‘COMPARATIVE EVALUATION OF EFFECT OF THERMOCYCLING ON FLEXURAL STRENGTH OF THREE PROVISIONAL RESTORATIVE MATERIALS FABRICATED BY DIFFERENT METHODS: AN *IN-VITRO* STUDY.’

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IN

PROSTHODONTICS INCLUDING REMOVABLE, FIXED, MAXILLOFACIAL AND IMPLANTOLOGY

BRANCH – I

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LIST OF ABBREVIATIONS USED

No.	Abbreviation	Full form
1	n	Number of samples in each group
2	p value	Probability of happening of an event
3	S.D.	Standard deviation
4	ANOVA	Analysis of variance
5	^0C	Degree Celsius
6	0	Degree
7	mm	Millimetre
8	i.e	That is
9	PMMA	Polymethyl Methacrylate
10	CAD/CAM	Computer Aided Designing and Computer Aided Machining
11	%	Percentage
12	MPa	Mega Pascal
13	PEMA	Polyethyl Methacrylate
14	Bis-GMA	Bisphenol A-glycidyl methacrylate
15	STL	Stereolithography/Standard Tessellation Language

INTRODUCTION

Prosthodontics is concerned with the rehabilitative services post damage to the teeth or surrounding tissues. The modalities involved in it aim at providing an alternative to the natural dentition either in the form of complete denture, partial denture or with a newer advancement in the filed named implant dentistry[1]. The demand for the prosthesis is increasing with time due to fact of advancement in science and medications which tend to increase the lifespan of humans[2].But with increase in age the dental problem too have increased. A lower age group deal with the problems of dental caries which is followed by gingivitis and periodontitis at middle age. At older age periodontitis is found in patients that ultimately lead to tooth loss[3]. Resorption of bone and decrease in bone density act as synergistic measures to it. Thus regaining dentition which would function for esthetics, speech, mastication and overall wellbeing of life becomes a necessity.

Any prosthesis which is fabricated follows certain steps. It initially starts with consultation to examine patient and get a thorough idea regarding their fit in either type of prosthetic treatments. For this, a diagnostic impression is made and the cast obtained is studied to make a treatment plan along with bone mapping procedures. After deciding the type of treatment, primary impression is made and the laboratory procedures are carried out. This is followed by making a final impression by relieving certain areas in case of complete denture(4).

This whole process of fabricating prosthesis with complete or partial coverage, takes around 7 to 10 days on an average. During this whole process the tooth prepared for placement of prosthesis needs to be protected from the oral environment. Additionally, preservation of the relationship of these teeth with adjacent teeth as well as opposing teeth becomes of utmost importance. Initially after final impression, the final prosthesis were provided to the patients without any trial replica of the final prosthesis. But this resulted in issues arising at the stage of insertion into the final prosthesis, clinicians have initiated with the practice of provisional restoration before cementing the final restoration which not just protects the prepared tooth from oral environment but also serves as a diagnostic tool for final prosthesis. This process of fabricating provisional restoration is termed as temporization(5). Familiar words used along in the literature are interim, provisional and transitional. As the name denoted ‘provisional’, this restoration is for a time being and serves in determining the prognosis of the final prosthesis depending on the quality of the provisional restoration used.

The ideal requisite of provisional restoration as stated by Schillenburg include the restoration to provide pulp protection, prevent the opposing tooth from supra eruption, prevent the adjacent tooth from tipping, serve to provide functional occlusion, should be able to withstand occlusal forces, should be retentive, should be pleasing to the patients esthetically, should be such that it can be polished so as to prevent accumulation of plaque and further periodontal diseases, should be sound enough so that the margins of the restoration do not intrude the gingival tissues and damage the gingiva inducing gingival pathosis and thus fabricated such that it can be easily maintained for hygiene conditions(5). Contributing further to these requisites, Wassel proposed functions of the provisional prosthesis to help in assessing the phonetics of the patients and thereby rectify the problems in phonetics before the insertion of final prosthesis, helps in measuring the amount of tooth reduction needed, provide temporary filing as a crown and isolation during endodontic procedures and performance as a mould construction of core(6).

The technique used for fabricating can be direct wherein the restorations are directly prepared over the tooth or indirectly, wherein an impression of the tooth is obtained to fabricate an interim restoration. Few clinicians follow a combination of direct and indirect technique to overcome the cons of the individual techniques and provide a better outcome. All these techniques depend on the restorative material used. Various materials are used to fabricate provisional restoration. The basic classification is into acrylics and resin composite materials. Few of the acrylic materials available for its use as provisional restoration in prosthodontics are polyethyl methacrylate resins, polymethyl methacrylate resins or a combination of both(7). Further they are classified based on their method of polymerization, whether light or heat activated, chemically activated or a combination of both.

Acrylics have been in used as a provisional restorative material from 1930. Since then these have been the most commonly used materials owing to their advantage of low cost, versatility and esthetic acceptance by the patients. Both polymethyl and polyethyl methacrylate have their own advantages and disadvantages. Polymethyl methacrylate has good wear resistance, high polishability to prevent plaque accumulation, provides good esthetics and colour stability along with low cost while on the other hand, this material gives a significant amount of heat during exothermic reaction thereby damaging pulpal tissue, presence of odour with the material, high degree of shrinkage providing a way for intrusion of microbes. Short working time and difficulty in repair once damaged. In case of polyethyl methacrylate, the heat given off during exothermic reaction is less, there is significantly less shrinkage of the material as compared to polymethyl and provides an extended working time while the disadvantages include low esthetics due to poor colour stability, poor wear resistance along with odour and difficult to repair once damaged just like polymethyl methacrylate(8).

Among the composites, Bis-GMA and Bis-acryl are the commonly used. These materials have an advantage of less shrinking property compared to acrylics thereby preventing the risk of microbial intrusion. The heat generation during exothermic reaction is less, provide excellent esthetics with minimum odour and can be easily polished at the chairside itself.

Apart from the conventional techniques used for fabricating provisional restorations, the advancement in the field of dentistry has led to the development of computer aided designing and manufacturing of provisional prosthesis known as CAD/CAM technology. CAD/CAM helps to overcome various drawbacks of the conventional technique by providing the shaping of the restoration with high precision. Any restoration will be regarded as successful if it can withstand oral environment and has a good marginal and internal fit. With improper marginal adaptation, the process of final placement of the prosthesis may get further delayed due to gingival inflammation(9).

One of the important aspect to be considered for any kind of technique and material is its flexural strength. All these materials will vary in flexural strength with respect to the materials used and the technique of fabrication followed. Flexural strength for a material can be defined as the maximum bending strength of a material before it undergoes permanent deformation of breakage. Thus it is important to assess whether the used material can withstand repeated functional forces present in the oral cavity and also withstand with same properties during temperature changes. Thermocycling is one such process used to determine the properties of the provisional restorative material by causing ageing of the material which leads to material fatigue(10). In order to understand the effect of thermocycling on the provisional restorative materials the present study was designed to evaluate and compare the effect of thermocycling on flexural strength of three provisional restorative materials (heat polymerized PMMA, Bis-Acryl composite resin and CAD/CAM milled) fabricated by different methods (heat polymerization, self-polymerization and CAD/CAM milling).

AIMS & OBJECTIVES

AIM:

To evaluate and compare the effect of thermocycling on the flexural strength of three different provisional restorative materials fabricated by different methods.

OBJECTIVES:

PRIMARY OBJECTIVE:

To evaluate and compare the effect of thermocycling on flexural strength of heat polymerized PMMA, Bis-Acryl composite resin and CAD/CAM milled provisional restorative materials fabricated by heat polymerization, self-polymerization and CAD/CAM milling methods respectively.

OTHER OBJECTIVE 1:

To evaluate the flexural strength of heat polymerized PMMA before and after thermocycling.

OTHER OBJECTIVE 2:

To evaluate the flexural strength of Bis-Acryl composite resin material before and after thermocycling.

OTHER OBJECTIVE3:

To evaluate the flexural strength of CAD/CAM milled provisional restorative material before and after thermocycling.

OTHER OBJECTIVE 4:

To compare the flexural strength of heat polymerized PMMA, Bis-Acryl composite resin and CAD/CAM milled provisional restorative materials fabricated by heat polymerization, self- polymerization and CAD/CAM milling methods respectively, before and after thermocycling.

REVIEW OF LITERATURE

Krug RS (1985)[(11)], gave a description on the functions, desirable requirements and materials used for provisional restorations. Esthetic acceptance, color stability, minimal pulpal irritation, good strength, poor thermal conductivity and ease of fabrication are important features that a provisional material should possess. Techniques for fabricating provisional restorations with poly (methyl methacrylate), poly (ethyl methacrylate) and epoxy resins were described.

Vahidi (1987)[(7)], suggested that for higher rate of success of definitive treatment, properly fabricated provisional restorations need to be utilized. This phase of treatment should be considered as a template for ensuing prosthesis and not just a temporary treatment. This will be useful in bypassing the challenges occurring in definitive phase. This article discussed the purposes and requirements of interim restorations including methods of fabrication and the materials employed.

Gegauff AG, Pryor HG (1987)[12], did a study to compare resistance to fracture of six resins used as interim restorative materials. These were broadly categorized as- epimine(1), poly (methyl methacrylates)(2), composite(1), poly (ethyl methacrylates)(2).The effect of pressure curing on their strength was also studied. They concluded that the epimine and the two poly (methyl methacrylates) had the greatest toughness where as poly (ethyl methacrylates) had the lowest. Pressure curing had no significant effect on their fracture toughness

Wang RL, Moore BK, Goodacre CJ, Swartz ML, Andres CJ (1989)[13], conducted a study in which comparison was done amongst the resins used for fabrication of interim fixed prosthesis. The materials included comprised of four acrylic and two composite resins for which temperature changes during polymerization, surface hardness, marginal fit, resistance to wear, surface roughness, strength after repair, polishability, colour stability and resistance to stain were determined. While certain materials exhibited superior properties in one or more of the tests, no one material was superior to the others in all tests.

Osman YI, Owen CP (1993)[14], did an invitro study to determine the flexure strength of temporary restorative materials. Similar conditions which are related to the stresses acting on the fixed partial dentures were imposed on five autopolymerizing provisional resin materials. PEMA material displayed highest resistance to fracture values. Amongst the 11 samples 2 recorded lower values for fracture resistance. The study concluded that, in descending order, the resistance to fracture of other materials were as follows: the PEMA materials, Caulk interim bridge resin and G-C Unifast temporary resin; the composite material, Protemp; and the epimine material, Scutan.

Gough M (1994)[15], reviewed the importance of provisional restorations in fixed prosthodontics. Successful crown and fixed partial dentures, relies upon the precise use of provisional restorations. This article also reviewed the recent materials like autopolymerizing and light cure resins, available for fabricating provisional restorations.

