EFFECT OF AGING AND THERMOCYCLING ON FLEXURAL STRENGTH OF POLY ETHER ETHER KETONE (PEEK) AS A PROVISIONAL RESTORATION FOR FULL MOUTH REHABILITATION- AN INVITRO COMPARATIVE STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the degree of

MASTER OF DENTAL SURGERY

BRANCH – I

PROSTHODONTICS AND CROWN AND BRIDGE

MAY -2019

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI – 600032

2016 – 2019

CERTIFICATE - I

This is to certify that the dissertation titled **"EFFECT OF AGING AND THERMOCYCLING ON FLEXURAL STRENGTH OF POLY ETHER ETHER KETONE (PEEK) AS A PROVISIONAL RESTORATION FOR FULL MOUTH REHABILITATION- AN INVITRO COMPARATIVE STUDY"** is a bonafide work done by **Dr. J.DHIVYA PRIYA**, Postgraduate student, during the course of the study for the degree of "Master of Dental Surgery" in Department of **PROSTHODONTICS AND CROWN & BRIDGE**, CSI College of Dental Sciences and Research, Madurai during the period of 2016-2019, under our supervision and guidance.

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ETHICAL COMMITTEE

Title of the work : Effect of Aging and Thermocycling on flexural strength of PEEK as a provisional restoration for full mouth rehabilitation: An in-vitro study

Principal investigator: Dr.J. Dhivya Priya (PG Student) **CSICDSR/IEC/27-1C/2016**

Department: Department of Prosthodontics

The request for an approval from the Institutional Ethical Committee (IEC) for the above mentioned study, submitted by the Principal investigator is considered in the IEC meeting held on 08.09.2016 at CSI College of Dental Sciences and Research, Madurai. The members of the committee are unanimously pleased to approve the proposed work mentioned above and is '**Advised to proceed with the study**'

The Principal investigator and their team are directed to adhere the guidelines given below:

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DECLARATION BY THE CANDIDATE

TITLE OF DISSERTATION	EFFECT OF AGING AND THERMOCYCLING ON FLEXURAL STRENGTH OF POLY ETHER ETHER KETONE (PEEK) AS A PROVISIONAL RESTORATION FOR FULL MOUTH REHABILITATION- AN INVITRO COMPARATIVE STUDY.
PLACE OF STUDY	CSI COLLEGE OF DENTAL SCIENCES AND RESEARCH
DURATION OF COURSE	3 YEARS
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I hereby declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Principal, CSI College of Dental Sciences and Research, Madurai. In addition, I declare that no part of this work will be published either in print or electronic without the guide who has been actively involved in this dissertation. The author has the rights reserved for publishing the work solely with prior permission of the Principal, CSI College of Dental Sciences and Research, Madurai**.**

Head of the Department **Guide** **Signature of the candidate**

CERTIFICATE – II

PLAGIARISM CERTIFICATE

This is to certify that this dissertation work titled **" EFFECT OF AGING AND THERMOCYCLING ON FLEXURAL STRENGTH OF POLY ETHER ETHER KETONE (PEEK) AS A PROVISIONAL RESTORATION FOR FULL MOUTH REHABILITATION- AN INVITRO COMPARATIVE STUDY "** of the candidate **Dr. J.DHIVYA PRIYA** for the award of **MASTER OF DENTAL SURGERY** in the **BRANCH I – PROSTHODONTICS AND CROWN AND BRIDGE**.

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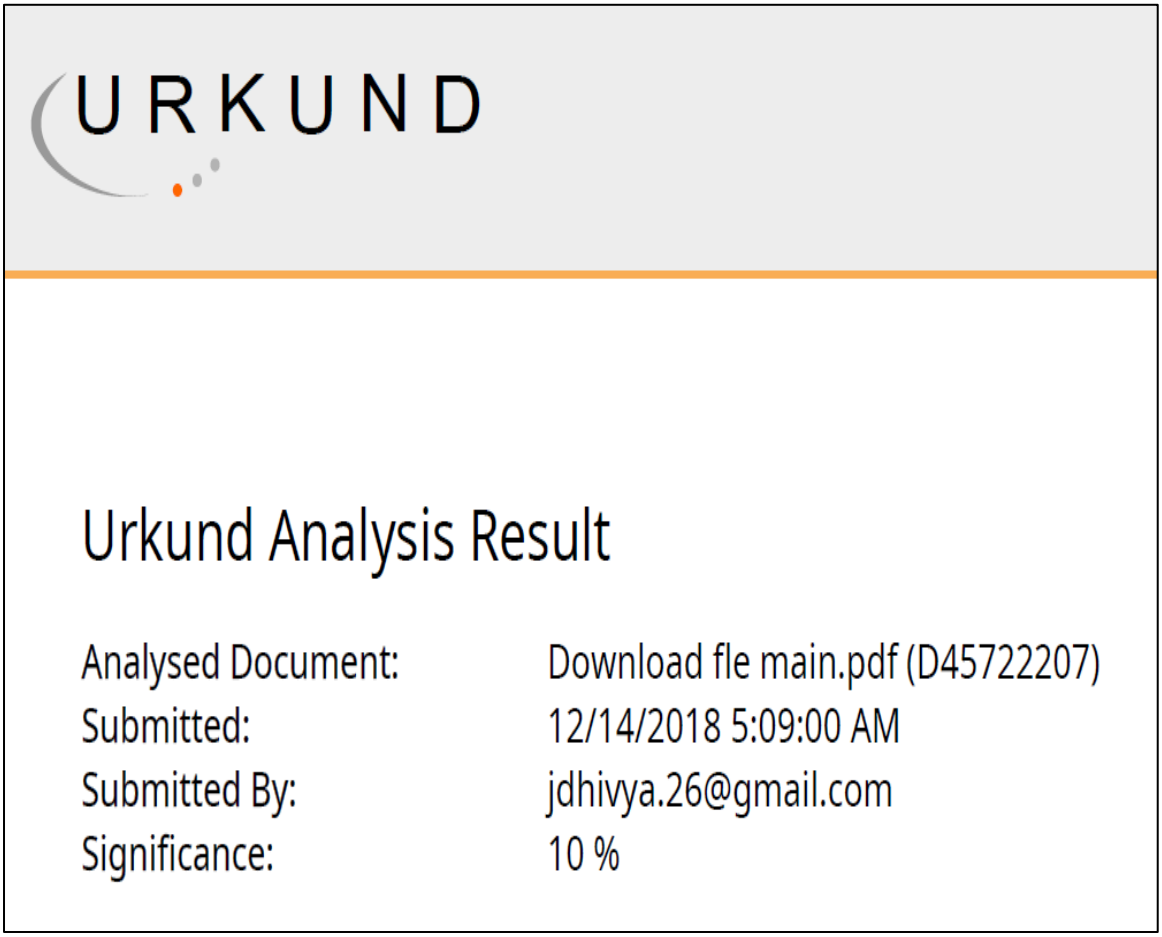
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Finally I bow in reverence before Almighty for answering my prayers and making me what I am today and for all the grace endowed upon me.

