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Comparative Evaluation of Flexural Strength of Four Commercially Available Conditioned Provisional Restorative Resins Before and After Thermal Cycling: An In Vitro Study

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ABSTRACT

Background: Flexural strength of provisional restorative materials is of particular concern with long span fixed partial dentures or in areas of heavy occlusal forces. The purpose of this study is to compare and evaluate the flexural strength of four commercially available conditioned provisional restorative materials before and after thermal cycling.

Materials and Methods: Eighty identical samples of dimensions 25×2×2 mm were fabricated from four materials (Heat Cure Acrylic (DPI), Tempron (GC), Protemp 4 (3M ESPE), Revotek LC (GC)) according to ADA/ANSI specification #27(n=20 for each material). All these samples were stored in artificial saliva for 14 days in an incubator at 37°C. Ten samples from each material (n=40) were subjected to thermal cycling for 2500 cycles (5° to 55°C) and the remaining forty samples were a used as the control group. All specimens were subjected to a standard 3-point bending test with a universal testing machine at a crosshead speed of 0.5mm/min.

Results: The lowest and highest mean flexural strengths before and after thermal cycling, were found for Revotek LC, a light cure composite resin and Protemp 4, a self-cure composite resin respectively. Thermal cycling has significantly decreased the mean flexural strength values of all the materials except for Tempron, which is a poly ethyl methacrylate resin.

Conclusions: Bis acryl provisional materials exhibited greater flexural strength values than the methacrylate and UDMA resin materials compared in this study. Thermal cycling of the specimens significantly decreased the flexural strength of all the materials except Tempron. These greater values should be considered while fabricating provisional restorations, especially when long-term use or long span fixed partial dentures are planned.

Keywords: Fixed Partial Denture, Provisional Restorations, Thermal Cycling, Heat Cure Acrylic, Self-Cure Composite, Poly Ethyl Methacrylate, Light Cure Composite.

INTRODUCTION

One of the most important aspects of successful crown and bridge work is to create an ideal provisional fixed prosthesis. Provisional or interim prosthesis or restoration is a fixed or removable

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dental or maxillofacial prosthesis designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis [1]. Currently, materials can be divided into two resin groups based on their composition as methacrylates and composite resins.

It is important to know the mechanical properties of the material in order to know the limitations, indications and contraindications for their clinical use. One such property to be considered is flexural strength, which is also known as transverse strength[2]. Flexural strength tests are essentially a test of a bar supported at each end, subjected to three point flexure[2]. These tests evaluate compressive stress at the point of application of load and tensile and shear stresses at the point of resistance to the load applied, making them similar to the stresses produced by multi-unit fixed partial denture[2].

Few studies on provisional restorations have evaluated flexural strength following polymerization. However, this method has limited ability in determining the clinical behaviour of a dental material as it evaluates the failure of a material without ageing the material. Ageing of the material by a process called thermal cycling can cause material fatigue and speeds up the deterioration of the material[3]. Studies evaluating the effect of thermal cycling on provisional materials and flexural strength are scarcely available in dental literature. The aim of this study is to evaluate and compare the flexural strength of four commercially available conditioned provisional restorative resins before and after thermal cycling.

MATERIALS & METHODS

In this study, the selection of materials was done based on two factors: their wide usage and availability in India and the composition of the materials.(Table -1)

FABRICATION OF 3 PIECE BRASS FLASK:

A customized 3-piece brass flask (Figure 1) of dimensions 85×50×25mm was machined which contained four equal sized mould spaces measuring 25mm in length, 2mm in width and 2mm in height (25×2×2mm) corresponding to the dimensions of the specimens required.(Figure 2) Twenty standardized specimens (25×2×2 mm – ANSI/ADA Specification No. 27)[4] for each of the four materials were fabricated giving a total of eighty specimens. Vents were provided at both the ends of the flask to facilitate flow of excess material. Samples were fabricated according to manufacturer's instructions for each material and were conditioned[5].