Christensens, GJ (1996)[16], gave a description on the different materials available for provisionalization and mentioned the advantages and disadvantages of each. He stated that temporary FPDs and crown are often not fabricated properly, which leads to miss fitting restorations, teeth sensitivity and occlusal instability. Provisional restorations are simple and cost effective to be made by learned staff and they provide assurance that the final prosthesis will fit well with minimal clinical modifications.

Lodding DW (1997)[17], stated that in the past years there have been tremendous change in the role of temporary indirect restorative and prosthodontic procedures. The temporary restorations are now regarded as provisional restorations. They play a vital role in diagnosis and assessment of various requirements of temporary prosthesis. In order to maintain the pulpal health of the tooth, accurate fit is required. These led to increased use of provisional materials and to development of newer protocols to achieve the required outcomes. Owing to the duration for which they have to be placed in the oral environment, a well-fabricated and stable restoration is of prime importance. This article reviewed the current provisional materials, techniques and concepts in fabricating and maintaining long-term esthetic provisional restorations.

Samadzadeh A, Kugel G, Hurley E, Aboushala A (1997)[18], conducted a study to assess the effect on fracture strength of PMMA reinforced with plasma treated polyethylene fibre and a provisional restorative material which is cured in two phase. Fabrication of a 3 unit posterior provisional prosthesis was done on a stainless steel die using a template made of Polyvinyl siloxane. In the reinforced groups, the occlusal surfaces of the abutments of 3 mm wide pieces were encorporated with fiber which was treated with methyl methacrylate or polyisocyanate, which was activator. Complete setting of material was done by light or autopolymerization after which they were divided into 4 groups of 10 each. When compared with the unreinforced restorations, no significant rise in fracture loads was shown by the restorations fabricated by Plasma-treated polyethylene reinforced PMMA, whereas a significantly higher fracture load was shown by the reinforced resin-based restorations than the conventional resin-based and PMMA interim restorations.

Kawano F, Ohguri T, Ichikawa T, Matsumoto N (2001)[19], in conducted a study to assess flexural strength and hardness of laboratory processed composites after thermocycling. The newer composite resins processed in laboratory significantly showed high flexural strength than the conventional resins. However it was reduced after thermocycling but the hardness for most of materials didn't change much after testing. Therefore the conclusion drawn from the study was that the properties of the hybrid composites which were processed in laboratory were affected by thermocycling.

Haselton DR, Diaz-Arnold AM, Vargas MA (2002)[20], conducted a study to compare the flexural strength of 5 methacrylate-based and 8 composite resins which are used to fabricate interim restorations and FPDs. Specimens were prepared and stored at 37 degree Celsius in artificial saliva for ten days and were checked for maximum load of fracture. The statistically similar groups were taken into consideration. The group with the highest strengths had 4 composite (bis-acryl) materials. It was concluded that the flexural strength was material rather than category-sensitive, and some, but not all, a significantly superior strength of flexure was shown by the Bis-Acryl resins over the traditional methacrylate resins.

Burns, D.R., Beck, D.A. and Nelson, S.K (2003)(21), reviewed on provisional fixed restorative materials and concluded that numerous materials, techniques, knowledge and experience is required in providing provisional therapy. There is no ideal material available which is suitable for all clinical applications. The selection of the material depends on the strength and is relative to the clinical mandates for specific treatments.

Chung SM, Yap AUJ, Chandra SP, Lim CT (2004)(22), conducted a study to compare two test methods used to evaluate the flexural strengths of dental composites which were resin based. Materials belonging to the same manufacturer were used- microfill, Minifilled, polyacid modified and flowable composites. Compared with the three point bending test , the ball –on –three ball biaxial test method has an advantage of using specimens of adequate size. However there are various contact stresses which are complex and thus lead to difficulty in reproducibility in biaxial test method. So it was concluded that biaxial test is not a reliable test method when compared to that of ISO three-point- bending test in evaluation of mechanical properties of dental materials.

Dagar S, Pakhan A, Tunkiwala A (2005)(23)**,** evaluated the flexural strength of auto polymerizing PMMA and heat polymerizing PMMA with a newly introduced composite resin Protemp-II . They stored the specimen at 37 Degree Celius for 24 hrs and then to mimic the oral environment the specimens were stored at room temperature for 24 hours and incubated in normal saline at 37 Degree Celius for 5 days. They tested the specimen with three point bent test and concluded that the highest value for fracture resistance was exhibited by heat polymerized PMMA followed by Protempt-II and self polymerized PMMA.

Göhring TN, Gallo L, Lüthy H (2005)[(24)], studied the flexural strength of veneering composites after thermocycling, storage in water and incorporation and site of placement of glass-fibres and concluded that flexural strength deteriorated after storing the samples in water, with and without thermocycling of the tested composites irrespective of the composition of the resin matrix or the quantity of the filler.

Kerby RE, Knobloch LA, Sharples S, Peregrina A (2013)[(25)], conducted a study to assess the flexure strength and modulus, work-of-fracture, and Weibull parameters of 4 composite (bis-acryl) and 2 urethane based interim resins after storing them in distilled water for 1 and 24 hours. The specimens of all the groups (n=23) were stored in distilled water at 37°C after fabrication. Flexural strength, flexural modulus, and WOF values were calculated after generation stress/strain curves. It was found that the values of mean flexural strength and modulous were greater in the group stored for 24-hours than the ones stored for 1 hour. It was inferred that, flexural strength and moduli of provisional resins significantly increased after postgelation polymerization.

Yao J, Li J, Wang Y, Huang H (2014)[(26)], carried out a study to evaluate the flexure strength and fit of the margins of 2 traditional bis-acryl composite resin provisional materials and 2 CAD/CAM interim materials (Teilo CAD and VITA CAD-Temp). Specimens of the 4 different materials were made (n=20). Every group comprised of 20 samples from which 10 were fractured under 3-point loading and the remaining were thermocycled to 5000 cycles and then tested. Left maxillary first molars (n=10) were prepared to obtain interim crowns from 4 different groups of fabricated from different materials. The marginal discrepancies were measured after 24 hours of cementation. After thermocycling highest mean flexural strength was shown by Teilo CAD while VITA CAD-Temp showed the lowest. It was observed that the flexural strength considerably decreased after thermal cycling. The interim crowns fabricated from bis-acryl showed more marginal discrepancies than the ones fabricated from CAD/CAM before and after thermocycling but it wasn’t significant.. The study inferred that CAD/CAM temporary materials displayed better properties and marginal fit than bis-acryl materials, especially after thermocycling.

Thompson GA, Luo Q (2014)[(27)], conducted a study to evaluate the effect on autopolymerizing PMMA and bis-acryl resin interim materials after thermal treatment, surface seal application, thermocycling, storage media, temperature for storage and aging. The evaluation of flexure strength and microhardness of PMMA and 2 bis-acryl composite resin temporary restorative materials was done and the effect of storage medium, temperature, time, thermocycling, thermal treatment, application of surface seal was recorded. Flexure strength was significantly affected by type of material used and thermocycling. Moreover, after investigation, a significant impact was seen on the values of Vickers microhardness after all experimental treatments.. Material and age of the material significant affected impact strength. Therefore it was concluded that the mechanical properties were enhanced by postpolymerization heat treatments or surface glazing.

Rayyan MM, Aboushelib M, Sayed NM, Ibrahim A, Jimbo R (2015)[28] , did a study to assess the stability of colour, absorption of water, resistance to wear, hardness of surface, resistance to fracture, and microleakage of CAD/CAM fabricated provisionals with those of conventional fabricated temporary prosthesis. A prepared maxillary first premolar was replicated. Four different materials namely- CAD/CAM PMMA blocks (CC), self-polymerizing provisional resin, automix temporary resin, and thermoplastic resin were used to fabricate interim prosthesis on the replicas. The specimens were cemented on the replicas and were then subjected to dynamic fatigue and thermocycling. The degree of colour alteration (ΔE) was more in conventionally fabricated provisionals. Colour stability was demonstrated by CC group. The properties like high wear resistance, surface hardness, fracture resistance and less water sorption was demonstrated by CAD/CAM interim restorations compared with conventionally fabricated itemporary restorations. The study concluded that, CAD/CAM temporary crowns demonstrated stable properties and may be opted for temporary restorations indicated for extended period.

Peñate L, Basilio J, Roig M, Mercadé M (2015)[29], conducted a study to analyse the fit of and fracture strengths of temporary FDPs fabricated by using a direct technique with different materials and temporary prostheses fabricated with

CAD/CAM system. A master die was made up of metal and 70 interim FDPs were fabricated by using varied materials. Amongst the 70 interim FDPs, 10 were reinforced with resin-impregnated, light-polymerizing glass fibre with direct technique. The samples were stored at 37°C for 24 hours and later thermocycled for either 2500 or 5000 cycles. The study concluded that, glass fibre reinforced Bis-acryl demonstrated lowest marginal discrepancy. There was no significant difference in the values of fracture strength amongst the interim FDPs reinforced with glass fibre and prostheses milled with CAD/CAM system and unreinforced temporary FDPs demonstrated lowest fracture strength.

Abdullah AO, Tsitrou EA, Pollington S (2016)(9) , studied the gap in margins, internal fit, strength and mode of fracture of CAD/CAM interim prosthesis with that of directly fabricated interim prosthesis and concluded that the CAD/CAM milled provisional crowns were superior. CAD/CAM group demonstrated less internal gap. Not all CAD/CAM provisional crowns demonstrated superior fracture strength to that of the direct provisional material, this led to the rejection of null hypothesis.

Kadiyala KK, Badisa MK, Anne G, Anche SC, Chiramana S, Muvva SB, et al (2016)(10) , did a study to investigate flexure strength of variuos interim restorative resins used for prosthetic rehabilitation. According to ADA/ANSI specification no. 27, 40 identical samples (25mm×2mm×2mm) were fabricated using self-polymerizing PMMA (Group A, n=10); heat polymerizing PMMA (Group B,n=10); autopolymerizing Bis-GMA composite resin (Group C,n=10) and light activated UDMA (Group D,n=10). After storing these samples in artificial saliva for

14 days, 10 samples from each material were subjected to thermal cycling for 2500 cycles (5°C to 55°C) followed by three point bending test. The results showed that the flexural strength of specimens was higher for Group C followed by Group B, Group A and Group D. A significant difference was seen between any two tested materials. Also the difference in the flexural strength values amongst the four tested groups was significant. The study concluded that the flexural strength observed was in the following order Bis-GMA composite resins having the highest values followed by heat activated PMMA, self polymerizing PMMA resins and least was for light cure resins.

Digholkar S, Madhav VNV, Palaskar J (2016)(30) , studied fexure strength and microhardness of fixed prosthetic materials fabricated by varied methods and concluded that the highest flexural strength was demonstrated by CAD/CAM resin group followed by CH resin group and rapid prototyping group. It was inferred that all the groups demonstrated higher values of flexural strength than the minimal value of 50 MPa.