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Introduction

INTRODUCTION

Fixed prosthodontic restorative treatment involves the partial or complete coverage of the natural teeth or the implant abutment which mostly depends on the indirect fabrication of the definitive prosthesis in the dental laboratory[10,47] . The prepared tooth has to be protected from the oral environment and its relationship with the opposing and the adjacent tooth needs to be preserved, prior to the fabrication of the final prosthesis. In order to protect the prepared abutment teeth, temporary restorations are fabricated. They are also known as 'treatment restorations', 'interim restorations' ,'provisional restorations' or 'transitional restorations'[28,30]. The process of fabrication is called as 'Temporization'[28,30].The ideal requirements of the provisional restoration includes aesthetics, comfort, speech and function, maintenance of periodontal health, occlusal stability, and continued evaluation of the fixed prosthodontic treatment plan.

The provisional restorations, apart from the functional, immediate protective and stabilizing value, are useful for diagnostic purposes where the aesthetic, functional and occlusal parameters are developed to identify an optimum treatment outcome before the completion of the definitive/final prosthesis [10].When selecting the provisional restoration it should fulfill the biologic, aesthetic and mechanical requirements. Significant properties of provisional/interim restoration includes its rigidity, repairability, strength of the material, exothermic reaction following polymerization and subsequent polymerization shrinkage, marginal integrity, protection of the pulp, and colour stability [41,47]. There is no single provisional/interim material that meets the optimal requirements for all the situations. But, there are materials that have been successfully used to meet the purposes. The materials

commonly used are poly methyl methacrylate resins (PMMA), Poly ethyl methacrylate resins (PEMA),vinyl ethyl methacrylate resins, butyl methacrylate, epimine resins, preformed matrices of plastic and cellulose shells, polycarbonate materials, bis-acryl composites, bis-GMA composites, Urethane Di methacrylate resin (UDMA) [52] .

The provisional prostheses may be short-term (until fabrication of the definitive restoration) or Long- term (when a patient requires a longer course of treatment, such as in complete/full mouth prosthodontic treatments) [39]. Long-term interim restorations require materials that have mechanical properties that ensure adequate fracture strength and colour stability and sufficient dimensional stability and marginal stability[39] .

The most commonly used materials for custom interim restoration are acrylic resins. Poly methyl methacrylate (PMMA) resins were introduced in 1936 as a heat processed thermosetting material. It was available as room temperature polymerizing methacrylate in the early 1940's. Later it was improved for the field of dentistry as a self-curing prosthetic and restorative resin[6]. The acrylic based resins is mainly composed of polymeric materials based on PMMA. These materials are a result of chemical initiation of a free radical polymerization reaction. The poly methyl methacrylate (PMMA) resins are relatively inexpensive with ease of handling, excellent polish and good marginal adaptation. The major disadvantage of these materials is the exothermic reaction, polymerization shrinkage ,low wear resistance, low strength and poor colour stability and pulpal irritation as a result of excess free monomers [32,39,41,47] . Poly R' methacrylates in comparison to PMMA resins , have low polymerisation shrinkage and low exothermic reaction. However these materials have a limitations in clinical use such as low strength, low wear resistance and low colour stability [32]. Bis - acryl composites were introduced to

overcome the disadvantages / negatives of the methacrylates. These materials are available as preloaded syringes or cartridges and mixed through an auto mixing tip which provides consistent mixture with no air contamination into the final mix [35,47].Bis – acryl composite materials are composed of bi-functional substrates which provides a cross linkage with one another and form monomer chain cross linkage which leads to the increase in impact strength and toughness [21,47]. Inorganic fillers are also present to increase the abrasion resistance of the bis – acryl composites. They also have low polymerization shrinkage, low exothermic reaction, reduced tissue toxicity, good wear resistance and strength. However, these materials are costly, brittle, and have less polishable and are difficult to repair [32,41,47,51]. Most commonly used luting cement used for the provisional restoration is Zinc oxide eugenol cement. Zinc oxide eugenol cement is weak which allows easy removal, thus enables the reuse of the provisional restoration. Zinc oxide eugenol cements in addition to its acceptable sealing properties also has an obtundent effect on the pulpal tissue. But the free eugenol acts as a plasticizer of methacrylate resins which has been shown to reduce surface hardness and strength. New resin material applied over the polymerized resin previously in contact with free eugenol results in softening of the resin added, making linings or repairs unsuccessful. The Poly R' methacrylate resins are affected severely by free eugenol whereas Poly methyl methacrylate (PMMA) resins are affected moderately, and the bis-acryl composites are only slightly softened [43].

