used to fabricate provisional crowns.

Material and methods: Bar-type specimens were fabricated according to ADA specification 27. After being immersed in artificial saliva for 10 days, tested for flexural and compressive strength, the specimens were fractured in a universal testing machine. Maximal loads to fracture were recorded in Newton. Mean flexural strengths and compressive strengths were calculated in MPa (n = 10 per group). Inter group comparison were made with INDEPENDENT t test and intra group comparisons were made with one way ANOVA and post hoc TUKEY Test was done.

Results: Test showed significant results with both compressive and flexural strengths of the 3 materials. Bis-acrylic resin material showed high compressive and Flexural strengths followed by Heat PMMA and Cold PMMA both pre and post storage in artificial saliva.

Conclusion: Bis-acryl interim materials exhibited higher flexural strength than the methacrylate resins tested within the limitations in this study.

Keywords: Interim/Provisional materials, Bis-acrylic resins, polymethylmethacrylate resins.

Keymessage: This article provides an overview of the interim materials including newer bis acrylic over the

traditional acrylic materials regardless of which material used, an interim material must protect the underlying tooth structure.

Introduction

Provisional fixed partial dentures (FPDs) are an important part of prosthodontics treatment procedures.[1] Resistance to functional loads and removal forces are “mechanical factors” that must be considered when, choosing a provisional restorative material for clinical use.[2] Consideration of all these factors and requirements are important because provisional resin restoration may be worn over a long period to assess the results of periodontal and endodontic therapies and also during the restorative phase of implant restorative and reconstructive procedures.[3] Investigators have studied, factors that contribute to the mechanical requirements of provisional restorative materials. For instance, mechanical properties of provisional resin have been assessed and in these in vitro studies, valuable information has been presented regarding the strength of various materials. Understanding of the mechanical properties of these materials is important in determining whether the restoration will be able to survive repeated functional forces.[4]

Physical and mechanical properties should be considered while selection of temporary restoration. Clinically significant properties include strength of the material, its rigidity and reparability, exothermic reaction following polymerization and subsequent polymerization shrinkage, marginal integrity and color stability.[5] Presently there is no single material that meets the optimal requirements for all the situations.[1] However, there are materials that have been successfully used for this purpose.

The primary monomer determines many of the material characteristics such as polymerization shrinkage, strength, and exothermic heat of reaction.[6] There is no interim material that meets optimal requirements for all situations.[7] Clinicians select a product based on factors that include ease of manipulation, cost effectiveness, esthetics, strength, and marginal accuracy.

In addition, the mechanical properties of the interim resin materials can be influenced by saliva, food components, beverages, and interactions among these materials in the oral environment.[8] The purpose of this study was to compare the flexural strength and compressive strength of three interim fixed restorative materials with different compositions.

The null hypothesis was that there was no difference between flexural strength and compressive strength of these interim restorative materials.

Materials and Methodology

The materials and methods used in this study have been described in the following order:

1. Preparation of metal dies.

2. Provisional resin specimens used:

Group 1 - Cold cured poly methyl methacrylate- *DPI*

Group 2 – Heat cured poly methyl methacrylate- *DPI*

Group 3 - Auto-polymerized Bis-acryl composites- *Protemp 3M*

The specimens described below were made with the help of split metal mold. The petroleum jelly was applied to the mold for easy separation of the specimen from the mold. Bar-shaped specimens of each material were fabricated in the dimensions of 25 x 2 x 2 mm in accordance to the American National Standards Institute/ADA specification # 27. All samples were fabricated using a machined aluminum split mold, and polymerized to manufacturers’ specifications. Twenty specimens from each provisional material of GROUP A, B and C (n = 20 × 3), Again twenty specimens for each provisional material of SUBGROUP A, B and C (n=20 × 3), After this the specimens were soaked in artificial saliva at 37˚ C for 10 days. Then, the specimens were washed and air dried.