Mehrpour H, Farjood E, Giti R, Barfi Ghasrdashti A, Heidari H (2016)(31) , did a study to compare the flexure strength of 5 interim materials. 5 temporary restorative materials were used to fabricated 50 samples (25×2×2-mm) according to ADA specification #27. Artificial saliva was used to store the samples, later thermocycling was carried out for 2500 cycles. The samples were then tested for flexural strength by conducting a three-point bending test. The results obtained showed that Bis-acryl resins had highest, and the light polymerized resin had lowest flexural strength. The study concluded that, statistically, the properties of Bis-acryl resins were better than conventional methacrylate and light-polymerized resins thus, application of bis-acryl resins should be encouraged in patients with heavy occlusion load and in patients requiring extended use of temporization.

Ozkir SE, Yilmaz B, Unal SM, Culhaoglu A, Kurkcuoglu I (2018)[32] **,** conducted a study to analyse the effect of multiple methods of polymerization on the flexure strength of PMMA resin. 4 different methods of polymerization (n = 10 in each group) were used to fabricate 40 PMMA specimens were made with 4 different methods of polymerization (n = 10 in each group). The methods included polymerization t different temperatures for different period of time and one group wherein microwave energy was used for polymerization. The samples were then thermocycled at 5°C and 55°C for 5000 times. Flexural strength of specimens was measured. Similar values of flexural strength were obtained of the heat polymerized groups whereas significantly lower values were shown by the microwave polymerized group. The study concluded that, conventional heat-cured PMMA when polymerized with the energy from microwave resulted in decreased in flexural strength. Thus, heat polymerization should be used instead of microwave curing when processing PMMA denture bases.

Yilmaz B, Alp G, Seidt J, Johnston WM, Vitter R, McGlumphy EA (2018)[33], conducted an in-vitro study for assessment of fracture of CAD-CAM high density polymer used for implant-supported implant fixed prosthesis with autopolymerized and injection molded resin. CAD-CAM HDP of 8 different brands "(Brylic Solid (BS); Brylic Gradient (BG); AnaxCAD Temp EZ (AE); AnaxCAD Temp Plus (AP); Zirkonzahn Temp Basic (Z); GDS Tempo-CAD (GD); Polident (Po); Merz M-PM-Disc (MAT)", autopolymerized and injection-molded acrylic resin were used to fabricate 5 samples of each the specimens were thermocycled for 5000 times and then were put in on the universal testing machine to receive loads after which load-to-fracture values were recorded. After getting the records, it was inferred that the differences in the values were significantly different amongst the HDPs. Highest load-to-fracture values were found with GD and Po CAD-CAM groups. The values of autopolymerized resin and BG CAD/CAM polymer were similar. The study concluded that the load-to-fracture value of BG CAD-CAM and autopolymerized acrylic resin was similar.

Arslan M, Murat S, Alp G, Zaimoglu A (2018)[34], conducted a study to assess the surface properties and flexural strength (FS) and of CAD/CAM milled PMMA-based polymers used for removable complete dentures with traditional heat-cured PMMA after thermocycling. Three CAD/CAM PMMA based materials were used to mill 20 rectangular specimens each, 10 specimens underwent thermocycling from each group and the other 10 were in controlled group. The specimens from one subgroup were subjected to 5000 thermocycles . It was inferred that CAD/CAM based PMMA materials showed superior properties to the conventional heat cured PMMA. Also, properties were significantly affected by thermocycling.

Alp G, Subasi MG, Johnston WM, Yilmaz B (2018)[35], conducted a study analysing the difference in the flexural strength of different CAD/CAM milled PMMA polymers and conventional temporary resin materials after thermocycling. 3 CAD/CAM PMMA-based polymers, 1 bis-acrylate composite resin, and 1 conventional PMMA, according to ISO 10477:2004 standards were used to fabricate **15 s**pecimens for each material. The specimens were thermocycled 10,000 cycles ranging from 5 to 55°C and then tested for flexural strength. The study inferred that the flexural strength of CAD/CAM PMMA- polymers was highest followed by the bis-acryl composite resin and then stood the conventional PMMA resin with lowest flexural strength values.

Çakmak G, Yilmaz H, Aydoğ Ö, Yilmaz B (2020)[36], conducted a study to evaluate the flexural strength of CAD-CAM and conventional interim resin materials. 5 different interim resin materials were used to fabricated the samples amongst which, 3 were CAD/CAM PMMA-based polymers and 2 were the conventional materials and 1 was the bis acryl composite resin. One surface of each sample was treated by either applying a surface sealant or conventional surface polishing. This was then followed by the testing of flexural strength of the materials. It was found that the surface treatments had no significant effect on the flexural strength. However, CAD/CAM PMMA based polymers had higher values than the conventional ones.

Niem T, Youssef N, Wöstmann B (2020)[37], conducted a study to analyse the influence of aging on the physical properties of different CAD/CAM restorative materials. Elastic recovery (ER), modulus of elasticity (ME), Flexural strength (FS) and modulus of toughness (MT) for three ceramic, twelve composite and five polymer-based materials was calculated. The samples were subjected to load after thermocycling until they break. No significant difference was observed on the properties of ceramic materials, however significant difference between storage of water and thermocycling, was seen amongst hybrid composites. All other polymer based materials showed significant difference. It was concluded that thermocycling led to degradation of properties of both polymer based CAD/CAM materials and composite.

Sadighpour L, Geramipanah F, Falahchai M, Tadbiri H (2021)[(38)] , conducted a study to assess the fit of margin of 3 unit provisional prosthesis before and after thermocycling fabricated from CAD-CAM systems. Preparation was done on a mandibular premolar and molar to receive a 3-unit all ceramic restoration. Metallic dies simulating a missing first mandibular molar were fabricated. Different techniques were used to fabricate 72 3-unit interim prosthesis from various materials which formed 6 groups(n=12). Direct technique was used to fabricate the restoration in first four groups. It was found that there was no significant difference regarding marginal gaps in the restorations obtained from the Amann Girrbach and Arum CAD-CAM systems. The marginal discrepancies were considerably more in the restorations fabricated from traditional materials than the ones which were CAD-CAM milled. The study concluded that, better marginal adaptation was seen in CAD-CAM milled provisional restorations as compared to conventional interim materials whereas the system of CAD/CAM had insignificant differences.

MATERIALS AND METHODOLOGY

Material and methodology have been divided under the following heads:

I. Materials

II. Armamentarium and equipment

III. Method

I. Materials: (Plate I)

Sr.No.	Material	Manufacturer	Batch No.
1.	Heat polymerizing acrylic resin (Tooth coloured) (Plate I, Fig 1	DPI Heat cure,(Dental products of India Ltd)	291
2.	Bis-acryl composite resin (Plate I, Fig 3)	AVUE T Crown (Dental Avenue (I) Pvt. Ltd)	72102870
3.	CAD-CAM PMMA (Plate I, Fig 4)	HUGE dental material CO., LTD.	180110010

4.	Gypsum type 4 (Plate I, Fig 5)	Ultrarock; Kalabhai Karson Pvt Ltd, India	151227
5.	Cold Mould Seal (separating medium) (Plate I, Fig 6)	DPI(Dental products of India Ltd)	8117

II. Armamentarium and equipment (Plate II and III)

1. Acrylizer with thermostat (Plate II, Fig 7)
2. Universal testing machine (Plate II, Fig 8)
3. Rubber bowls and spatula (Plate II, Fig 9)
4. Varsity flasks and clamps (Plate II, Fig 9)
5. Sand paper (Plate II, Fig 10)
6. Camel hair brush (Plate II, Fig 10)
7. Porcelain jar and dapen dish (Plate II, Fig 10)
8. Brass metal dies (Plate II, Fig 11)
9. Hydraulic bench press (Plate II, Fig 12)
10. Vernier caliper (Plate II, Fig 13)
11. CAD/CAM system (Plate II, Fig 14)
12. Thermocycling unit (Plate III, Fig 15)
13. Dispensing gun (Plate III, Fig 16)

III. Methodology (Plate IV)

The basic methodology consisted of-

a) Die preparation

b) Preparation of gypsum molds for specimen fabrication

c) Preparation of heat polymerized polymethyl methacrylate provisional restorative resin specimens

d) Preparation of Bis-Acryl composite provisional restorative resin specimen

e) Preparation of CAD/CAM milled provisional PMMA specimens

f) Testing of the specimens before and after thermocycling for flexural strength.

In all 120 samples were fabricated in every group having 20 specimens in each group and sub group respectively.

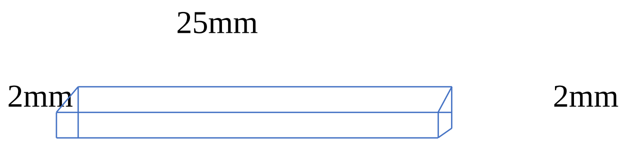
The specimens were divided under the following sub-groups :-

GROUP A		GROUP B		GROUP C	
Heat polymerised PMMA		Bis-acryl composite resin		CAD/CAM milled	
Before thermocycling (A1) n=20	After thermocycling (A2) n=20	Before thermocycling (B1) n=20	After thermocycling (B2) n=20	Before thermocycling (C1) n=20	After thermocycling (C2) n=20
TOTAL=120					

a) Die preparation: (Plate I, Fig 11)

Metal dies were fabricated to prepare the molds for the preparation of heat polymerized polymethyl methacrylate and Bis-Acryl composite resin specimens. 6 brass metal dies of dimensions 25mm in length, 2mm in width and 2mm in height (25×2×2) were fabricated. They were then used for mould formation.

Diagram of die



b. Preparation of gypsum mold for fabrication of specimens: (Plate IV, Fig 16)

Preformed brass metal dies were used to prepare the gypsum mold. Petroleum jelly was applied on the surface of the dies in a thin layer before investing them in gypsum in the lower half of the varsity flask. Die stone was used for base flasking, care was taken to embed only half the thickness of the metal die[39]. Once the investment material sets, the dies were coated with petroleum jelly on the exposed surface and counter flasking was done. The flasks were closed and a metal to metal contact of the flasks were ensured. After the material was set the flask were opened and the dies removed. Any traces of the petroleum jelly were removed by immersing them in hot water and separating medium was applied. The molds were then used for fabrication of heat polymerized polymethyl methacrylate and Bis-Acryl resin provisional resin specimens.

c) Preparation of heat polymerized PMMA provisional restorative resin specimens: (Plate IV, Fig 18)

40 specimens were prepared using conventional heat polymerized provisional restorative resin (PMMA).

Powder and liquid were mixed in 1:2.5 ratio by weight as per manufacturer's recommendations [39]. Packing was done at dough stage, following which trial closure was performed. Final closure was done under a hydraulic bench press at a pressure of 3000psi for 3 mins (according to the manufacturer). The flasks were maintained under pressure for 1 hour after clamping[(40)]. They were then immersed in acrylizer with water at room temperature. The temperature was then raised slowly upto 74^0C and was held for 2 hours. The temperature was then increased to 100^0C and was maintained for 1 hour. After completion of short curing cycle, the flasks were removed from the water bath, they were left to cool at room temperature before deflasking.