In 1980, the computer aided design and computer aided manufacturing (CAD/CAM) system was developed. This system reduced the chairside fabrication time and simplified the technique. Both the interim and definitive restorations are fabricated using the CAD /CAM system. The CAD /CAM system prevents porosities , hence the

CAD/CAM restorations have increased mechanical strength and thereby improves clinical outcome [31,39]. This system allows the milling of 3D - designed objects from bulk material and the technique is reported to provide high precision [41]. CAD/CAM Provisional restorations are made from pre-processed Poly methyl metharcylate (PMMA) based acrylic resin blocks and they possess better colour stability and more precise marginal quality than the conventionally processed resin [4,31,41,55].

In recent times Poly-ether-ether-ketone (PEEK) has been used in various purposes in medical field .PEEK is a sulfonated aromatic high- temperature thermoplastic material which has been used in the field of orthopaedic surgeries since 1980's as a replacement of titanium and cobalt- chromium alloys ,most notably for artificial hip joints or spinal cages. In 1992 ,PEEK was introduced in the field of dentistry. PEEK material has now been used increasingly in prosthetic dentistry. It combines excellent mechanical properties with a high level of biological compatibility. In particular almost non-existence material fatigue, the bone- like elasticity, the lack of metal, plaque resistance and the low specific weight ensure that this material has found its place in the field of prosthetic dentistry. The material is supplied as industrially -manufactured milling blanks for CAD/CAM – supported processing [49,53,56,64,65] .PEEK is used as a removable partial denture framework, implant material, metal- and ceramic-free crowns and bridges. Due to its tooth like white colour it provides appropriate aesthetics. PEEK is an excellent biomaterial for short-term applications, like temporary abutments and healing caps [13,17,20,34,46].

One among the important aspects of provisional restorations, especially in case of long-span provisional/interim prosthesis is the flexural strength [43].The material of choice for the long-term and long-span interim prosthesis was Cast metal restorations [30].Flexural

strength of the provisional prosthesis plays a critical role in case of full mouth rehabilitation cases, long span FPD's, TMJ dysfunction therapies and in patients with para-functional habits, bruxism or clenching. It is difficult for both the patients and clinician to keep the interim restoration intact. Any probable breakage of the restoration might lead to tooth movement as well as aesthetic and functional problems. Additionally the repair procedure may be time consuming [32,35]. The flexural strength of the provisional restoration is greatly tested during mastication. Flexural strength should be considered as an important component in determining the ability of a material to prevent fracture. Long span fixed provisional/interim restoration functions as a beam , greater the length of the edentulous area being spanned with pontic, greater is the flexure of the restoration. Hence, understanding of the mechanical properties of the provisional/interim restoration materials is important in determining whether the provisional/interim restoration will be able to survive the repeated functional forces in the oral environment [27,35].

Evaluation of the flexural strength of the provisional restorations immediately after the polymerization, evaluates the failure of the material without aging of the material there by limiting the ability to determine the clinical behaviour of the material. Aging of the material through the process of conditioning and thermocycling causes material fatigue and fastens/hastens up the deterioration of the material [15].

In light of the above considerations, the purpose of the present in- vitro study is to compare and evaluate the flexural strength of Autopolymerizing PMMA resin, CAD/CAM milled PMMA and CAD/CAM milled PEEK after being subjected to aging and thermocycling.

The objectives of the present study included the following:

1. To evaluate the effect of aging and thermocycling for 7 days and 500 cycles respectively on the flexural strength of Autopolymerizing PMMA resin (Group I (a)).
2. To evaluate the effect of aging and thermocycling for 14 days and 1000 cycles respectively on the flexural strength of Autopolymerizing PMMA resin (Group I (b)).
3. To evaluate the effect of aging and thermocycling for 7 days and 500 cycles respectively on the flexural strength of CAD/CAM milled PMMA (Group II (a)).
4. To evaluate the effect of aging and thermocycling for 14 days and 1000 cycles respectively on the flexural strength of CAD/CAM milled PMMA (Group II (b)).
5. To evaluate the effect of aging and thermocycling for 7 days and 500 cycles respectively on the flexural strength of PEEK (Group III (a)).
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17. To compare the mean flexural strength after aging and thermocycling for 7 days and 500 cycles with 14 days and 1000 cycles of PEEK (Group III (a) and Group III (b)).

Review of literature

REVIEW OF LITERATURE

Stober EJ et al (1984)[56],conducted a study to evaluate the sorption and desorption behaviour in fluids of Polyetheretherketone (PEEK) films of different crystallinity. Water, methyl chloride and skydrol were used as fluid environment used at two temperatures and the weight gain was recorded. Density, thermomechanical, and dynamic mechanical measurements were made before and after the fluid exposure of the film. The results confirmed the solvent resistance of PEEK .But, the exposure to methyl chloride produced the two significant effects : additional crystallization and plasticization.

Osman YI et al (1993)[36], tested flexural strength of five autopolymerizing provisional resin materials stored at room temperature for 24 hours and then incubated in normal saline at 37^{O}C for atleast 24 hours. The results concluded the fracture resistance in decreasing order as follows : poly(methyl methacrylate) resin , Caulk temporary bridge resin and G-C Unifast temporary resin; Protemp, the composite material ; and Scutan, the epimine material.

