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Original Article

A Comparative Study to Evaluate the Effect of Thermal Cycling on the Flexural Strength of Bis-Acryl Composite Resin, Light Cure Resin and Cad/Cam Resin for Provisional Restorations-An In Vitro Study

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ABSTRACT

Aim: To compare the effect of thermal cycling on the flexural strength of Bis -acryl composite resin, light cure UDMA resin and CAD/CAM PMMA resin for provisional restorations.

Materials And Methods: This study included 60 specimens. Twenty bar-shaped specimens were fabricated for each group Bis-Acryl composite resin, Light cure UDMA Resin and CAD/CAM Resin with the use of a split acrylic mold. These specimens were stored in artificial saliva for 10 days. The specimens were then subjected to thermal cycling. Flexural strength was calculated using three point bending test under universal testing machine. Data were analyzed using student-ttest (α=0.05) @ 90% power.

Results: The highest mean and standard deviation before thermal cycling was seen in CAD/CAM Resin (106.74 ± 3.61) and the lowest in Bis-Acryl composite Resin (92.57± 1.36). The highest mean and standard deviation after thermal cycling was seen in CAD/CAM(94.83± 2.56) and the lowest in Bis-Acryl Composite Resin (81.34 ± 1.64).

Conclusion: Within the limitations of this study by analyzing the results, it was concluded that the Thermal cycling had shown significant impact on the flexural strength of all the materials. Group A Specimens (CAD/CAM PMMA Resin) exhibited highest flexural strength before and after thermal cycling followed by Group C Specimens (Bis- Acryl Composite Resin) and Group B (UDMA Resin group).

Key Words: *Flexural strength, Provisional restoration, CAD/CAM PMMA Resin, Urethane Dimethacrylate Resin, Bis-Acryl Resin*

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INTRODUCTION

Provisional fixed dental prostheses (FDP) are an integral part of fixed Prosthodontics and Dental implantology. The increased desire for aesthetics has lead interim restorations to serve as valuable diagnostic tools in fixed prosthodontics[1] .The term provisional, interim, temporary or transitional restorations are used interchangeably. The assignment of the term 'temporary' may lead to the misconception that it is of less value or importance and that eventual placement of the final restoration will miraculously remedy the detrimental effects of a poorly fabricated provisional restoration.[2]

The uses of a provisional FDP are diagnostic purpose when the functional, occlusal and esthetic parameters are to be developed to identify an optimum treatment outcome before the completion of definitive prosthesis, providing a template for defining tooth contour, esthetics, proximal contacts and occlusion. It can also provide an important psychological management of patients until the final restorations are cemented[1].

Conventionally, various types of materials have been introduced to provide a provisional restoration for esthetic, easy to fabricate, with adequate high strength and hardness. The materials most commonly used for fabricating provisional restorations are resin based namely poly (methyl methacrylate), poly (ethyl methacrylate), bisphenol a glycidyl methacrylate, bis-acryl composite resin, epimine resin and urethane di-methacrylate resins[4].

These materials differ with regard to the method of polymerization, filler composition, and monomer type. Traditional poly methyl methacrylate based resin (PMMA) possesses low mechanical properties.[5] They also lack marginal integrity[6,7] and have poor color stability[8,9]. Other problems associated with them are their high polymerization shrinkage, heat generation, water sorption, and degradation of the resin matrix .[10]Attempts have been made to reinforce this material with fillers such as glass[11-16], silica[17], carbon fiber[14,16] , Steel Wires[11,12] and polyethylene to increase their mechanical stability.

CAD/CAM technologies have started a new age in dentistry. The quality of dental prostheses has improved significantly by means of standardized production processes.[19]This offers numerous new treatment options such as an extended preliminary treatment phase. Currently, many manufacturers offer high-density polymers based on highly cross-linked PMMA acrylic resins or composites for CAD/CAM manufacturing methods. Since they are manufactured in an industrial process, provisional restorations made of high-density polymer exhibit qualities superior to those of direct restoration.[19]

The flexural strength of an interim restorative material is greatly tested during mastication. Long span fixed provisional prosthesis functions as a beam, greater the length of the edentulous area being spanned with pontic, greater is the flexure of the restoration. So an understanding of the mechanical properties of these materials is important in determining whether the restoration will be able to survive repeated functional forces in the oral environment. In some clinical scenarios like raising the vertical dimension in case of full mouth rehabilitation cases, long span FPDs, TMJ dysfunction therapies and in patients exhibiting parafunctional habits the flexural strength of the interim restorations play an important role.[21]

Most of the studies on flexural strength of provisional restorative materials which have been done so far have compared different traditional resin materials and /or those materials with reinforcements such as polyethylene, glass, nylon, and carbon. There is a scarcity of research on determination of properties of provisional restorative materials fabricated by those utilizing the recent technologies of computer aided design/ computer aided manufacturing (CAD/CAM) [22].