The polymerized specimens were meticulously removed and specimens with defects were discarded. Finishing of the specimens was done using sand paper (No. 120). The finished specimens were stored in distilled water.

d) Preparation of Bis-Acryl composite restorative resin specimens: (Plate IV, Fig 18)

40 specimens were prepared of this group and later divided in 2 subgroups (B1 &B2).

A cartridge of Bis-Acryl composite temporary restorative resin was attached to a dispensing gun. It is available as base and catalyst which is mixed in the mixing tip while dispensing. The material was then dispensed in the molds maintaining contact with the mold so that the material is evenly dispensed thus reducing the possibility of incorporation of porosity due to discontinuation. The flasks were then closed completely till the material sets as instructed by the manufacturer. The samples were retrieved, finished and stored in distill water.

e) Preparation of CAD/CAM milled specimens: (Plate IV, Fig 19)

40 specimens were prepared of this group and later divided in 2 subgroups (C1 &C2).

In this study, HUGE dental material PMMA resin disc was used to mill the samples of C (C1&C2) group. STL (stereolithography/standard tessellation language) format was made to be utilized by the unit for milling. The samples were milled from the PMMA disc which was prepolymerized (HUGE) of the shade A2. The finishing and polishing were done within the milling machine with the assistance of the conventional trimmers and cutters.

e) Testing of samples:

The specimens were tested in a metallurgical lab.

The specimens of the groups A1, B1, C1 having n=20 samples each were tested for flexural strength. The specimens belonging to A2, B2 and C2 having n=20 specimens were subjected to thermocycling of 5000 cycles from 5-55 degrees and then were tested for flexural strength.

Flexural strength was tested with universal testing machine at crosshead speed of ±1%, Cross head speed : 0.5 mm/minute . Throughout the flexural tests the stress- strain curves were recorded. During fracture, maximum load was recorded and determined from the chart as fracture load in Newton and the flexural strength was calculated in Mega Pascal (MPa).

$$FS = {3Pl}/{2bd^2}$$

Where,

FS = flexural strength (N/mm^2),

P = load at fracture (N),

I = distance between the supporting wedges (mm),

b = width of the specimen (mm) &

d = thickness of the specimen (mm).

The values of flexural strength obtained were in MPa by the software.

PLATE I

MATERIALS

Fig 1: Heat cure PMMA polymer (tooth coloured)

Fig 2: Heat cure PMMA monomer

Fig 3: Bis-Acryl composite resin

Fig 4: CAD/CAM PMMA disc

Fig 5: Type IV gypsum (die stone)

Fig 6: Cold Mold Seal (separating medium)

PLATE II

ARMAMENTARIUM AND EQUIPMENTS

Fig 7: Acrylizer with thermostat

Fig 8: Universal testing machine

Fig 9: Rubber bowl, plaster spatula, lacron's carver and varsity flask & clamp

Fig 10: Porcelain jar,petroleum jelly, dapan dish,sandpaper (No.120),camel hair brush,Sterile syringe ,mixing spatula

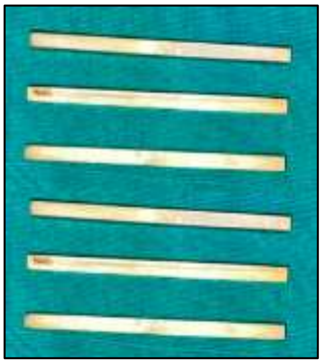


Fig 11: Brass metal dies

Fig 12: Hydraulic bench press

Fig 13: Vernier caliper

Fig 14: CAD/CAM milling machine

PLATE III

ARMAMENTARIUM AND EQUIPMENTS

Fig 15: Thermocycling Unit

Fig 16: Dispensing gun

PLATE IV

METHODOLOGY

Fig 17: Preparation of gypsum mould

Fig 18: Molds to obtain heat cure PMMA and Bis-Acryl samples

Fig 19: STL file and milling to obtain the CAD/CAM milled samples

Fig 20: Total samples of all the group and subgroups (A1,A2,B1,B2,C1,C2)

RESULTS

The following study was conducted in order analyse the difference in flexural strength before and after thermocycling between provisional restorative materials; Heat polymerised PMMA, Bis-Acryl Composite and CAD/CAM PMMA.

A total of 120 samples were fabricated from heat polymerised PMMA(tooth coloured), Bis-Acryl composite resin and CAD/CAM milled PMMA with n=40 each respectively, which were further subdivided in 3 subgroups forming a total of 6 groups.

Distribution of samples into groups:

GROUP A		GROUP B		GROUP C	
Heat polymerised PMMA		Bis-acryl composite resin		CAD/CAM milled	
Before thermocycling (A1) n=20	After thermocycling (A2) n=20	Before thermocycling (B1) n=20	After thermocycling (B2) n=20	Before thermocycling (C1) n=20	After thermocycling (C2) n=20
TOTAL=120					

STATISTICAL ANALYSIS

The statistical calculations were performed using the software SPSS for Windows (Statistical Presentation System Software, SPSS Inc. 1999, New York) version 19.0. The following statistical methods were employed in the present study.

- The following statistical tests were employed for the analysis of the result:

  A. Unpaired t-test was applied to assess the difference within the group before and after thermoycling.

  B. One-way ANOVA test followed by TUKEY'S POST-HOC test was applied between the groups to assess the difference in flexural strength.

One-way ANOVA

- The One-Way ANOVA test produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis when several means are equal. This technique is an extension of the two-sample t test.

- In addition to determining that differences exist among the means, we may require to know which means differs and post hoc tests was used. In the present study one- way ANOVA was applied to find out the mean difference.

Tukey's post hoc Test

- Once it is determined that differences exist among the means, post hoc range tests and a pair-wise multiple comparisons aid in determining which means differ. Range tests identify homogeneous subsets of means that are not different from each other. Pairwise multiple comparisons test the difference between each pair of means, and yield a matrix where asterisks indicate significantly different groups means at an alpha level of 0.05.

- "Mean is the sum of all observations and divided by number of observations."
- "Median is the value of the variable that divides the distribution into two equal parts. i.e. 50 % observations will lie below and above it."
- "Standard Deviation is summarized as the amount of variation (change) in the observation from their average value (mean)."
- "Standard Deviation: It is the most frequently used measure of deviation. It is defined as the root mean square deviation and is denoted by s or SD."
- The formula used for calculating standard deviation:

$$SD = \sqrt{\frac{\Sigma(\overline{X} - X)^2}{n-1}}$$

Where:

$\overline{X}$ = Mean

X = Values of the variables

Σ= Sum of the value

n = Number of observations

Min = Minimum Value

Max = Maximum Value

- **NULL HYPOTHESIS:**

Thermocycling does not have any effect on the flexural strength of provisional restorative materials fabricated by different methods i.e. Group A=Group B= Group C and Group A1=Group B2=Group C2

- **ALTERNATE HYPOTHESIS:**

Thermocycling affects the flexural strength of provisional restorative materials fabricated by different methods. Group A1 ≠ Group B1 ≠ Group C1 and Group A2 ≠ Group B2 ≠ Group C2

- **Level of Significance:** α=5%

Table no.1 represents the mean flexural strength in Heat polymerised PMMA group before and after thermocycling. The flexural strength before thermocycling was 85.94 MPa with standard deviation of 6.65 MPa. The minimum and maximum flexural strength before thermocycling was 75.00MPa and 98.81 MPa. After thermocycling the flexural strength decreased to a mean of 70.90 MPa with a standard deviation of 16.41 and minimum and maximum values of 55.20 MPa and 117.93MPa respectively.

Table no.1- Mean flexural strength of Heat polymerised PMMA group in MPa

Thermocycling	N	Minimum	Maximum	Mean	Std. Deviation
Before Thermocycling	20	75.00	98.81	85.9415	6.65101
After Thermocycling	20	55.20	117.93	70.8970	16.41812

Graph no.1

Graph no.1 represents the bar diagram with mean flexural strength in Heat polymerised PMMA group before and after thermocycling. The x-axis represents the Heat polymerised PMMA material and the y-axis represents the mean flexural strength. The flexural strength is observed to be decreased after thermocycling in Heat polymerised PMMA group.

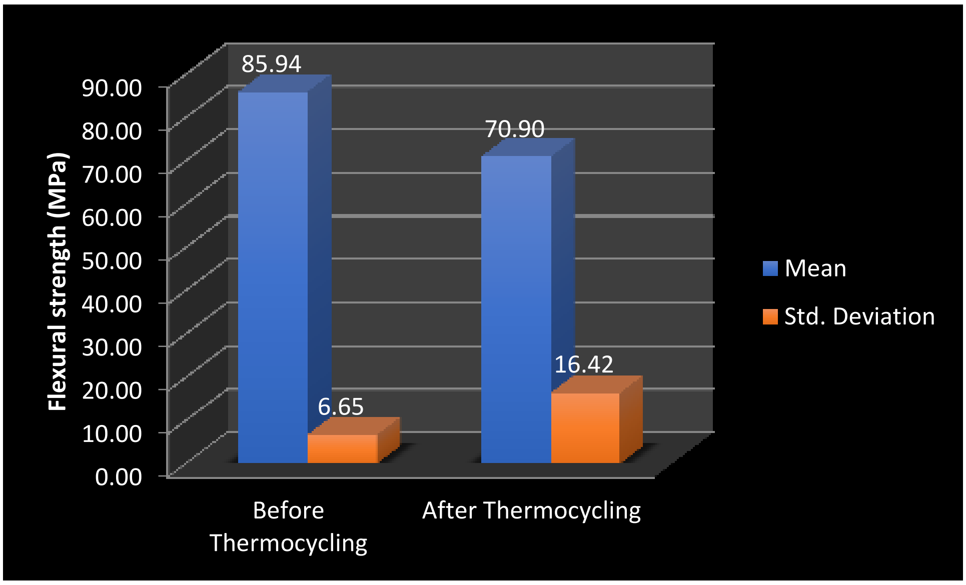


Table no.2

Table no.2 represents the mean flexural strength in Bis-Acryl Composite group before and after thermocycling. The flexural strength before thermocycling was 93.25 MPa with standard deviation of 13.47MPa. The minimum and maximum flexural strength before thermocycling was 78.00 MPa and 128.81 MPa. After thermocycling the flexural strength decreased to a mean of 81.50 MPa with a standard deviation of 14.45 and minimum and maximum values of 58.31 MPa and 110.43 MPa respectively.

Table no.2- Mean flexural strength of Bis-Acryl Composite group in MPa

Thermocycling	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Before Thermocycling	20	78.00	128.81	93.2510	13.47465
After Thermocycling	20	58.31	110.43	81.5020	14.45032

Graph no.2

Graph no.2 represents the bar diagram with mean flexural strength in Bis-Acryl Composite group before and after thermocycling. The x-axis represents the Bis-Acryl Composite material and the y-axis represents the mean flexural strength. The flexural strength is observed to decrease after thermocycling in Bis-Acryl Composite group.