Vallittu PK (1998)[60], conducted a study to determine the load required to fracture a three-unit provisional fixed partial denture restoration, which had been reinforced with an experimental glass fibre reinforcement. The results concluded that, even though the glass fiber reinforcements were positioned on the least favourable side of the fixed partial denture in terms of the physical properties of the materials. The fracture resistance of the provisional/interim fixed partial denture considerably increased with these reinforcements.

Kawano F et al (2001)[24], evaluated the effect of thermocycling in water on the flexural strength and hardness of various laboratory composite systems. The results revealed that the flexural strength of the laboratory processed composite resins (Artglass ,Targis, and Estenia) was significantly higher than that of conventional resins(Dentacolor and Cesead II) and flexural strength reduced on thermocycling but not a reduction of the hardness for most of the materials.

Haselton DR et al (2002)[21], compared the flexural strength of 5 methacrylate -based resins and 8 bis-acryl resins used for the fabrication of the provisional crowns and fixed partial dentures after being immersed in artificial saliva at 37º C for 10 days. The results showed that the highest flexural strength in the group consisted of bis-acryl materials (Provipont, Integrity, Protemp 3 Garant, and Luxatemp).

Scherrer SS et al (2003)[45], compared the flexural strength and the resistance to fatigue loading of composites (Artglass, Columbus, and Targis) and an acrylic resin for provisional restorations (Jet, Protemp Garant, and Provipont DC). Fatigue tests were conducted with rotating -bending cantilever design and Monotonic flexural strength was determined in 3-point bending tests. They concluded that the correlations between monotonic flexure strength and resistance to fatigue loading were weak. Since the fatigue tests are considered more pertinent than monotonic tests as to their predictive value, the flexural strength data alone may not provide relevant information for long-term clinical performance.

Balkenhol M et al (2007)[7], compared the flexural strength and flexural modulus of four provisional crown and bridge materials (Trim , Luxatemp AM Plus Solar and Cool Temp Natural) by testing in a 3-point bending test at various times after mixing

(dual-curing vs self-curing) (37º C dry/water) including thermocycling (5000 cycles, 5-55º C).Flexural strength and flexural modulus significantly depended on the time after mixing of the provisional materials and are dependent on the chemical nature as well as the curing mechanism of the provisional material used.

Balkenhol M et al (2007)[8], compared the flexural strength and flexural modulus of four di-methacrylate based provisional crown and bridge materials were tested in a 3-point bending test at various storage times after mixing (37º C dry/water) including thermocycling (5000 cycles, 5-55º C). Flexural strength and flexural modulus of temporary crown and bridge materials significantly depended on the time after mixing i.e. the mechanical stability of the provisional crowns is comparably low in the first hours after its fabrication.

Nejatidanesh F et al (2008)[35], compared the flexural strength of seven interim resins (Trim, Acropars, Protemp 3 Garant, Unifast LC, TempSpan, Tempron, Duralay) after storing in artificial saliva for 14 days and thermocycling for 2500 cycles (5º to 55º C). They concluded bis-acryl interim materials had higher flexural strength than the methacrylate resins.

Alt V et al (2010)[4], conducted a study aiming to investigate the influence of fabrication method, storage condition and materials on the fracture strength of temporary 3- unit fixed partial dentures. 3 unit temporary fixed partial dentures where fabricated either by milling from pre-fabricated blanks (Trim, Luxatemp AM plus , Cercon Base PMMA) or by direct fabrication (Trim, Luxa Temp) and subjected either to water storage at 37º C for 24 hours and 3 months, respectively, or thermocycled. Maximum force at fracture (Fmax) determined with a 3- point bending test at 200 mm/min. Temporary FPD's

fabricated using CAD/CAM showed a significant higher Fmax compared to the directly fabricated bridges ($p< 0.05$).

Patras M et al (2011)[38], illustrated the management of provisional restorations deficiencies in which they highlighted the possible failures of custom- fabricated provisional restorations and described the methods to prevent their occurrence and the clinical techniques for their management.

Regish K et al (2011)[42],reviewed the various techniques for the fabrication of interim/ provisional restorations that are available to suit the specific needs of the clinician and of the particular clinical situation, from a single unit to a complete- arch interim/ provisional fixed prostheses.

Al Twal EQH et al (2012)[3], conducted an in vitro study to determine the three point flexural strength and flexural fatigue characteristics of a chairside temporary crown and bridge material (Pro temp 4) and a laboratory resin composite (Ceramage) in both reinforced and unreinforced states. The reinforcement was provided by Everstick crown and bridge and Ribbond THM materials. The testing was done following one week of storage in distilled water at 37º C using universal testing machine. The results concluded fibre reinforcement with Everstick C&B significantly ($p< 0.001$) increased flexural strength of both materials. The fibre incorporation significantly ($p<0.001$) increased the flexural fatigue limits of both Protemp 4 and Ceramage.

Kamble VD et al (2012)[23], compared the flexural strength of polymethyl methacrylate (PMMA) and bis-acryl composite resin reinforced with polyethylene and glass fibres. The results revealed of the two fibre reinforcement methods, glass reinforcement for PMMA resin and bis-acryl composite resin materials had the highest

flexural strength.

Stawarczyk B et al (2012)[55], tested the fracture load of fixed partial dentures fabricated from four CAD/CAM milled resins (artBlock Temp, Telio CAD, ZENO PMMA and CAD-Temp) , two conventionally fabricated resins (Integral esthetic press and CronMix K) and a glass ceramic (IMAGINE PressX) after storing in artificial saliva at 37º C and subjecting to chewing stimulation (120.000-1.200.000, 49N,5º C/50º C). The results showed that aging did not influence the fracture load of FPDs made of CAD/CAM resins whereas FPDs made of glass ceramic showed significantly lower fracture load than those of all resin FPDs.