Measuring of flexural strength

The specimens of each group were placed on surface of the platform of the universal testing machine to undergo three-point bend test. A load of 10 KN load cell at a crosshead speed of 0.75 mm/min was applied. For rectangular specimens under a load in a 3 point bend setup is 3PL/2wt2, where F is the load (force), L is the length of the support span, b is width of the sample, d is the thickness of the sample. The force of fracture was recorded in Newtons and calculated in MPa with the use of testing machine software. The mean and standard deviation estimated from the specimen for each material was statistically analyzed. Figure 01(a), 01(b).

Measuring of compressive strength-

The same specimens of each group were then placed on top of the flat platform of the universal testing machine. A load of 10 kN load cell at a crosshead speed of 0.75 mm/min was applied. The force the sample could withstand till the start of deformation was recorded in Newton and calculated in MPa with the use of testing machine software. Figure 02.

RESULTS:

Flexural strength –Intra group

When the mean flexural strength of three provisional crown materials (Table 3) was considered, independent t test was used, Bis-acrylic showed the highest flexural strength followed by Heat activated PMMA and Self cured PMMA showed least flexural strength.

Compressive strength –Intra Group

When the mean compressive strength of three provisional crown materials (Table 3) was considered Independent t test was used Bisacrylic showed the highest compressive strength followed by Heat activated PMMA and Self cured PMMA showed least compressive strength. Mean compressive strength values of 3 materials after storage in artificial saliva, showed non-significant results in case of all three materials.

Abbreviations: Cold PMMA: Cold Cure Poly Methyl Methacrylate Resin. Heat PMMA: Heat Cured Poly Methyl Methacrylate Resin. Bis A: Bisacrylic Resin. Without S: Without dipping in saliva. S: Significant. NS: Non Significant.

Compressive and Flexural strength – Inter group One-way Anova with Post hoc TUKEY test showed significant results with both compressive (Table 4) and flexural strengths (Table 4) of the three materials. Bisacrylic showed high compressive and Flexural strengths followed by Heat PMMA and Self PMMA both pre and post storage in artificial saliva.

Discussion

Provisional restorations are the most essential part of fixed prosthodontic treatment which helps to accomplish several functions during the use in the mouth. These materials should protect the pulpal tissue hostile to physical, biochemical and thermal injuries; maintain positional stability and occlusal function should provide strength, retention and aesthetics for the prepared teeth. In addition, they can also be used for correcting irregular occlusal plane, altering vertical dimensions and changing the contour of the gingival tissue.

The flexural strength (transverse strength, bending strength or modulus of rupture) is defined as force per unit area at the instant of fracture in a test specimen subjected to flexural loading..[4] The flexure strength is obtained when one load a single beam simply supported at each end with a load in middle, such a test is called a three point bending or flexure test and the maximum stress measured in the test is called flexure strength. The equation for the maximum stress developed in a rectangular beam loaded in the centre of the span is as follows.[9] $\sigma = 3PL/2wt^2$, σ- Maximum flexural stress (N/mm^2), P- Load at fracture (N),

L- Distance between two supports (mm), w- Width of specimen, t- Thickness of specimen.

Compressive strength is measured using the universal testing machine using the similar specimens and placed on surface of the platform of universal testing machine and the load is applied from the above when the material starts deformation the reading is noted.

In this study, 10 specimens were fabricated for each material and stored in artificial saliva (1 L double distilled H2O, 1.6802 g NaHCO3, 0.41397 g NaH2PO4·H2O, and 0.11099 g CaCl2)17 at 37°C for 10 days in separate plastic jars. They were tested for flexural strength and compressive strength after 24 hours. The results were obtained and statistically compared by one way ANOVA and Post-Hoc TUKEY tests(table no.4).

At 24 hours' time interval, a significant difference in flexural strength and compressive strength was seen between all the materials. The fracture toughness at this time interval was similar for all the groups(table no.3). However, the highest value of flexural strength with p value being <0.001 according to table no. 7 and compressive strength with p value being <0.001 according to table no. 8 was exhibited by Protemp 3M, a Bis-acryl resin.