Ageing of the material by a process called thermal cycling can cause material fatigue and hastens up the deterioration of the materials[19]. This laboratory procedure is an in vitro simulation of thermal alterations that occur inside oral cavity. According to Gale and Darvell, intolerable temperatures inside oral cavity can range from 0°C to 68°C. Furthermore, constant temperature range between 4 °C and 60 °C impair some material properties such as cohesive, compressive, flexural and shear strength, as well as hardness and roughness of the provisional fixed restorations.[23]

In complex treatment, provisional restorations are an integral part of the treatment planning process and must maintain their strength, marginal accuracy and esthetics throughout the diagnostic and restorative phases. This study aims to evaluate and compare the flexural strength of three provisional resins materials before and after thermal cycling. The null hypotheses were that no difference would be found among the flexural strength of three different provisional restorative materials before and after thermal cycling.

AIM:

Therefore a study was designed to compare the flexural strength of CAD/CAM polymethyl methacrylate Resin, urethane dimethacrylate (UDMA-Light Polymerizing Resin) and Bis-acryl Composite Resin before and after thermal cycling.

MATERIALS AND METHODS:

The present study was conducted in Department of Prosthodontics and Implantology, Government Dental College & Research Institute, Bangalore, Karnataka.

OVERVIEW OF STUDY DESIGN

The study consist of three main groups of provisional restorative materials Group A, Group B and Group C i,e CAD CAM PMMA Resin (Ceramill Temp), light cure UDMA Resin (Revotec LC) and Self-cure Bis-GMA Resin (Protemp 4).Twenty Standard specimens (25x2x2 mm - ANSI/ADA specification # 27) were fabricated from all the three materials giving a total of Sixty Specimens.

METHOD OF FABRICATION OF SPECIMENS:

FABRICATION OF GROUP A SPECIMENS (CAD CAM PMMA RESIN)

The CAD CAM PMMA resin is supplied in the form of blanks. A mock specimen of the dimension 25x2x2mm was made with dental stone. The sample specimen was then embedded in a putty impression material that was placed on diagnostic cast. An extra oral scanner was used to scan the diagnostic cast with the putty placed on the cast having the specimen. The first scan was done after removing the sample from the putty and a second scan was done with the specimen embedded in the putty. The scanned image of the putty with the specimen dimension 25x2x2mm in the computer is now converted into STL file. The CAD CAM PMMA resin was loaded in the milling machine and any final adjustments required were done and corrected in the computer and then signal were transferred to the CAD CAM machine for milling. Two CAD CAM PMMA blanks were used to mill 20 specimens. Each blank was used to mill 10 specimens.

The specimens of Group B and Group C were made with the help of acrylic mold and glass slab. The mold was having a space of dimension 25x2x2mm (ADA-ANSI specification #27).Petroleum jelly was applied to the mold and onto the glass slab for easy separation of the specimen from the mold. The materials were mixed according to manufacturers recommendations and loaded into the mold and another glass slab was placed on top of the mold and gentle pressure was applied for uniform flow of materials.

After the material sets the specimens were grossly trimmed using tungsten carbide bur and then polished with sandpaper.

FABRICATION OF GROUP B SPECIMENS (UDMA RESIN)

The material is supplied in the form of a putty stick and the main component of the material is UDMA Resin. Required amount of material was dispensed using a spatula and the material was loaded onto the slots in the acrylic mold. Petroleum jelly was applied on the glass slab and then pressed over the acrylic mold. Initial light curing was done using a Light Emitting Diode (LED) powered visible light curing unit for 10 seconds in fast cure mode (440−480nm) for each specimen according to the manufacturer's instructions. The specimens were then retrieved and final curing was done for 10 minutes with Traid Light curing Unit. All the 20 specimens, were prepared and polished in the similar manner.