Graph no.2- Bar diagram representing flexural strength of Bis-Acryl Composite group before and after thermocycling

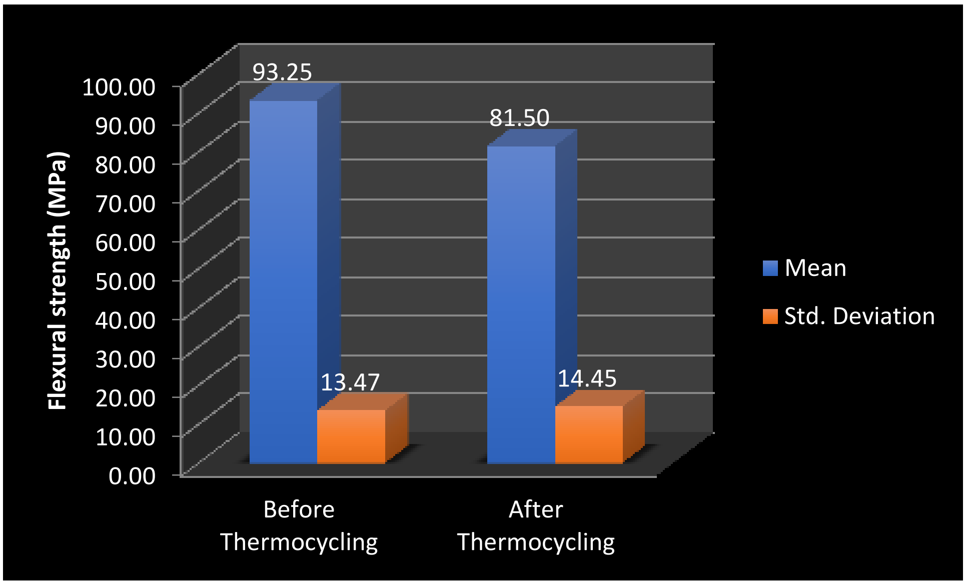


Table no.3

Table no.3 represents the mean flexural strength in CAD/CAM PMMA group before and after thermocycling. The flexural strength before thermocycling was 163.98 MPa with standard deviation of 5.56 MPa. The minimum and maximum flexural strength before thermocycling was 151.31 MPa and 171.19 MPa. After thermocycling the flexural strength decreased to a mean of 158.57 MPa with a standard deviation of 2.97 and minimum and maximum values of 153.18 MPa and 163.87 MPa respectively.

Table no.3- Mean flexural strength of CAD/CAM PMMA group in MPa

Thermocycling	N	Minimum	Maximum	Mean	Std. Deviation
Before Thermocycling	20	151.31	171.19	163.9765	5.56398
After Thermocycling	20	153.18	163.87	158.5680	2.97135

Graph no.3

Graph no.3 represents the bar diagram with mean flexural strength in CAD/CAM PMMA group before and after thermocycling. The x-axis represents the CAD/CAM PMMA material and the y-axis represents the mean flexural strength. The flexural strength is observed to decrease after thermocycling in CAD/CAM PMMA group.

Graph no.3- Bar diagram representing flexural strength of CAD/CAM PMMA group before and after thermocycling

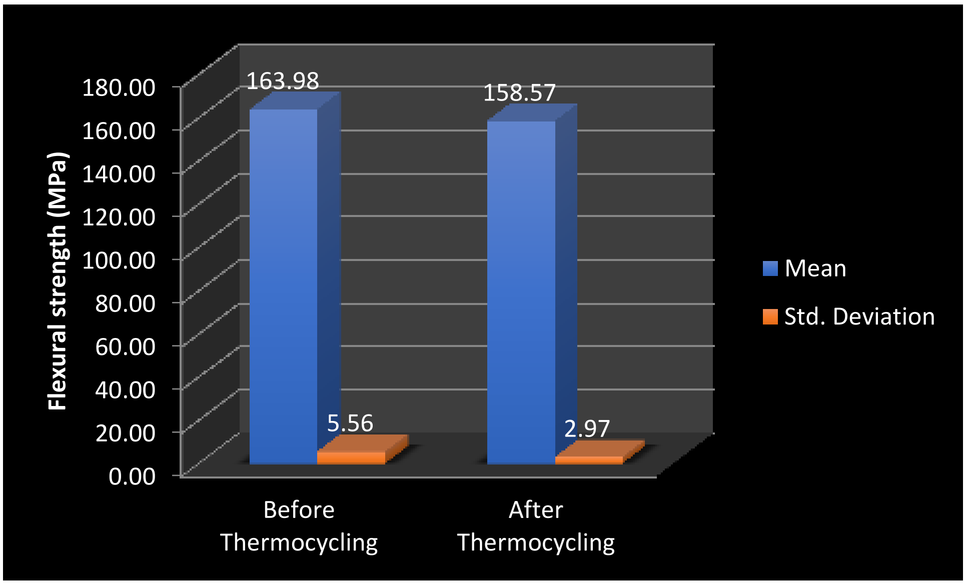


Table no.4

The table represents difference in mean flexural strength before and after thermocycling in Heat polymerised PMMA group. The mean difference was 15.04 with t-value of 4.110. A significant difference was present in flexural strength within the group before and after thermocycling. The flexural strength was significantly less after thermocycling with p=0.001.

Table no.4- Difference in mean flexural strength before and after thermocycling in Heat polymerised PMMA group (MPa)

Thermocycling	Mean	Mean difference	t-value	Significance (p)
Before Thermocycling	85.9415	15.04450	4.110	**0.001***
After Thermocycling	70.8970			

**Significance at p<0.05*

A significant difference is present flexural strength before and after thermocycling. The flexural strength is significantly less after thermocycling.

Table no.5

The table represents difference in mean flexural strength before and after thermocycling in Bis-Acryl Composite group. The mean difference was 11.75 with t-value of 2.508. A significant difference was present in flexural strength within the group before and after thermocycling. The flexural strength was significantly less after thermocycling with p=0.021.

Table no.5- Difference in mean flexural strength (MPa) before and after thermocycling in Bis-Acryl Composite group

Thermocycling	Mean	Mean difference	t-value	Significance (p)
Before Thermocycling	93.2510	11.74900	2.508	**0.021***
After Thermocycling	81.5020			

**Significance at p<0.05*

A significant difference is present flexural strength before and after thermocycling. The flexural strength is significantly less after thermocycling.

Table no.6

The table represents difference in mean flexural strength before and after thermocycling in CAD/CAM PMMA group. The mean difference was 5.41 with t-value of 4.195. A significant difference was present in flexural strength within the group before and after thermocycling. The flexural strength was significantly less after thermocycling with p=0.0001.

Table no.6- Difference in mean flexural strength (MPa) before and after thermocycling in CAD/CAM PMMA group

Thermocycling	Mean	Mean difference	t-value	Significance (p)
Before Thermocycling	163.9765	5.40850	4.195	**<0.0001***
After Thermocycling	158.5680			

**Significance at p<0.05*

A significant difference is present in flexural strength before and after thermocycling. The flexural strength is significantly less after thermocycling.

Table no.7

The table represents difference in mean flexural strength after thermocycling between Heat polymerised PMMA, Bis-Acryl Composite and CAD/CAM PMMA groups. After applying One-way ANOVA test the F value was 281.98. There was a difference present in flexural strength between the materials after thermocycling with p<0.0001.

Table no.7- Difference in the flexural strength (MPa) between the groups after thermocycling.

Thermocycling	**Mean**	**F value**	**Significance (p)**
Heat Polymerised PPMA	70.8970	281.978	**<0.0001***
Bis-Acryl Composite	81.5020		
CAD/CAM PPMA	158.5680		

**Significance at p<0.05*

A significant difference is present in flexural strength between the materials after thermocycling.

Table no.8

To determine the exactly which groups are presenting with the difference in mean flexural strength after thermocycling, post hoc Tukey test was applied. The table represents the groups showing significant difference in mean flexural strength. A significant difference in flexural strength after thermocycling was present between: Heat polymerised PMMA and CAD/CAM PMMA with mean difference of 87.67 and p<0.0001, Heat polymerised PMMA and Bis-Acryl Composite with mean difference of 10.60 and p=0.029, Bis-Acryl Composite and CAD/CAM PMMA with mean difference of 77.07 and p<0.0001. After thermocycling the mean flexural strength was highest with CAD/CAM PMMA material followed by Bis-Acryl Composure and Heat polymerised PMMA materials.

Table no.8- Post hoc Tukey test

Groups		**Mean Difference**	**Significance (p)**
Heat Polymerised PMMA	Bis-Acryl Composite	10.60500	**0.029***
	CAD/CAM PMMA	87.67100	**<.0001***
Bis Acryl Composite	Heat polymerised PPMA	10.60500	**0.029***
	CAD/CAM PMMA	77.06600	**<.0001***
CAD/CAM PMMA	Heat polymerised PMMA	87.67100	**<.0001***
	Bis-Acryl Composite	77.06600	**<.0001***

**Significance at p<0.05*

A significant difference is present in flexural strength after thermocycling between-

Heat polymerised PMMA- CAD/CAM PMMA

Bis-Acryl Composite -CAD/CAM PMMA

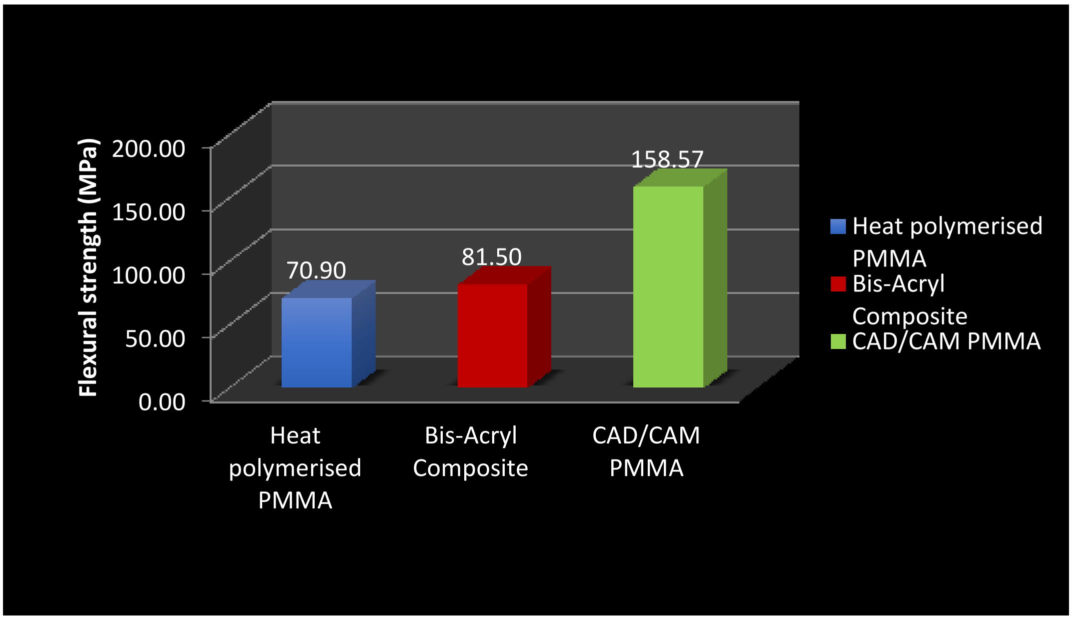
CAD/CAM > Bis Acryl Composite > Heat Polymerised PMMA

Graph no.4

Graph no.4 represents the bar diagram with mean flexural strength in Heat polymerised PMMA, Bis-Acryl Composite and CAD/CAM PMMA groups after thermocycling. The x-axis represents the provisional restorative materials and the y-axis represents the mean flexural strength. The flexural strength is observed to be highest for CAD/CAM PMMA material followed by Bis-Acryl Composure and Heat polymerised PMMA materials.