Haselton DR et al, compared the transverse strength of five auto-polymerizing PMMA resins and eight bis-acryl composite resins. This study compared the flexural strengths of 13 provisional crown materials with n=10 per group were used. Although materials with the greatest flexural strength with Provipont which belonged to the bis-acryl resin category with the mean of and Protemp , in the poly methyl metacrylate resin group, the flexural strength of Caulk belong to Bis acrylic resin was found to be highest with the mean.[3] Whereas when compared to our study highest flexural strength was seen in Protemp 3M i.e Bis acrylic category followed by heat cure polymethyl methacrylate resin(table no.3 and 4), least was seen in self-cure poly mehyl metaacrylate resin material thus, the results were nearly similar to our study.

According to Lang R et al., polymethyl metacrylate resin materials showed water absorption up to 32µm/mm, primarily because of the polar properties of the resin molecules, which may act as a plasticizer and thus reduce the fracture strength of the material.[10]

Rawls HR et al., have stated, when water penetrates into the space between the polymer chains and pushes them further apart, the van der Waals forces between the polymer chains decline. This adds weight and causes volume to increase.[11] the greater the absorption of water by the material, lower the strength. Another reason could be the degree of polymerization which is low for these materials leading to higher residual monomer content (3%-5%), which acts as an internal plasticizer.

The chemically activated polymethyl methacrylate resins have an edge over the Bis-acrylic composites resins. The increase in strength may be because of the concomitant effects such as interpenetration among the new and the old resins.

As a second factor in this study, flexural strength and compressive strength of three provisional crown materials subjected to store in the artificial saliva for 10 days were evaluated by using universal testing machine. The tested results in the study may not correlate the conditions of mouth but serve the comparison of materials in a controlled situation.

D. Saisadan et al, conducted a study to choose a material to serve as a better interim prosthesis and to compare three different properties – flexural strength, compressive strength, and color stability, using Revotek LC(light cure), Protemp 4 (self cure) and TemSpan(dual cure). The results obtained was, the flexural and compressive strength mean was of self cure was found to be highest, followed with

dual cure and lastly light cure.[12] Where as in our study the highest flexural strength was seen in Protemp i.e a Bisacrylic resin, followed by heat cure polymethyl metacrylate resin and least was seen in selfcure poly methyl metacrylate resin was noticed concluding Bis acylic resin material have higher flexural and compressive strength followed by heat cure and then self-cure polymethyl metacrylate resin materials after storing in artificial saliva foe 10 days(table no. 4)

For intra group comparison, Mean compressive strength(table no.3) values of 3 materials after storage in artificial saliva, showed non-significant results in case of all three materials.

Inter group comparison of flexural and compressive strength, One way Anova with Post hoc TUKEY test showed significant results (table no. 4) with both compressive and flexural strengths of the 3 materials. Bisacrylic resin showed high compressive and Flexural strengths followed by Heat cure polymethyl metacrylate resin and Self cure polymethyl metacrylate resin both pre and post storage in artificial saliva.

Despite the major developments in resin based provisional materials, all the materials exhibit a certain degree of volume reduction during polymerisation shrinkage. The measurement of shrinkage during polymerization is important for assessing a materials accuracy of fit. Materials with low polymerization shrinkage provide for good clinical fit of the temporary restoration. Studies have shown this volumetric contraction is dependent on the amount of filler concentration.

Conclusion

With the limitations of the study, the following conclusion could be derived:

1. When the intra group comparison of flexural strength and compressive strength of three provisional crown materials was considered Bisacrylic showed the highest flexural strength followed by Heat activated PMMA and Self cured PMMA.
2. Intra group comparison of flexural strength values of three materials after storage in artificial saliva, showed significant results in case of Self cure PMMA and Heat cure PMMA where flexural strength decreased, while the flexural strength was decreased and the results were non-significant in case of Bis acrylic. whereas compressive strength showed non-significant results in case of all three materials.
3. The inter group results showed that Bisacrylic showed high flexural and compressive strengths having the acceptable mean values 102.2MPa and 48.5MPa respectively, followed by Heat PMMA having the mean values 92.2MPa and 41.5MPa respectively, then lastly Self PMMA having the mean values 79.3MPa and 26.8MPa respectively.
4. After storing in saliva for 10days the inter group results showed that Bisacrylic showed high flexural and compressive strengths having the acceptable mean values 101.2MPa and 46.9MPa respectively, followed by Heat PMMA having the mean values 89.2MPa and 40.0MPa respectively, then lastly Self PMMA having the mean values 76.9MPa and 25.1MPa respectively.