Gujjari AK et al (2013)[19], conducted an in vitro study to evaluate the color stability and flexural strength of polymethyl methacrylate (PMMA) and bis-acrylic composite based provisional crown and bridge auto polymerizing resins exposed to artificial saliva, tea, coffee, cola, and food dye and stored in an incubator at 37º C. The study revealed that PMMA was more color stable than bis-acrylic composite based resin and the Flexural strength of bisacryl was significantly higher than that of PMMA after immersing in all the solutions.

Kerby RE et al (2013)[26], evaluated the flexural strength , flexural modulus, work of fracture and weibull parameters of 4 bis -acryl(Protemp Plus, Integrity, Turbo Temp 2, Temphase Fast-set) and 2 urethane (Nuform and Tuff-Temp) provisional resins after being stored in distilled water for 1 hour and 24 hours at 37º C using universal testing machine. They concluded Post gelation polymerization plays an important role in increasing the flexural strength and the rigidity of the bis-acryl and, to a lesser extent urethane resins between 1 to 24 hours.

Poonacha V et al (2013)[40], evaluated and compared the flexural strength and elastic modulii of three provisional/interim materials (methyl methacrylate based autopolymerized resin , bis-acryl composite based autopolymerized resin and urethane dimethacrylate based light polymerized resin) after storing in artificial saliva for one hour at room temperature and testing at intervals of 24 hours and 7 days. The results concluded that methacrylate based autopolymerizing resin had the highest flexural strength and elastic moduli and the bis-acrylic composite resin had the least flexural strength.

Sharma S et al (2013)[50], conducted an in vitro evaluation of the flexural strength of provisional restorative materials fabricated using light polymerized composite resin, Urethane dimethacrylate (UDMA) and autopolymerized resin, Poly methyl methacrylate (PMMA) after storing in artificial saliva for 10 days. The study concluded that the flexural strength of poly methyl methacrylate (134.1 Mpa) was significantly higher than the urethane dimethacrylate (107.8 Mpa).

Singla M et al (2014)[48], reviewed the various aspects associated with the provisional restorations used in fixed prosthodontics such as available materials and the techniques used to reline, modify , or repair the provisional restorations.

Yanikoglu N et al (2014)[62], conducted an in-vitro study to evaluate the effects of different solutions (coffee, burn-energy drink, cola) and distilled water (control group) on the flexural strength of one methacrylate-based resin (Takilon) and three bis-acryl resin (Protemp 4, Structur 2SC and Access Crown) provisional materials after storing for 14 days at 37^0 C. A standard three-point bending test was conducted on the specimens with an Instron universal testing machine at a crosshead speed of 0.5mm/min. They concluded , methacrylate -based resin (Takilon) showed least fracture strength (61.6-85.6 MPa) and

Protemp 4 showed the highest fracture strength (112-128 MPa) and the different solutions have no statistically significant effect on the flexural strength values on the four provisional materials.

Yao J et al (2014)[61], conducted a study to compare the flexural strength and marginal accuracy of two traditional bis acryl composite interim materials (Protemp 4 and Structur 2 SC/QM) and two CAD/CAM interim materials (Telio CAD and VITA CAD-Temp) before and after thermocycling (5000 cycles, 5^0 C and 55^0 C).Flexural strength evaluated using the three-point loading universal testing machine and marginal discrepancy measured under a stereomicroscope. They concluded the CAD/CAM interim materials were stronger and had better marginal accuracy properties than bis-acryl materials especially after thermocycling.

Uhrenbacher J et al (2014)[59], conducted a study to evaluate the retention strength of Polyetheretherketone crowns after different surface modifications. Conditioning was done as : airborne-particle abrasion, sulfuric etching, piranha etching, and no conditioning. The groups were divided in adhesive systems : Signum PEEK Bond, Ambarino P60, visio.link, and no adhesive and luted to dentin abutments. After water storage for 60 days and thermocycling (5000 cycles, 5^0 C and 55^0 C), and the retention strength was evaluated with a pull-off test. The results concluded that the adhesion of the tested PEEK crowns to dentin was satisfactory after treatment with airborne-particles abrasion or etching with sulfuric acid and/ or when additional adhesive systems like visio.link or Signum PEEK Bond were used.

Thompson GA and Luo Q (2014)[57] , conducted a study to evaluate the effect of thermal treatment, surface sealing, thermocycling ,storage media, storage temperature,

and age on autopolmerizing poly(methylmethacrylate) (Jet Acrylic) and two bis acryl composite (Protemp 3 Grant and Integrity) interim restorative materials on the flexural strength, Vickers microhardness, and impact strength. The results showed all experimental treatments had significant effects on flexural strength, with material and thermocycling being dominant and had overall impact on the Vickers microhardness with material and Palaseal glaze showing large effects. The material used and the age had a significant effect on impact strength of the materials.

Gracia-Gonzalez D et al (2015)[17], compared the mechanical impact behaviour of PEEK with Ti6Al4V titanium alloy through a combination of experiments and finite element simulations. They concluded PEEK appeared to be an attractive material as a matrix for impact applications and for implants.

Karaokutan I et al (2015)[25], evaluated the effect the fabrication method and material type on the fracture strength of the provisional crowns subjected to water storage at 37ºC for 24 hours and then thermocycled (5000 cycles, 5- 55º C).The maximum force at fracture was measured with a universal testing machine at 1mm/min. The findings concluded that PMMA based CAD/CAM fabricated provisional crown showed higher fracture strength than the directly fabricated crowns.