All the 80 specimens (Figure 3) prepared were stored in artificial saliva (MP Sai Enterprises; Mumbai; India), with a composition as detailed in table-2, at 37 °C in an incubator for 14 days to simulate oral environment.[6](Figure 4) At the end of the conditioning period, the samples were divided into sub groups(Table -3). Sub group A (n=40) samples were washed under running water and air-dried. These specimens were directly tested for flexural strength. Sub group B (n=40) samples were subjected to 2500 thermal cycles between 5°C to 55°C for a dwell time of 6 seconds[6] by using a thermal cycler(manual) (Figure 5) and then were subjected to 3 point bending test.(Figure 6)

TESTING OF THE SPECIMENS FOR FLEXURAL STRENGTH USING UNIVERSAL TESTING MACHINE:

Each specimen was subjected to 3 – point bend test, at a crosshead speed of 0.5 mm/min carried out by Unitek 95100 testing apparatus utilizing FIE software to collect the data. The load was applied to the centre of the specimen until the specimen fractures.(Figure 7) The breaking load was noted in Newtons. The procedure was repeated accordingly for all the specimens. These breaking load values were converted to flexural strength using the formula,

S = (3FL) / (2bd2)

Where,

•S = Flexural strength / modulus of rupture in Mega Pascals

•F = Load at the fracture point in Newtons at which specimens failed between load bearing edges

•L = Length of the support span (20mm)

•b = width of specimen (2mm)

•d = thickness of the specimen (2mm)

By, substituting the above formula for each load value obtained, the flexural strength of all 80 specimens was calculated. The flexural strength value obtained was in Mega Pascals (MPa)

PHOTOGRAPHS

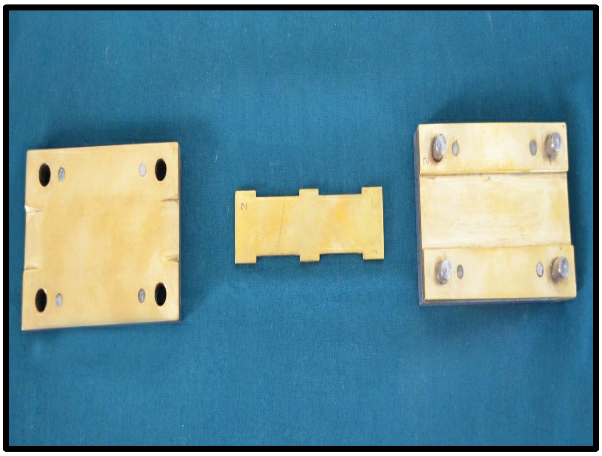


Fig 1: Customized Brass Flask,

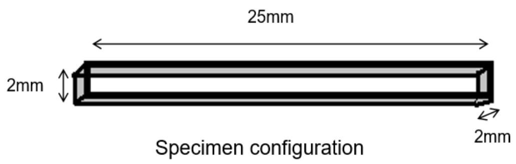


Fig 2: Specimen configuration

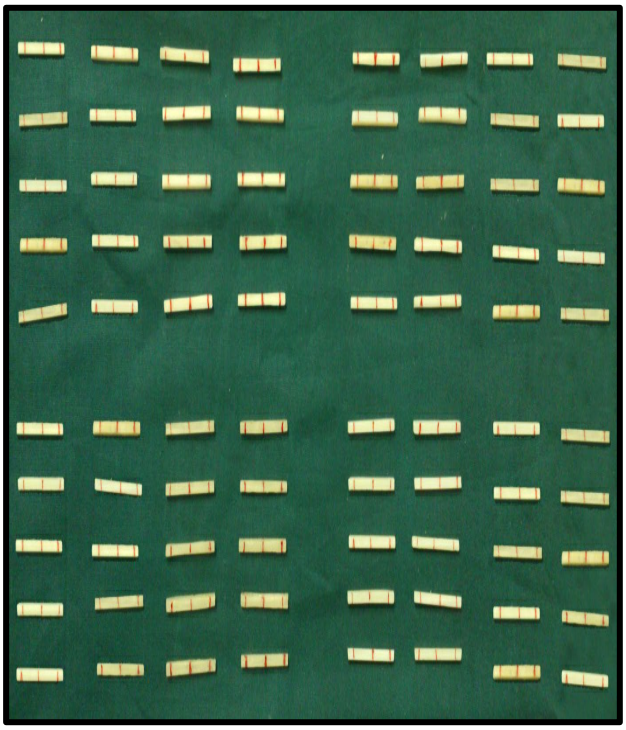


Fig 3: Total 80 Specimens.