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Legend Tables

Table 1: Measurement of Flexural Strength after 24hours of Fabrication and After Storing in Artificial Saliva for 10days:

N=60	Cold PMMA		Bis Acrylic		Heat PMMA	
	After 24 hours	In saliva	After 24 hours	In saliva	After 24 hours	In saliva
1.	79.76	77.76	100.78	99.01	91.02	90.72
2.	78.01	76.01	104.56	103.7	94.23	89.76
3.	79.01	77.01	100.44	100.5	93.86	88.87
4.	80.69	78.69	101.54	99.75	91.32	87.76
5.	78.09	76.1	102.57	101.54	91.09	90.32
6.	80.21	78.21	105.84	103.34	90.12	88.69
7.	78.78	76.76	104.34	102.96	94.32	87.54
8.	79.56	75.01	103.09	103.76	92.06	87.06
9.	79	76.3	99.44	98.36	91.57	89.92
10.	80.22	77.44	100.23	99.42	92.99	91.99

Table 2: Measurement of Compressive Strength after 24hours of Fabrication and After Storing In Artificial Saliva for 10days:

N=60	Cold PMMA		Bis Acrylic		Heat PMMA	
	After 24 hours	In saliva	After 24 hours	In saliva	After 24 hours	In saliva
1.	22.217	21.712	43.82	42.98	36.89	35.91
2.	24.225	23.213	44.82	44.21	43.92	42.99
3.	27.712	25.819	49.89	47.83	39.88	37.88
4.	30.419	27.221	55.87	54	40.2	37.76
5.	29.193	26.888	45.67	45.01	45.72	45.51
6.	27.212	25.2	45.9	43.78	37.99	36.23
7.	26.177	26.118	53.77	51.22	38.66	38
8.	30.218	28.222	44.78	42.76	43.88	43.11
9.	25.813	24.719	50.65	50.02	44.88	42.33
10.	25.013	22.777	49.88	47.98	42.99	40.99

Table 3: before and after storing in saliva, Flexure strength and Compressive strength –Intra Group.

		Group	Mean	Std. deviation	p-value	Sig.	Test used
COLD PMMA	Flexure strength	Without S	79.33	0.91	<0.001	S	Independent t test
		Saliva	76.92	1.49			
	Compressive strength	Without S	26.81	2.66	0.14	NS	Independent test
		Saliva	25.18	2.10			
BIS A	Flexure strength	Without S	102.28	2.14	0.28	NS	Independent t test
		Saliva	101.23	2.08			
	Compressive strength	Without S	48.50	4.14	0.40	NS	Independent test
		Saliva	46.97	3.86			
HEAT PPMA	Flexure strength	Without S	92.25	1.49	<0.001	S	Independent t test
		Saliva	89.26	1.56			
	Compressive strength	Without S	41.50	3.14	0.33	NS	Independent test
		Saliva	40.07	3.33			