FABRICATION OF GROUP C SPECIMENS (Bis-GMA Resin)

The material is supplied in cartridge form as base and catalyst pastes and the main component of the material is Bis-GMA. The cartridge was placed in the mixing gun and the material was loaded into the mold spaces of the lubricated acrylic mold. Petroleum jelly was applied on the glass slab and then pressed over the acrylic mold .After five minutes, the samples were retrieved and polished. All the 20 samples were prepared in the same way.

CONDITIONING OF THE SPECIMENS

All the experimental Specimens (n=30) from the subgroups A2, B2 AND C2 were stored in artificial saliva at room temperature for 14 days. At the end of conditioning period, the specimens were subjected to thermal cycling and later tested for flexural strength. Subgroup A1, B1 and C1 (n=30) were kept as control and directly tested for flexural strength.

THERMAL CYCLING

Thermal cycling of the experimental specimens (n=30) was done by immersing the samples in two temperature controlled water baths maintained at 5°C (cold bath) and 55°C (hot bath). The samples of each group were put in cold and hot water baths alternatively and the dwell time was 6 seconds in each water bath. A total of 2500 cycles were carried out in similar manner.

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

All these specimens (n=60) were subjected to three point bend test, at a crosshead speed of 0.75mm/min carried out by Universal Testing Machine. The load was applied to the centre of the specimen until the specimen fractured. The breaking load was noted in Newton and calculated in MPa with the use of testing machine software .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 Newton's at which specimens failed between load bearing edges,

L= Length of the support span (15mm),

b = Width of specimen (2mm),

d = Thickness of the specimen (2mm).

By, substituting the above formula for each load value obtained, the flexural strength was calculated for all the 60 specimens. The flexural strength value obtained was in Mega Pascals (M Pa).

STATISTICAL ANALYSIS

Data collected was entered in an excel format and descriptive and analytical statistics were computed. The statistical analysis was done with the SPSS Version 22 software package (IBM Corporation, SPSS Inc., Chicago, IL, USA).

Descriptive statistics with frequency, mean and standard deviation were computed. Statistical tests were applied between the experimental and control group and within the experimental group. Chi Square/Fisher exact test was used to find out differences between proportions. Normality test was performed based on which Mann Whitney U Test was used to compare between two groups and by Kruskal-Wallis test to compare between three groups. Statistical significance was considered at $p < 0.05$ (confidence interval of 95% was taken).

'P' Values : $P \leq 0.05$ – Significant; $P \leq 0.01$ – Highly significant; $P \leq 0.001$- Very highly Significant; $P > 0.05$ – Not Significant.

RESULTS:

All the three groups i.e GroupA, Group B and Group C consisiting of 20 Specimens (10 before thermal cycling and 10 after thermal cycling) were subjected to flexural strength test using universal testing machine.

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DISCUSSION

Provisional Restorations are designed to enhance esthetics, stabilization and function for a short period of time. The use of provisional Restorations relies on a reasonable time from tooth preparation to completion of definitive treatment. However, there are certain situations where the provisional restorations may be worn for 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. Provisional restorations also help in the psychological management of patients where a mutual understanding of treatment outcome and limitations of treatment can be identified.

Conventionally, various types of materials have been introduced to provide a provisional restoration for esthetic, easy to fabricate, with adequate high strength and hardness. The materials most commonly used for fabricating provisional restorations are resin based namely poly (methyl methacrylate), poly (ethyl methacrylate), bisphenol a glycidyl methacrylate, bis-acryl composite resin, epimine resin and urethane di-methacrylate resins.[22]

CAD/CAM technologies have started a new age in dentistry. The quality of dental prostheses has improved significantly by means of standardized production processes.[5]This offers numerous new treatment options such as an extended prelimiary treatment phase. Currently, many manufacturers offer high-density polymers based on highly cross-linked PMMA acrylic resins or composites for CAD/CAM manufacturing methods. Since they are manufactured in an industrial process, provisional restorations made of high-density polymer exhibit qualities superior to those of direct restorations.[25]

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 materials flexural strength, also known as transverse strength, which is the strength of the material under a static load. This measurement is a combination of tensile and compressive strength tests with elements of proportional limit and elastic measurements. The flexural strength of provisional restoration is important particularly when the patient must use provisional restoration for an extended perio

In this study the flexural strength of three provisional restorative resin materials were compared before and after thermal cycling i.e., CAD/CAM PMMA Resin (Group A), light activated UDMA (Group B) and autopolymerizing Bis-GMA composite resin (Group C). These materials were chosen because of their wide clinical usage.