Overall, the results of the study reveal that there is a significant decrease in the flexural strength after thermocycling in all the three material. When compared to three materials, the decrease in flexure strength after thermocycling was least with CAD/CAM PMMA material followed by Bis-Acryl Composite. The highest decrease in flexural strength was with Heat polymerised PMMA material thereby indicating CAD/CAM PMMA material to be superior compared to Bis-Acryl Composite and Heat polymerised PMMA.

Graph no.4- Flexural strength after thermocycling with all the three materials



DISCUSSION

When interim restorations are to be used for a longer duration their mechanical properties become utmost important. Of all the properties, flexural strength contributes to a great extent for mechanical strength of a material. It governs its stiffness and rigidity. An interim restoration with high flexural strength is less likely to fail(21). Conventional interim materials have been reported with reduced mechanical stability. These materials have porosities incorporated and undergo polymerization shrinkage during the process of manipulation and adjustments. These factors are dependent on the operator, polymerization technique used, mixing ratio considered, device used and the time taken(41)(42)(43).

In the present study, the mean flexural strength in Heat polymerised PMMA group was evaluated and the flexural strength before thermocycling was found to be 85.94 MPa and after thermocycling as 70.90 MPa. Flexural strength significantly decreased after thermocycling in the present study. The findings of this study are supported by various literatures in the past. A study reported by Tasin S and Ismatullaey[44] that studied the effect of thermocycling with different number of cycles presented a significant decrease in flexural strength when fabricated from autopolymerized polymethyl methacrylate (PMMA). Correspondingly, conventional PMMA following 5000 thermal cycling procedures reported with a significant decrease in the flexural strength[34]. Thompson GA and Luo Q[27] reported a significant effect on flexural strength of polymethylmethacrylate material with thermocycling being the dominant effect.

In contrast, a material characteristic comparable to that of polymethyl methacrylate (PMMA) was analysed in the study by Cakmak G et al[36]. The polyethyl methacrylate (PEMA) when used as an interim material demonstrated alike results of the effect of thermocycling. The thermocycling did not significantly affect the flexural strength of PEMA. The possible reason for this could be the surface treatment of PEMA in Cakmak G et al[36] study with polishing conventionally and application of surface sealant. The surface sealants have been reported to improve the mechanical properties as well as surface smoothness of the materials as they fill the microdefects and microfissures. The difference in the flexural strength of Cakmak G et al[36] study with that of present study could be assigned to the chemical composition of the materials and the polarity. PMMA have molecules which are linear in the interim resins and the PEMA materials have secondary bonds[45]. In addition, PMMA have increased tendency of water uptake into their polymer network.

With respect to the Bis-Acryl Composite material assessed in the present study the results revealed that the flexural strength before thermocycling in Bis-Acryl Composite group was 93.25 MPa which decreased to 81.50 MPa after thermocycling.

The present study reported a significant effect of thermocycling on Bis-Acryl Composite material with significantly decreased flexural strength after thermocycling. The present study got the results which are in similar to the study reported by Thompson GA and Luo Q[27] wherein, Bis-Acryl interim material was evaluated for the effects of thermocycling. The results showed a considerable decrease in the mean flexural strength after various treatments with thermocycling being the dominant one. Similarly, Yao J et al[26] investigated the flexural strength of traditional Bis-Acryl composite resin like Protemp 4 and Structure 2 SC/QM when used as an interim material. After subjecting the samples to 5000 thermocycles the flexural strength of Bis-Acryl composite significantly decreased.

Another study evaluated the effect of thermocycling on material surface treated with conventional polishing and surface sealants. The study demonstrated that the thermocycling did not bring a statistically significant difference in the flexural strength in Bis-Acryl composite material. The author stated that the surface treatment with sealant forma layer over the material and when these materials are subjected to thermocycling, the sealant layer is affected without or causing less effect to the interim material beneath thereby causing less cracks and porosities in the material and maintaining the desired flexural strength[36]. The present study did not use any surface treatment over the interim materials thereby providing contrast results from the study reported by Cakmak G et al.

In addition to multifunctional monomer that is Bis-GMA and TEGDMA the Bis-acrylate composite resin also have inorganic fillers particles and organic matrix. The have a cross-linked polymer structure between the monomer chains. It is because of this cross-linkage and the inorganic filler particles, the Bis-Acryl composite resin possess increased strength and material durability compared to the PMMA material. Moreover, Bis-Acryl composite materials present less plasticizing action as well as less water absorption because of their hydrophobic structures[(46)(31)].

The third material that was analysed in the present study was CAD/CAM PMMA. The flexural strength before thermocycling with CAD/CAM PMMA was 163.9. After thermocycling the mean flexural strength decreased to 158.57 MPa. A significant difference in the decrease in flexural strength was demonstrated due to thermocycling in the present study. The results in line with the present study were reported with Niem T el al[(37)] that investigated the influence of thermocycling on CAD/CAM materials and their physical properties. After subjecting the material to 5000 cycle at 5– 55 °C, the flexural strength of the material significantly decreased. It was observed that the CAD/CAM milled materials were susceptible to degradation induced by thermocycling. Another study by Cakmak G et al[(36)] evaluated three different CAD/CAM materials; Polident-PMMA, Telio CAD, M-PM-Disc and demonstrated a significant effect of thermocycling on flexural strength after 10000 thermocycles. Correspondingly, Arslan M et al[(34)] stated in their study that thermocycling had a significant effect on flexural strength on CAD/CAM PMMA-based polymers when subjected to 5000 thermal cycles.

Comparable results were also noted in Yao J et al(26) with CAD/CAM interim materials; Teilo CAD and VITA CAD-Temp showing decrease in flexural strength after 5000 thermal cycles. In the literature, one of the study reported alike results. The study by Tasin S and Ismatullaey[(44)] A compared the effect of thermocycling on CAD-CAM milled material when subjected to thermocycling of 2500 and 10000 cycles at 5 °C to 55 °C. The results reported no significant difference in the mean change of flexural strength in CAD/CAM PMMA group across different thermocycling periods. Through the results is was demonstrated that the CAD/CAM PMMA which is digitally fabricated possessed better mechanical properties and had high stability to absorb energy.

The structure of CAD/CAM materials is more homogenous compared to other interim materials. Because of this homogenous structure, the water absorption and solubility of the material is less. Furthermore, the storage of CAD/CAM materials provides additional support for the higher flexural strength. The CAD/CAM materials are stored in air until the time they are used. This ensure the that the post polymerization process occurs accompanying the relaxation phenomena(47)(41).

When all the three material; Heat polymerised PMMA, Bis-Acryl composite and CAD/CAM PMMA were compared for flexural strength in the present study, the results revealed that a significant difference in flexural strength after thermocycling was present between; Heat polymerised PMMA and CAD/CAM PMMA with mean difference of 87.67, Heat polymerised PMMA and Bis-Acryl Composite with mean difference of 10.60, Bis-Acryl Composite and CAD/CAM PMMA with mean difference of 77.07. After thermocycling the mean flexural strength was highest with CAD/CAM PMMA material followed by Bis-Acryl Composure. The Heat polymerised PMMA material presented with the lowest flexural strength among all materials. These results are in accordance with the studies reported in literature assessing thermocycling effect on the interim materials. Tasin S and Ismatullaey A(44) in their study demonstrated that the digitally fabricated interim materials like CAD/CAM PMMA demonstrated better mechanical properties than traditional polymerized materials like PMMA and Bis-Acryl resins. The material which was milled showed highest stability in maintaining the capacity to energy when compared to other materials. When CAD/CAM PMMA materials were compared with other interim resin materials such as polyethyl methacrylate (PEMA) and Bis-Acryl composite resin after subjecting to 10000 thermocycles and fabricating with surface sealant applications the results demonstrated significantly higher flexural strength with CAD-CAM PMMA-based polymers over conventional interim resin materials. Moreover, in comparison to the present study, CAD-CAM PMMA-based polymers had highest flexural strength followed by conventional Bis-Acryl composite resin while it was least with PEMA interim resin materials post thermocycling[(36)].

Likewise, the flexural strength of CAD/CAM milled PMMA polymers and conventional interim resin materials like PMMA and Bis-Acryl composite resin ranged between 66.1 ± 13.1MPa to 131.9 ± 19.8 MPa. After subjecting these materials to 10000 thermocycles at 5°C to 55°C, the CAD/CAM material presented with a greater flexural strength which was followed by Bis-Acryl resin and conventional PMMA resin[(35)]. Parallel to the these results, Arslan M et al evaluated flexural strength of conventional heat-polymerized PMMA and PMMA-based CAD/CAM polymers when subjected to 5000 thermocycles and observed higher flexural strength of CAD/CAM polymer compared to Heat polymerised PMMA. Of the CAD/CAM materials, Pink CAD/CAM Disc Polident demonstrated higher flexure strength while heat polymerised PMMA showed the lowest flexure strength thereby indicating the effect of thermocycling on the materials.

The flexure strength composite resins which were laboratory processed like Artglass, Targis and Estenia were established to be significantly higher than the conventional materials like Dentacolor and Cesead II. Though the materials showed decrease in flexural strength post thermocycling but the hardness was found to be intact[19]. The investigation of flexural strength of two Bis-Acryl composite interim materials; Protemp 4 and Structur 2 SC/QM when compared with two CAD/CAM materials; Teilo CAD and VITA CAD-Temp after subjecting to 5000 thermocycles demonstrated difference in flexural strength with respect to the materials used. The Teilo CAD/CAM material had the highest flexural strength after thermocycling while VITA CAD-Tem showed the lowest flexural strength values. But when compared to the bis-acryl materials, the CAD/CAM interim materials were stronger after thermocycling[26]. Additional evidence was provided by Kadiyala KK et al[10] by comparing heat polymerised PMMA with that of Bis-GMA composite resin for the effect of thermocycling after 2500 cycles at temperature of 5°C to 55°C. the flexural strength for Bis-GMA composite resin was demonstrated to be 102.98 MPa while that of PMMA was 91.86 MPa. The study stated that Bis-GMA composite resins had greatest flexural strength followed by heat polymerised PMMA and lowest with light cure resins. Another study demonstrated with similar results with highest flexural strength consisting with Bis-Acryl materials like; Provipont, Integrity, Protemp 3 Garant, and Luxatemp over traditional methacrylate resins.