Liebermann A et al (2015)[29], assessed the effects of different aging regimens/durations on the roughness, solubility, water absorption, martens hardness and indentation modulus on different CAD/CAM polymers. The results revealed that storage media had no effect on surface roughness and water absorption. The hardness parameters of PEEK were comparable with those of PMMA- based resin materials.

Rayyan MM et al (2015)[41], conducted an in vitro study to compare the color stability, water sorption, wear resistance, surface hardness, fracture resistance, and microleakage of computer-aided design/ computer-aided manufacturing (CAD/CAM) fabricated interim/provisional restorations with those interim/provisional restorations which were manually fabricated. The results revealed CAD/CAM interim restorations had stable physical and mechanical properties and hence can be used for long- term interim restorations.

Najeeb S et al(2015)[34] ,reviewed the applications of Polyether ether Ketone (PEEK) in many areas of dentistry such as in oral implantology (Implant material and Implant abutments) and prosthodontics namely as removable prosthesis material, crown, CAD/CAM milled fixed partial dentures.

Penate L et al (2015)[39] , compared the marginal fit and fracture strengths of the interim fixed partial dentures fabricated by using a direct technique with different materials (Structur 3, Trim, DuraLay) with interim prostheses (Telio CAD) made with a computer-aided design and computer manufacturing (CAD/CAM) system stored at 37ºC for 24 hours before thermocycling. They concluded that bis-acryl reinforced with glass fiber showed the least marginal discrepancy and no difference differences were found between fracture strengths of interim FPD's fabricated with CAD/CAM system and interim FPD's reinforced with glass fiber. But unreinforced interim FPD's showed the lowest fracture strength.

Schwitalla AD (2015)[46], tested eleven different Polyether ether ketone (PEEK) compounds were tested via a three- point bending test using universal testing machine after dry storage and after placing in incubator at 37º C in Ringer solution for 1 day,7 days, 28

days and 84 days. The results showed PEEK compounds involved in the study exhibited high flexural strength values.

Abdullah AO et al (2016)[1] , compared the marginal gap, internal fit , fracture strength and mode of fracture of CAD/ CAM provisional crowns namely VITA CAD-Temp, PEEK, Telio CAD-Temp with that of direct provisional crowns (Pro temp 4). They concluded CAD/CAM fabricated provisional crowns demonstrated superior fit and better strength than direct provisional crowns.

Digholkar S et al (2016)[14], evaluated and compared the flexural strength and microhardness of the provisional materials fabricated using

(1) 3 dimensional printed light-cured micro-hybrid filled composite by Rapid prototyping resin group ,

(2) a milled polymethyl methacrylate using CAD-CAM and

(3) a conventionally fabricated heat activated polymerized polymethyl methacrylate resin group.

The study concluded that the CAD-CAM based polymethyl methacrylate had the highest flexural strength but rapid prototyping based 3D printed whereas the light cured micro-hybrid filled composite had the highest microhardness compared to the others.

Tom NT et al (2016)[58], reviewed the various techniques and materials available for fabricating a provisional restorations . They concluded Bis-acryl resin is most commonly used for provisional restorations, but for restorations of three units or more, assistant-made PMMA shells lined intraorally with PEMA to provide more strength and color stability. In cases involving more than 5 unit bridges and full mouth rehabilitation cases heat polymerizing PMMA is the material of choice and Autopolymerizing PMMA or

Protemp II can be used for anterior region.

Kadiyala KK et al (2016)[27], evaluated the flexural strength of different provisional restorative resins used for prosthetic rehabilitation namely autopolymerizing polymethyl methacrylate (PMMA), heat activated PMMA, autopolymerizing Bis- GMA composite resin and light activated urethane Dimethacrylate resin (UDMA) stored in artificial saliva for 14 days and subjected to thermocycling (2500 cycles, 5-55º C) using universal testing. The results showed the greatest flexural strength was observed in Bis-GMA composite resins followed by heat cure methacrylate resins, autopolymerizing methacrylate resins and light cure resins.

Mehrpour H et al (2016)[32],compared the flexural strength of five provisional restorative materials (TempSpan, ProTemp 4, Unifast III,Trim and Revotek LC) stored in artificial saliva for 2 weeks and then thermocycled (2500 cycles, 5-55º C).The results showed Bis-acryl resins were statistically superior to traditional methacrylate and light-cured resins.

Mehrpour et al (2016)[33], evaluated the effect of three different mouthwashes namely Listerine, Oral B and Chlorhexidine ,on the flexural strength of five interim/provisional restorative materials (TempSpan, Protemp 4,Unifast III and Revotek LC) stored for 14 days at 37º C. The results showed both the bis-acryl resin composite materials had higher flexural strength than the methacrylate and light cured resins after 14 days storages. Bis-acryl resins (TempSpan) showed the highest flexural strength and light polymerized resin (Revotek LC) had the least flexural strength.

Singh A et al (2016)[47], conducted an in vitro study to evaluate and compare the flexural strength of three polymethyl methacrylate based materials (DPI, SC10 and

Truion) and three bis-acrylic based composite resins (Protemp, Cooltemp and Luxatemp) after storing in artificial saliva and tested after 24 hours and 8 days and testing in the universal testing machine. The results of the study revealed that the flexural strength decreased for all the provisional materials tested from 24 hours to 8 days ,though flexural strength between polymethyl methacrylate and bis-acrylic resins were almost identical at 24 hours and 8 days interval of time.