Fig 4: Total 80 Specimens in Artificial Saliva stored in Incubator at 37°C.

Fig 5: Hot and Cold Water Baths for Thermal Cycling.

Fig 6: Universal Testing Machine

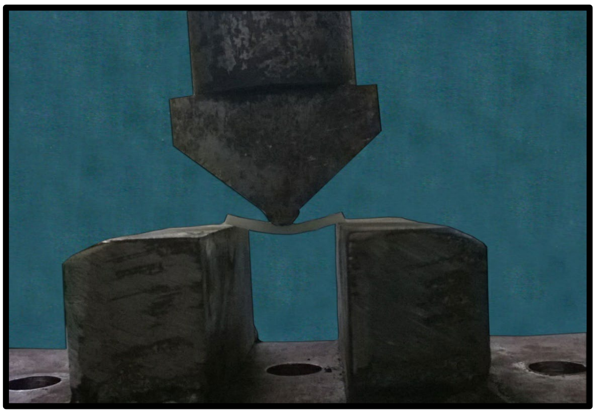


Fig 7: Samples being tested for 3 Point Bend Test.

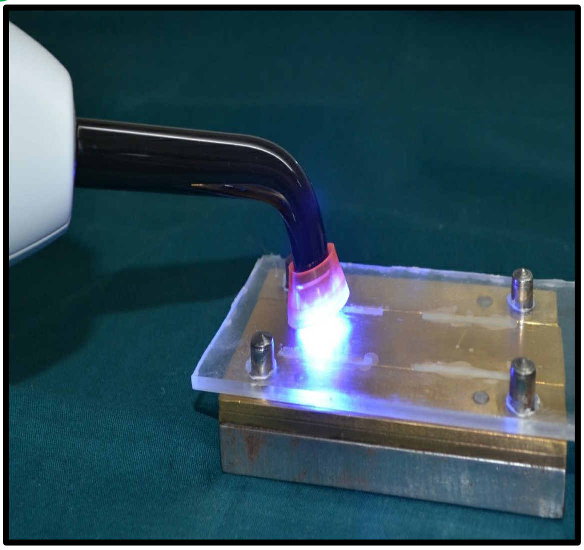


Figure 8: Initial Curing of Revotek LC Specimens.

Fig 9: Final Curing of Revotek LC Specimens.

STATISTICAL METHODS EMPLOYED:

Mean and Standard deviation was determined for all the groups. Data were analysed using the Kruskal Wallis test, and materials were ranked with the Mann Whitney U test. The mean values between groups of each sub group and the mean values between subgroups of each group were analyzed by Kruskal Wallis test. The inter group comparison and overall comparison between sub groups of all the groups was done by Mann Whitney U test (Table 4). The results were analyzed using the software package SPSS 16 (IBM, USA). P value ≤ 0.05 was considered as statistically significant.

RESULTS

Comparison of mean, standard deviation and test of significance of mean values of flexural strength between different sub groups of each groups by Mann Whitney U test revealed that, within the limitations of the study, there was high significance in subgroups of the respective groups except for Tempron (Group II) specimens before and after thermal cycling. (Table 4; Histogram 1). Analysing the statistical data using SPSS 16 software for MS Excel 2007 (Micrososoft USA), within the limitations of the study, the mean flexural strength values of the materials compared were in the following descending order: Protemp 4 (Group III) > DPI tooth moulding powder and liquid (Group I) > Tempron (Group II) > Revotek LC (Group IV).