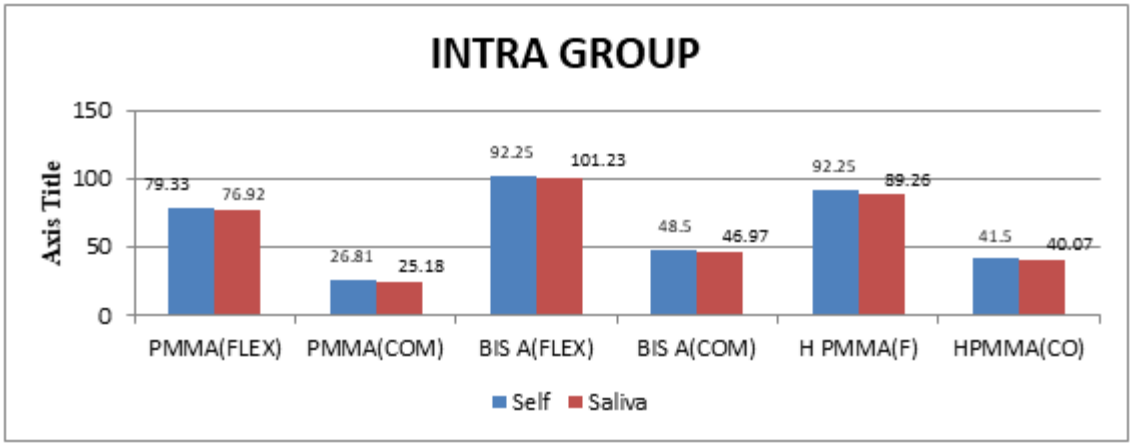

Figure 1: (a) and (b)- Universal Testing Machine used for flexural strength.

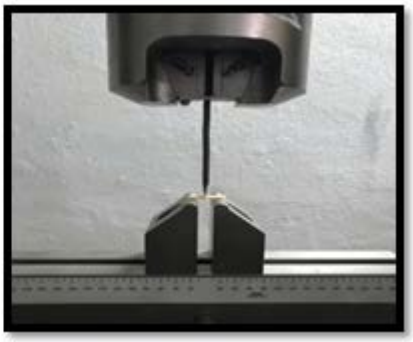

Table 4: Before and after storing in saliva, Flexural and compressive strength – Inter Group

Condition	Group	Mean	Std.dev	p-value	Post-hoc
Self (FLEXURE STRENGTH)	COLD PMMA	79.33	0.90	<0.001(S)	BIS A >heat PMMA > Cold PMMA
	BIS A	102.28	2.14		
	HEAT PMMA	92.25	1.49		
Self (COMPRESSIVE STRENGTH)	COLD PMMA	26.81	2.66	<0.001(S)	BIS A >Heat PMMA > Cold PMMA
	BIS A	48.50	4.14		
	HEAT PMMA	41.50	3.14		
Saliva (FLEXURE STRENGTH)	COLD PMMA	76.92	1.12	<0.001(S)	BIS A >Heat PMMA > cold PMMA
	BIS A	101.23	2.08		
	HEAT PMMA	89.26	1.56		
Saliva (COMPRESSIVE STRENGTH)	COLD PMMA	25.18	2.09	<0.001(S)	BIS A >Heat PMMA > PMMA
	BIS A	46.97	3.85		
	HEAT PMMA	40.07	3.32		

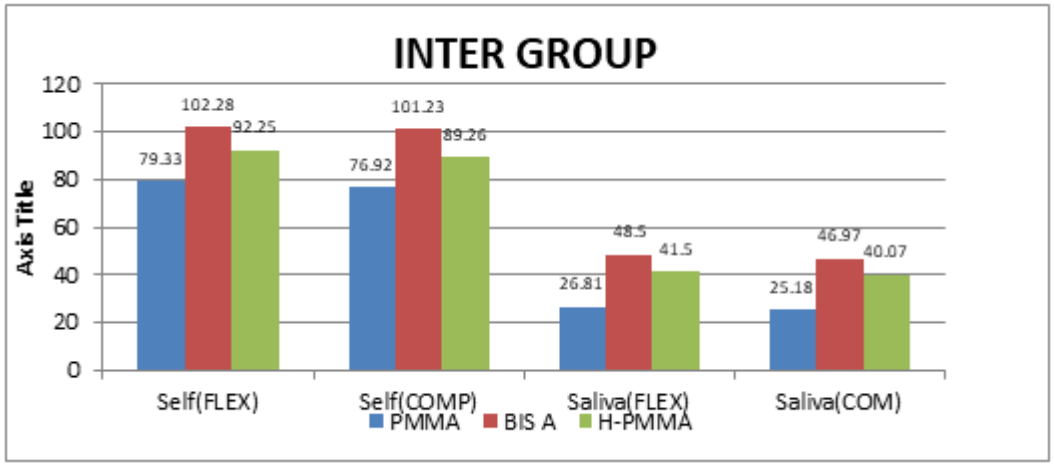

Figure 2: Universal Testing Machine used for testing Compressive Strength.