Zoidis et al (2016)[65], used a polyetheretherketone (PEEK) (BioHPP) framework veneered composite rein as an alternative material for the fabrication of an interim three pontic resin -bonded fixed dental prosthesis after the implant placement. They concluded that the low modulus of elasticity (4 GPa) of PEEK material combined with the use of indirect light-polymerized resin as a veneering material used for a resin -bonded fixed dental prosthesis provided an advantage over metal ceramics or ceramics in dampening the occlusal forces and reducing debonding rates and also further long-term clinical evidence is required before recommending the application as a substitute material.

Pascutti FPN et al (2017)[37],evaluated the flexural strength of CAD/CAM milled resins namely resin PMMA block, resin bis-acryl and resin heat polymerized after thermocycling and tested using universal testing machine. The results showed the resin CAD/CAM VIPI PMMA blocks had the highest flexural strength followed by resin acrylic heat polymerized VIPI which was superior to resin bis-acrylic Protemp [4].

Shafter M et al (2017)[51], investigated the impact of thermocycling (5000cycles, 5 and 55^{o} C) on the flexural strength of the various chairside CAD/CAM restorative materials namely Telio CAD, VITA CAD-Temp, 3M^{TM} ESPE^{TM} Lava^{TM} Ultimate restorative and CERASMART, lithium disilicate ceramic (e-max CAD) and

composite resin (Paradigm MZ100). One group of each material was subjected to thermocycling and the other group was not subjected to the thermocycling and tested for flexural strength with universal testing machine. The results concluded that there was significant differences in the mean flexural strength of the tested materials and thermocycling treatment had no significant difference impact on the flexural strength compared to water soaking ($p = 0.11$).

Materials & Methods

MATERIALS AND METHODS

The present in-vitro study was conducted to compare and evaluate the flexural strength of Autopolymerizing PMMA resin , CAD/CAM milled PMMA and CAD/CAM milled PEEK after being subjected to aging and thermocycling.

The following materials and equipment's were used for the study:

MATERIALS EMPLOYED:

- Petroleum Jelly (PRS Pharmaceuticals Pvt. Ltd.,) (Fig.1)
- Autopolymerizing tooth powder (DPI Self cure tooth molding powder, Mumbai, India) (Fig.2a)
- Cold cure monomer (DPI -cold cure monomer, Mumbai, India) (Fig.2b)
- Distilled water (Fig.3)
- PEEK (Juvora Dental disc, Juvora Dental innovations, UK) (Fig.4)
- CAD/CAM MILLED PMMA blank (Ruthinium Disc, Dental manufacturing S.p.A, Italy) (Fig.5)
- Thread (Fig. 6)
- Gauze (Jaya Muthu Surgicals, Rajapalayam, Tamilnadu) (Fig .7)

INSTRUMENTS AND EQUIPMENTS EMPLOYED:

- Digital Vernier caliper (Aerospace Digital Caliper) (Fig.8)
- Incubator (Guna incubator, Guna Enterprises, Chennai, Tamilnadu) (Fig.9)
- Pressure pot (Nrpki, model :AW2000-02, NRPKI Pneumatic co., Ltd) (Fig.10)
- Measuring bowl and filler (Fig.11)

- Plastic Petri dish (Fig.12)
- Water distiller (Megahome model : MH943TWS) (Fig.13)
- Automated thermocycling unit (Willytec, Thermoelectron cooperation, Germany) (Fig.14)
- Universal Testing machine (Instron, model 3345) (Fig.15)
- Custom made stainless steel flask (Fig.16)
- Laboratory Micromotor (NSK ultimate XL model: NE213,Nakanishi INC., Japan) (Fig.17)
- Acrylic trimmers (Shofu, Japan) (Fig.18)
- Bard Parker blade no.15 (Fig.19)
- BP blade handle (Fig.20)
- Stainless steel scale (Fig.21)
- Wide Bladed Spatula (Fig. 22)
- Wax carver (Lecrons wax carver, German dental instruments) (Fig.23)
- MB COBRA MILL 5M milling machine (Fig.24)
- CORE TEC 350i milling machine (Fig.25)

DESCRIPTION OF THE EQUIPMENTS:

Description of the customized stainless steel flask: (Fig.16)

In the present study , a customized stainless steel flask was used to fabricate the test samples of Autopolymerizing provisional resin (PMMA). The customized three piece stainless steel flask of dimensions 85 mm x 50 mm x 25 mm was machined which consists of four equal sized mould spaces measuring 25 mm in length , 2mm in width and 2 mm in height (25 mm x 2 mm x 2 mm) corresponding to the dimensions of the specimens

according to the ADA specification No: 27.

The flask consisted of three pieces : the upper member , centre plate and the lower member. The slots were machined in the centre plate which is sandwiched between the upper and the lower member. For the proper positioning and securing the flask members properly during the polymerization of the resin there was a provision with a male and female component in the upper and lower member respectively and a screw with handle was provided.

Description of water distiller: (Fig.13)

The countertop water distiller (Megahome MH943TWS) was used in this present study to collect the distilled water for conditioning of the test samples. The completion of 1 gallon of pure steam distilled water was in 5.5 hours. The distilled water produced was pure, and is suitable for any distilled water need. It consisted of a boil chamber, including upper cover, collection bottle with a removable lid and handle. The boil chamber was filled with water, start button was switched on and the distiller automatically shuted-off at the end of the cycle. The distilled water was collected in the collection bottle.