DISCUSSION

Provisional restorations are designed to enhance esthetics, stabilization and function for a short period of time.[7] The use of provisional restorations relies on a reasonable turnaround time from tooth preparation to completion of definitive treatment. However, there are certain situations where the provisional restorations may be worn over a long period of time to assess the results of periodontal and endodontic therapies, during the restorative phase of implant reconstructive procedures, and in situations like full mouth rehabilitations.[8] Provisional restorations also help in the psychological management of patients where a mutual understanding of treatment outcome and limitations of treatment can be identified.[9]

The objectives of provisional restorative material depend on important physical properties of resins including polymerization shrinkage, wear resistance, colour stability and strength. In long span provisional restorations, strength is a critical property. Strength is the stress that is necessary to cause fracture or a specified amount of plastic deformation. One method to evaluate the ability to withstand the functional loads is to evaluate the material's flexural strength, also known as transverse strength, which is the strength of a material under a static load. This measurement is a combination of tensile and compressive strength tests with elements of proportional limit and elastic measurements.[2,5,7,10,11]

Table 1: Manufacturer and composition of the materials used in the study.

MATERIAL	MANUFACTURER	COMPOSITION
DPI Tooth Moulding Powder and liquid	Dental Products Of India Ltd;WallaceStreet,Mumbai	Heat cure poly methyl methacrylate
Tempron	GC Corporation;Tokyo;Japan	Poly ethyl methacrylate resin
Protemp 4	3M ESPE;St.Paul,U.S.A	Self-cure composite (Bis-GMA)
Revotek LC	GC Corporation;Tokyo;Japan	Light cure composite (Urethane dimethacrylate)

Table 2: Composition of artificial salive.

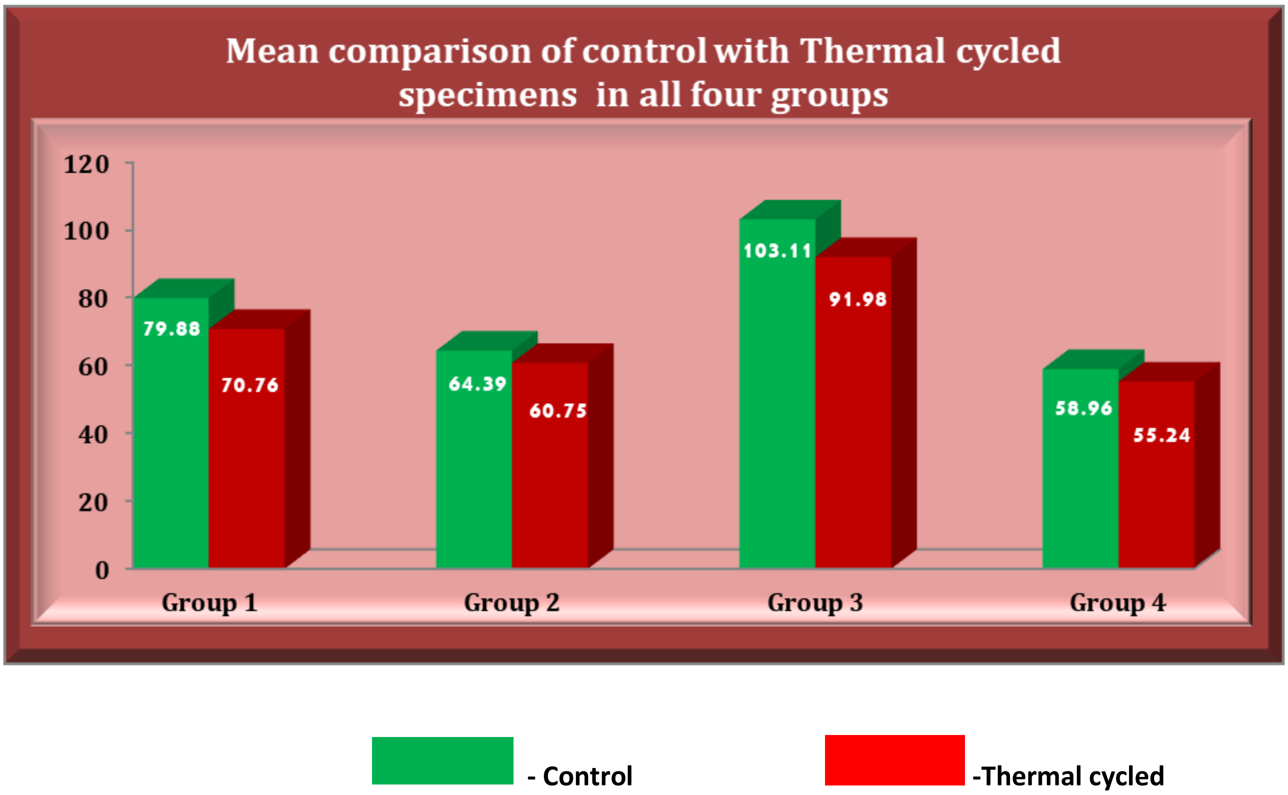
COMPOSITION OF ARTIFICIAL SALIVA	
COMPONENT	QUANTITY
Double distilled water	1 liter
Sodium Bicarbonate	1.6802 gm
Sodium phosphate monobasic monohydrate	0.41397 gm
Calcium Chloride	0.11099 gm