Moreover, when studies were conducted by reinforcing the CAD/CAM materials with resin-impregnated, light-polymerizing glass fibre (GrandTEC), the reinforcement did not show difference in fracture strength of CAD/CAM system and interim FDPs reinforced with glass fibre but presented with greater values compared to unreinforced interim FDPs[29]. In addition, CAD/CAM interim crowns presented with stable physical and mechanical properties so as to be used for long-term interim restorations[28]. The high flexural strength of CAD/CAM materials reported in the present study along with the supporting evidence from other studies attributes to its fabrication process. Because of the technique in which CAD/CAM based polymer materials are fabricated they possess decreased risk of porosities and voids leading to decrease in waster absorption during thermocycling thereby providing higher flexural strength[(28)].

SUMMARY

Provisional restorations form an integral part of fixed prosthodontics and implantology. These restorations must fulfill various requirements like pulpal protection, periodontal health, occlusal compatibility, maintaining tooth position, protection against fracture, resistance to functional loads, resistance to removal forces, maintaining inter-abutment alignment, be easily contourable, color stable, and have sufficient translucency. They are used for diagnostic purposes and for achieving optimum treatment outcome with permanent prosthesis.

Various materials and methods are used for fabrication of provisional restorations. The materials include- PMMA, PEMA, Bis-Acryl composite resins, etc.

The methods for fabrication include- heat polymerisation, auto polymerisation, CAD/CAM milling, 3D printing, etc. Improvements have been introduced owing to increase in their performance which include better strength, colour stability, marginal fit, etc. when it comes to the use of these restorations for an extended period of time, flexural strength plays a very important role.

Therefore this study aimed at testing the flexural strength of three provisional restorative materials fabricated by different methods and how they get affected by thermocycling. Heat polymerised PMMA (group A), Bis-Acryl composite resin (group B) and CAD/CAM milled PMMA (group C) were used in this study. 40 samples of each group were fabricated which were further subdivided in 2 groups i.e.- group A1,A2,B1,B2,C1,C2 of which A1 and A2 were fabricated from heat polymerised PMMA, b1 and B2 were Bis-Acryl composite resin and C1 and C2 were CAD/CAM milled PMMA.

Groups A1,B1 and C1 were subjected to load and flexural strength was assessed whereas groups A2,B2 and C2 were subjected to thermocycling and then tested for flexural strength.

The mean flexural strength obtained before thermocycling for groups A1,B1 and C1 were- 85.94MPa, 93.25MPa and 163.97MPa respectively and those for groups A2,B2 and C2 were- 70.89, 81.50 and 158.56 respectively. The data was analyzed statistically using ANOVA followed by Tukey’s post hoc test at a significance level of 5%.

Therefore from this study it can be inferred that flexural strength significantly decreased after thermocycling in all the three groups. At the same time, the flexural strength was observed to be least for A1 and A2 fabricated from heat polymerised PMMA and highest for CAD/CAM milled PMMA. This increased strength in the CAD/CAM milled PMMA can be owed to the prepolymerised discs which reduced the incorporation of porosities and other discrepancies. Thus, in patients requiring extended use of provisional restorations the used of CAD/CAM milled PMMA followed by Bis-Acryl composite resin should be advocated.

CONCLUSION

Within the limitations of this study following conclusions can be enlisted:

1. The values of flexural strength before and after thermocycling were found to be highest in the CAD/CAM milled groups (C1 AND C2) followed by Bis-Acryl composite resin and it was least in samples fabricated from Heat Polymerised PMMA.

2. Thermocycling led to significant deterioration of the properties especially flexural strength of all the three groups.

3. In order to consider temporization treatment for an extended period of time, the use of CAD/CAM milled PMMA followed by Bis-Acryl composite resin and heat cured PMMA should be advocated.

SCOPE FOR FURTHER STUDIES:

1. Fatigue testing of the materials under dynamic loads, using saliva or its substitutes.

2. Further research is required to evaluate other physical and mechanical properties like abrasion resistance, colour stability and thermal diffusivity.

3. Evaluation and comparison of flexural strength of reinforced heat polymerised PMMA with other provisional restorative materials.

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TABLES

Table no.1- Mean flexural strength in Heat cure PMMA group (MPa)

Thermocycling	N	Minimum	Maximum	Mean	Std. Deviation
Before Thermocycling	20	75.00	98.81	85.9415	6.65101
After Thermocycling	20	55.20	117.93	70.8970	16.41812

Table no.2- Mean flexural strength in Bis-Acryl Composite group (MPa)

Thermocycling	N	Minimum	Maximum	Mean	Std. Deviation
Before Thermocycling	20	78.00	128.81	93.2510	13.47465
After Thermocycling	20	58.31	110.43	81.5020	14.45032

Table no.3- Mean flexural strength in CAD/CAM PMMA group (MPa)

Thermocycling	N	Minimum	Maximum	Mean	Std. Deviation
Before Thermocycling	20	151.31	171.19	163.9765	5.56398
After Thermocycling	20	153.18	163.87	158.5680	2.97135

Table no.4- Difference in mean flexural strength before and after thermocycling in Heat polymerised PMMA group (MPa)

Thermocycling	Mean	Mean difference	t-value	Significance (p)
Before Thermocycling	85.9415	15.04450	4.110	**0.001***
After Thermocycling	70.8970			

**Significance at p<0.05*

A significant difference is present in flexural strength before and after thermocycling. The flexural strength is significantly less after thermocycling.

Table no.5- Difference in mean flexural strength before and after thermocycling in Bis-Acryl Composite group (MPa)

Thermocycling	Mean	Mean difference	t-value	Significance (p)
Before Thermocycling	93.2510	11.74900	2.508	**0.021***
After Thermocycling	81.5020			

**Significance at p<0.05*

A significant difference is present flexural strength before and after thermocycling. The flexural strength is significantly less after thermocycling.

Table no.6- Difference in mean flexural strength before and after thermocycling in CAD/CAM PMMA group (MPa)

Thermocycling	Mean	Mean difference	t-value	Significance (p)
Before Thermocycling	163.9765	5.40850	4.195	**<0.0001***
After Thermocycling	158.5680			

**Significance at p<0.05*

A significant difference is present in flexural strength before and after thermocycling. The flexural strength is significantly less after thermocycling.

Table no.7- Difference in the flexural strength between the groups after thermocycling (MPa)

Thermocycling	**Mean**	**F value**	**Significance (p)**
Heat Cure PMMA	70.8970	281.978	**<0.0001***
Bis Acryl Composite	81.5020		
CAD/CAM PMMA	158.5680		

**Significance at p<0.05*

A significant difference is present in flexural strength between the materials after thermocycling.

Table no.8- Post hoc Tukey test

Groups		**Mean Difference**	**Significance (p)**
Heat polymerised PMMA	Bis Acryl Composite	10.60500	**0.029***
	CAD/CAM PMMA	87.67100	**<.0001***
Bis Acryl Composite	Heat polymerised PPMA	10.60500	**0.029***
	CAD/CAM PMMA	77.06600	**<.0001***
CAD/CAM PMMA	Heat polymerised PMMA	87.67100	**<.0001***
	Bis Acryl Composite	77.06600	**<.0001***

**Significance at p<0.05*

A significant difference is present in flexural strength after thermocycling between-Heat polymerised PMMA- CAD/CAM PMMA

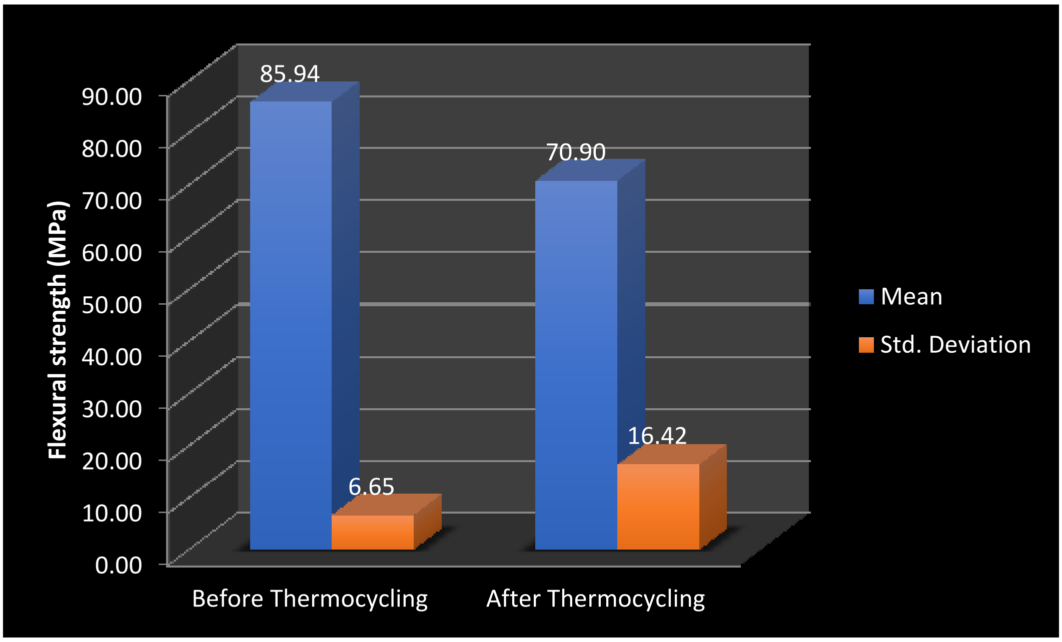
Heat polymerised PMMA- Bis Acryl Composite

Bis Acryl Composite -CAD/CAM PMMA

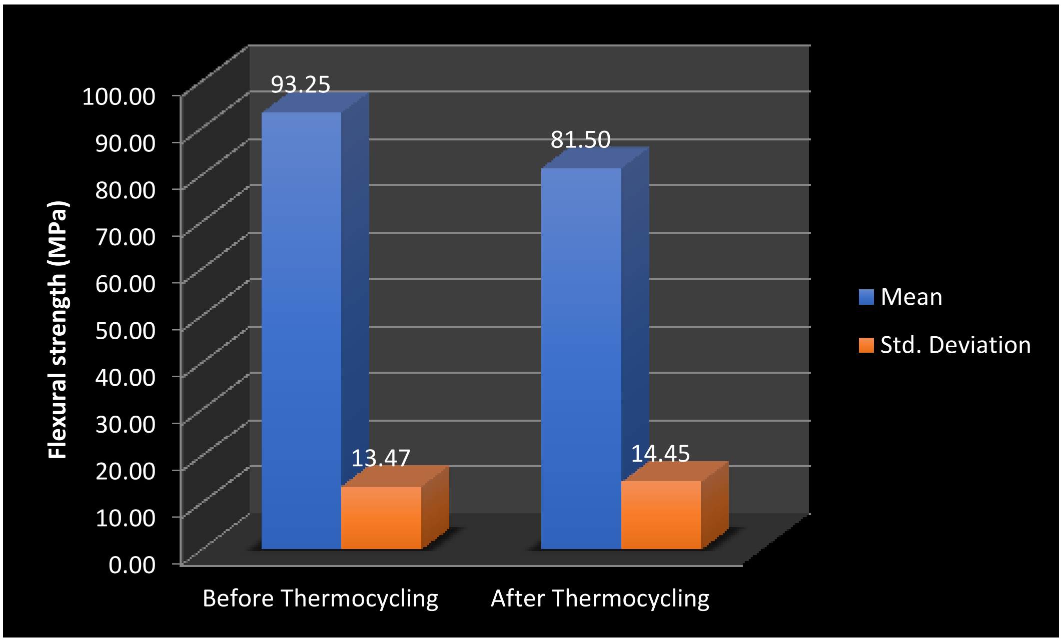
CAD/CAM > Bis Acryl Composite > Heat polymerised PMMA