Flexural strength tests are essentially a test of a bar supported at each end, subjected to three point flexure. These tests evaluate stresses as compressive at the point of application of load and tensile and shear at the point of resistance to the load applied, making them similar to the stresses produced by multi-unit FPD. Flexural strength can be determined by three point bend test in Universal Testing Machine[26,27]. Various studies have documented about the use of three point bend test in order to determine the flexural strength of provisional restorative resins. The flexural strength of provisional materials may be influenced by saliva, food components, beverages and interactions among these materials[28,29]. 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 ageing of the material and simulates changes in oral environment.

Thermal cycling had considerable impact on the flexural strengths of the materials and the flexural strength of all the three resins i,e CAD /CAM PMMA Resin, UDMA Resin and Bis-GMA Resin decreased significantly after thermal cycling. However CAD/CAM PMMA Resin interim material still possessed superior flexural strength after thermal cycling among all the three materials. Results also showed highly significant difference between subgroups of CAD /CAM PMMA Resin (Ceramill Temp), UDMA Resin (Revotec LC) and Bis-GMA Resin(Protemp 4).Theoretically, thermal cycling allows the repeated shrinkage and expansion of the material and, consequently, a situation of internal tension that can influence prostheses durability and bond strength between artificial denture teeth and acrylic resin denture base . The tension induced in the material by thermal shock can also takes to microcracks formation, causing a possible reduction of mechanical properties including hardness. Microcracks in artificial denture teeth facilitate water penetration, which can accelerate the process of PMMA plasticizing. Therefore, the effect of hydration would be another important factor related to thermal cycling.[32,33]

CAD/CAM PMMA resin material (Ceramill Temp) exhibited greater flexural strength than the other materials because CAD/CAM interim materials are prefabricated from industrially polymerized blocks, which prevents the heat of polymerization and shrinkage. Murakami et al reported an improvement in some mechanical properties of conventional PMMA when treated under high pressures, given the consequent elevation in the average molecular weight of the PMMA polymer matrix in addition to decreased concentrations of residual monomers and internal voids. The accompanying reduction in the plasticizing effect exerted by residual monomers is expected to improve surface hardness, lower water sorption, and enhance the level of flexural properties in CAD/CAM PMMA. The superiority of flexural strength in the CAD/CAM PMMA groups might be related to the existence of noted levels of voids and porosities associated with the manufacturing process of the conventional heat-cured PMMA and other resins.[31] Moreover, the composition and the formation of the PMMA chains might explain the superiority of the CAD/CAM PMMA groups.

Bis-GMA composite resin material (Protemp 4) exhibited greater flexural strength than UDMA Resin because of multifunctional monomers, which increase the strength due to cross-linking with other monomers. Additionally, they contain inorganic nano fillers which further improve the strength of the material[34]. The method of dispensing Bis- GMA by cartridge delivery system was accurate and the auto mixing system ensures complete polymerization. It is hydrophobic in nature, ensuring minimal water uptake and thus reducing the plasticizer action when stored in artificial saliva[18,35] 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.

The results obtained in this study are consistent with those of past studies in which flexural strength of CAD/CAM PMMA Resin before and after thermal cyling was higher than Bis-Acryl composite resin and other conventional provisional restorative materials. However, the direct comparison among various studies cannot be done as this property is material specific and continuous developments to improve the material properties are taking place.

CLINICAL IMPLICATIONS:

Mechanical properties like fatigue strength, impact strength, elastic modulus, fracture resistance are some of the properties required to serve as a good provisional material and should also possess less desirable characteristics such as tendency to stain, lack of polish ability, difficult manipulation, or poor esthetics. It is important to note that flexural strength is just one of the properties of provisional material.

STUDY 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. Based on this study, it cannot be concluded that CAD/CAM PMMA is better than UDMA and Bis-Acryl Resin. There are many other properties and different clinical situations have to be considered before choosing a provisional material appropriate for each patient.

CONCLUSION

Within the limitations of this study by analyzing the results, it was concluded that the Thermal cycling had shown significant impact on the flexural strength of all the materials. Group A Specimens (CAD/CAM PMMA Resin) exhibited highest flexural strength before and after thermal cycling followed by Group C Specimens (Bis- Acryl Composite Resin) and Group B (UDMA Resin group).

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