Table 3: Grouping of materials.

GROUPS	SUBGROUPS	SAMPLES
GROUP I (DPI HEAT CURE) (n=20)	A (CONTROL)	10
	B (THERMAL CYCLED)	10
GROUP II (TEMPRON) (n=20)	A (CONTROL)	10
	B (THERMAL CYCLED)	10
GROUP III (PROTEMP 4) (n=20)	A (CONTROL)	10
	B (THERMAL CYCLED)	10
GROUP IV (REVOTEK LC) (n=20)	A (CONTROL)	10
	B (THERMAL CYCLED)	10

Table 4: Data represents the statistical inference comparing the mean, standard deviation and test of significance between subgroups of each group.

	Subgroup	n	Mean (in Mpa)	Sd	Mann Whitney U value	p	Inference
Group I	A	10	79.88	0.82	0.000	<0.01	Highly significance
	B	10	70.76	2.25			
Group II	A	10	64.39	1.78	28.01	0.105	Not significance
	B	10	60.75	4.87			
Group III	A	10	103.11	2.18	0.000	<0.01	Highly significance
	B	10	91.98	3.38			
Group IV	A	10	58.96	0.89	0.000	<0.01	Highly significance
	B	10	55.24	0.86			



Histogram 1: Mean comparison of control with thermal cycled specimens in all four groups.

Also, the changes that occur to a material when subjected to various temperature regulations should be assessed when the material is used in the long run. Thermal cycling is one such process, which causes aging of the material. 10,000 cycles represent one year on clinical usage.[3,12] Hence 2,500 cycles represents that, the material studied is subjected to stresses that are equal to 3 months of its clinical usage. Mouth temperatures range between −8°C and +81°C, and the resulting temperatures on the surfaces of a construction between 5°C and 55°C.[3,6,12] The flexural strength of provisional materials may be influenced by saliva, food components, beverages and interactions among these materials.[6,13] Various studies conducted by Nejatidanesh et al[6], Lang et al[12], and Yao et al[14] supported the use of thermal cycling process to age the material. To partially simulate the oral environment, specimens were conditioned by storing for 14 days in artificial saliva and then thermocycled for 2,500 cycles (5°C to 55°C). Then standard three-point bending test was conducted on the specimens.

According to the International Organization for Standardization (ISO 4049) and the American National Standards Institute (ANSI)/American Dental Association (ADA) Specifications #27, an interim fixed prosthesis material must have a minimum strength of 50 MegaPascals (MPa) when a bar of the material undergoes a 3-point bend test.[4] All the specimens tested in this study had flexural strength values more than 50 MPa, which infers that all the materials, can comfortably be used for the fabrication of provisional restorations.