GRAPHS

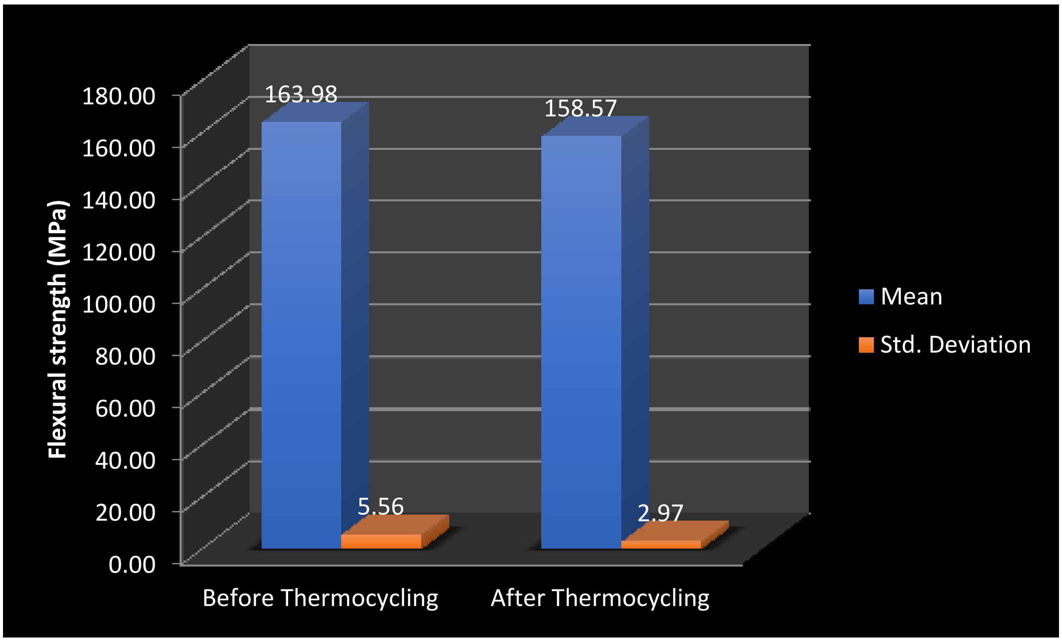
Graph no.1- Bar diagram representing flexural strength in Heat polymerised PMMA group before and after thermocycling



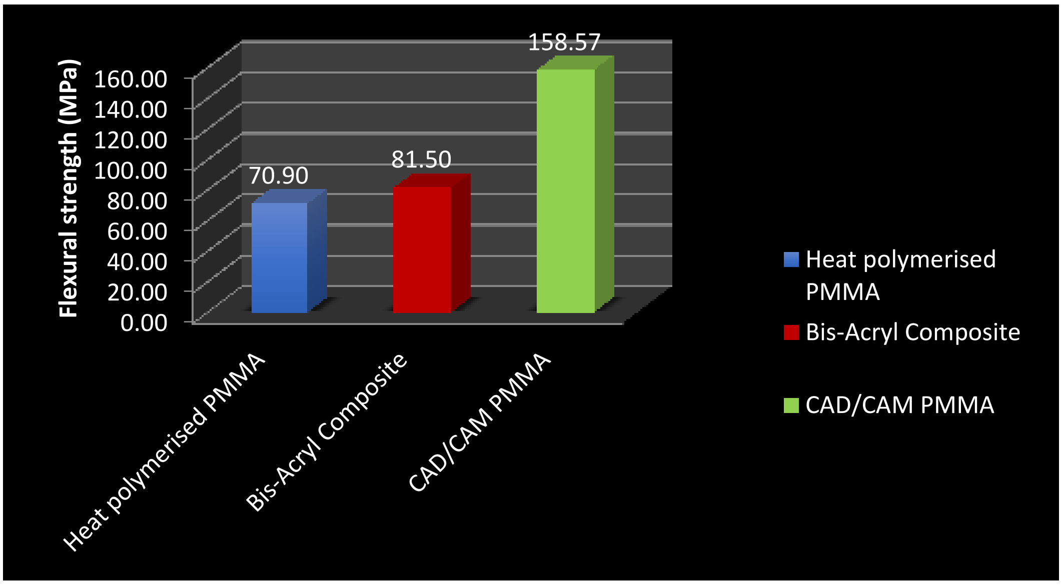
Graph no.2- Bar diagram representing flexural strength in Bis Acryl Composite group before and after thermocycling



Graph no.3- Bar diagram representing flexural strength in CAD/CAM PMMA group before and after thermocycling



Graph no.4- Flexural strength after thermocycling with all the three materials



ANNEXURE

MASTER CHARTS

1. Values of flexural strength of Group A (Heat polymerised PMMA) before and after thermocycling

Group : Heat Cured PMMA								
Before Thermocycling (A1)					**After Thermocycling (A2)**			
Sr. No.	Sample No.	Max. load (N)	Flexural Strength (MPa)		Sr. No.	Sample No.	Max. load (N)	Flexural Strength (MPa)
1	No.1	25.15	94.31		1	No.1	22.95	86.06
2	No.2	24.40	91.50		2	No.2	15.55	58.31
3	No.3	20.00	75.00		3	No.3	19.85	74.43
4	No.4	25.80	96.75		4	No.4	31.45	117.93
5	No.5	23.60	88.50		5	No.5	18.05	67.69
6	No.6	21.70	81.37		6	No.6	17.35	65.06
7	No.7	22.10	82.87		7	No.7	26.65	99.94
8	No.8	26.35	98.81		8	No.8	15.60	58.50
9	No.9	21.35	80.06		9	No.9	18.30	68.63
10	No.10	22.15	83.06		10	No.10	16.50	61.87
11.	No.11	22.3	83.3		11.	No.11	21.68	55.2
12.	No.12	24.28	76		12.	No.12	22.8	56.45
13.	No.13	23.42	92.18		13.	No.13	19.54	64.02
14.	No.14	24.2	84.3		14.	No.14	30.05	62.34
15.	No.15	25.3	87		15.	No.15	17.82	61.56
16.	No.16	23.46	93.42		16.	No.16	24.1	67.8
17.	No.17	23.31	83.42		17.	No.17	17.88	94.2
18.	No.18	22.52	82.00		18.	No.18	26.62	72.33
19.	No.19	23.2	80.56		19.	No.19	22.8	66.82
20.	No.20	21.33	84.42		20.	No.20	18.74	58.8
		Average	**85.94**				**Average**	**70.89**

2. Values of flexural strength of group B (Bis-Acryl composite resin) before and after thermocycling.

Group : BIS Acryl								
Before Thermocycling (B1)					**After Thermocycling (B2)**			
Sr. No.	Sample No.	Max. load (N)	Flexural Strength (MPa)		Sr. No.	Sample No.	Max. load (N)	Flexural Strength (MPa)
1	No.1	21.10	79.12		1	No.1	24.55	92.06
2	No.2	21.00	78.75		2	No.2	29.00	108.75
3	No.3	20.80	78.00		3	No.3	22.00	82.50
4	No.4	23.65	86.69		4	No.4	21.40	80.25
5	No.5	24.95	93.56		5	No.5	29.45	110.43
6	No.6	24.70	92.63		6	No.6	20.75	77.81
7	No.7	34.35	128.81		7	No.7	20.95	78.56
8	No.8	22.25	83.43		8	No.8	17.50	65.62
9	No.9	30.25	113.43		9	No.9	18.00	67.50
10	No.10	25.50	95.63		10	No.10	15.55	58.31
11.	No.11	20.2	83.32		11.	No.11	27	76.62
12.	No.12	22.1	78.8		12.	No.12	24.65	78.8
13.	No.13	33.42	83.3		13.	No.13	28.2	76.9
14.	No.14	24.6	94.3		14.	No.14	22.6	88.2
15.	No.15	22.2	110.4		15.	No.15	28.88	91
16.	No.16	20.62	86.6		16.	No.16	26.9	68.23
17.	No.17	30.4	93.68		17.	No.17	25.87	78.2
18.	No.18	24.8	98.2		18.	No.18	18.8	106.5
19.	No.19	31.3	106.5		19.	No.19	17.32	78.3
20.	No.20	27.3	99.87		20.	No.20	15.7	65.5
		Average	**93.25**				**Average**	**81.50**

3. Values of flexural strength of group C (CAD / CAM Milled PMMA) before and after thermocycling.

Group : CAD / CAM Milled PMMA								
Before Thermocycling (C1)					**After Thermocycling (C2)**			
Sr. No.	Sample No.	Max. load (N)	Flexural Strength (MPa)		Sr. No.	Sample No.	Max. load (N)	Flexural Strength (MPa)
1	No.1	42.65	159.94		1	No.1	42.50	159.37
2	No.2	44.90	168.38		2	No.2	41.80	156.75
3	No.3	43.00	161.25		3	No.3	43.10	161.62
4	No.4	44.75	167.81		4	No.4	41.95	157.31
5	No.5	45.50	170.25		5	No.5	43.35	162.56
6	No.6	44.45	166.69		6	No.6	42.45	159.19
7	No.7	45.65	171.19		7	No.7	41.30	154.87
8	No.8	44.00	165.00		8	No.8	43.70	163.87
9	No.9	40.35	151.31		9	No.9	42.35	158.81
10	No.10	43.10	161.63		10	No.10	40.85	153.18
11.	No.11	44	161.6		11.	No.11	43	155.6
12.	No.12	43.8	168.9		12.	No.12	41.1	161.2
13.	No.13	45.6	157		13.	No.13	42.76	158.88
14.	No.14	46	155.87		14.	No.14	41.34	153.63
15.	No.15	42.7	170		15.	No.15	43.65	161.22
16.	No.16	44.85	164.68		16.	No.16	41.45	159.9
17.	No.17	45	157.3		17.	No.17	40	160
18.	No.18	44.62	167.87		18.	No.18	41.37	158.9
19.	No.19	43	164		19.	No.19	42.8	154.9
20.	No.20	42.4	168.86		20.	No.20	41.9	159.6
		Average	**163.97**				**Average**	**158.56**