Protemp 4 is a self-cure Bis GMA composite resin material. The Bisacryl resins contain multifunctional monomers, which increase the strength due to cross-linking with other monomers.[6,9,15] Additionally, Protemp 4 contains inorganic nano fillers which further improve the strength of the material.[14] Also, the material was dispensed by cartridge delivery system which allowed for a more accurate and consistent mix that can be completely polymerized.[15,16,17] It is hydrophobic in nature, ensuring minimal water uptake and thus reducing the plasticizer action when stored in artificial saliva.[13,17,18] However, during thermal cycling, the material was subjected to stresses resulting in the dissolution of filler particles. Thus, the mean flexural strength of the material after thermal cycling is significantly less when compared to the mean flexural strength of the material before thermal cycling.[14]

DPI tooth moulding powder and liquid is a heat cure poly methyl methacrylate. Heat polymerization eliminates excess residual monomer (0.2-0.5%), leading to a higher degree of polymerization and therefore makes the material stronger.[5,17] However, the presence of even a small amount of residual monomer and its evaporation makes the material absorb water when placed in an aqueous environment. These water molecules interfere with the polymer chains and act as plasticizer when stored in artificial saliva.[11,17,19] The reason for decreased flexural strength values of thermal cycled group may be because of deterioration of the material to some extent because of polymerization shrinkage.[3] The main disadvantages of heat cure acrylic are longer time taken for fabrication, additional laboratory processes for the preparation of wax patterns, and the need for the use of a split moulds.[17]

Tempron is a self-cure poly ethyl methacrylate resin. Conventional methyl methacrylate resins are mono functional, low molecular weight linear molecules that exhibit decreased strength and rigidity.[5,5] Poly ethyl methacrylate resins are high molecular weight resins capable of cross linking.[5]They exhibit low polymerization shrinkage when compared to PMMA resins. Thus they exhibit comparatively greater flexural strength.[5] However, the reasons for decreased flexural strength could be less time available for the monomer in self-cure resins to wet the polymer beads so a less homogenous polymer is produced. The reasons for non-significance in mean flexural strength values of Tempron before and after thermal cycling could be the deformation of the material to stress rather than fracture.[6,12,20,21] The material deforms under stresses subjected by thermal cycling unlike other materials which deteriorate on thermal cycling. Historically, ethyl methacrylates have shown poor wear resistance and poor esthetics. Thus the methyl methacrylates and the Bis-acryl composite resins possess a larger market share.[22]

Revotek LC is a light polymerized urethane dimethacrylate composite resin. The flexural strength of the material was comparatively low among all the materials compared. The reason for this result was mainly because of less crystalline silica filler particles (15 - 35%) when compared to normal composites (85% by weight).[2,17,23] These glass filler ions are slowly leached out in the presence of artificial saliva and thus reducing the flexural strength of the material.[13,17] The material was initially polymerized in the brass mould (Figure 8) and later was carried out in a TRIAD visible light curing unit for complete polymerization. (Figure 9) During the retrieval process there may be chances for distortion of the specimen leading to change in flexural strength value.[7] The reasons for decreased mean flexural strength values after thermal cycling may also be attributed to the leaching out of glass filler ions making the material weaker to resist stresses.[23] Secondly, the material exhibits inherent brittleness to resist the stress that it is subjected to, during thermal cycling procedure. Recently, scientists studied more closely, the effects of moisture in the oral environment on the flexural strengths of interim materials. The oral environment, however, may cause interim prostheses to deteriorate, which results in the softening of resin matrixes, release of unreacted monomers, degradation of products, and leaching of filler ions, all of which negatively affect mechanical strength.[14,24]

LIMITATIONS

The main limitation of the present study was that, the flexural strength was assessed in vitro simulating the oral environment, but it actually differs from the conditions the material experiences intra orally. In addition, there is a weak correlation between monotonic flexural strength and resistance to fatigue loading. The fatigue tests are more pertinent than monotonic flexural strength. The longevity of a material depends on various other properties like marginal accuracy, micro hardness, fracture toughness etc. Hence, flexural strength values alone cannot be considered while selecting a material for long-term clinical performance. The material is subjected to flexural strength evaluation in the form of a rectangle bar, which is different from the form during clinical usage. Thus, there may be differences in mean flexural strength values for specimens being tested in laboratory and in clinical scenario.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interest regarding this article.

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