Description of the Thermocycling Unit: (Fig.14)

In the present study ,an automated thermocycling unit (Willytec, Germany) with cooling system (Haake EK 30 ,Germany) (Figure No:14) was used for thermocycling the test samples to simulate the temperature changes in the oral cavity. The thermocycling unit consisted of two water baths, each maintained at different temperatures. The first bath had a temperature variation from 25^0 C to 100^0 C and the second bath was connected to a cooling device where it had a temperature variation from – 5^0 C to 100^0 C. The required cycles can be easily adjusted via the display from 0 to 9999 cycles. The unit had an

automatic refill for the baths to compensate evaporation during the long duration test. It had the capability of auto-start. Both the baths were connected by a rolling unit with an open sample container in the centre for holding the test samples. The test samples were placed in the open sample container which was immersed cyclically in the baths of warm and cold water. Exposure of the test samples to various temperature fluctuations simulates the intra oral environment.

Description of the Universal Testing Machine: (Fig.15)

Universal testing Machine (Instron, model 3345) (Figure No:15) was employed in the present study for obtaining the flexural strength of the test samples. The machine rested on a table top. It consisted of an upper member, a lower member, a display board which displayed the amount of force required to fracture the samples and it was connected to the computer. The upper member was attached to the lower with the help of two horizontal bars, which also housed the hydraulic pressure machine in the upper member. The lower member had a bench vice test specimen fixture to hold the jig for holding the test specimens during the testing. The upper member portion had a grip on which the mono bevelled chisel blade could be attached .The whole unit was attached to a computer for recording and converting the data.

METHODOLOGY

I. Fabrication of the test samples:

a. Fabrication of the Autopolymerizing provisional PMMA resin samples.

b. Fabrication of the CAD/CAM milled PMMA samples.

c. Fabrication of the PEEK samples.

II. Grouping of the test samples

III. Aging / Conditioning of the test samples.

IV. Thermocycling of the test samples.

V. Evaluation of flexural strength of the test samples.

VI. Data tabulation and Statistical Analysis.

I. Fabrication of the samples :

a. Fabrication of the Autopolymerizing PMMA resin samples: (Fig:26)

In this study Autopolymerizing tooth powder (DPI Self cure tooth molding powder, Mumbai, India) and Cold cure monomer (DPI -cold cure monomer, Mumbai, India) was used. The material is supplied in the powder and liquid form as polymer and monomer respectively. The main component of the material is Polymethylmethacrylate (PMMA). According to the manufacturer's instruction the manipulation of the material was carried out. The standard polymer/monomer ratio is 1.0 gm/0.5 ml. Spatulation of the material was done for approximately for 20-30 seconds to evenly wet the polymer particles. The mould spaces was lubricated with the petroleum jelly and the mixed material was placed in the mould spaces. The flask members were approximated under constant pressure until the flash comes out. The position of the flask members maintained by tightening the screws and placed in Pressure pot maintained at 20 psi for 20 minutes until the polymerization is completed (Figure:26). The samples were retrieved and the excess trimmed and polished (Figure:27). The dimensions of the test samples fabricated was 25mm x 2mm x 2mm. Similarly, all the 20 samples were fabricated and the dimensions were checked using digital vernier caliper.

b. Fabrication of the CAD/CAM milled PMMA samples : (Fig:28)

In this study , CAD/CAM MILLED PMMA (Ruthinium Disc, Dental manufacturing S.p.A, Italy) was used. The MAGICS CAD SOFTWARE was used to design the required dimensions (25mm x 2mm x 2mm) of the test sample. Using the subtractive technique, the required dimension of the samples were milled from a 25 mm thickness Ruthinium PMMA blank (Fig : 5) using the MB COBRA MILL 5M milling

machine (Fig :24). All the 20 samples were milled from a single blank and the dimensions were checked using digital vernier caliper.

c. Fabrication of PEEK samples : (Fig:30)

In this study, PEEK (Juvora Dental disc, Juvora Dental innovations, UK) was used. The imes- icore CAD SOFTWARE was used to design the required dimensions (25mm x 2mm x 2mm) of the test sample. Using the subtractive technique, the required dimension of the samples were milled from a 25 mm thickness Juvora PEEK blank (Fig :4) using the CORE TEC 350i milling machine (Fig :25). All the 20 samples were milled from a single blank and the dimensions were checked using digital vernier caliper.

II. Grouping of the samples: (Fig:32)

All the sixty samples were divided into twenty samples and designated as Group I , Group II and Group III. These twenty samples were again sub divided into ten samples each and Group I (A) , Group I (B), Group II (A) , Group II (B), Group III (A) and Group III (B) based on the number of days of aging/conditioning and number of cycles subjected in the thermocycling unit.

The Group I (A), Group II (A) and Group III (A) test samples of Autopolymerizing PMMA resin , CAD/CAM milled PMMA and PEEK respectively where planned for 7 days of aging/conditioning and 500 cycles of thermocycling. The Group I (B), Group II (B) and Group III (B) test samples of Autopolymerizing PMMA resin, CAD/CAM milled PMMA and PEEK respectively where planned for 14 days of aging/conditioning and 1000 cycles of thermocycling.

III. Aging / Conditioning of the samples: (Fig :33)

After the Grouping of the test samples they were placed separately in plastic

Petri dish, ten samples in each petri dish. The distilled water obtained from the water distiller was used. The test samples in the each petri dish filled with distilled water obtained from the water distiller and was labelled. These plastic petri dishes were placed in incubator maintained at 37^0 C temperature and subjected to aging/conditioning. The Group I (A), Group II (A) and Group III (A) test samples of Autopolymerizing PMMA resin , CAD/CAM milled PMMA and PEEK respectively where subjected to 7 days of aging/conditioning. The Group I (B), Group II (B) and Group III (B) test samples of Autopolymerizing PMMA resin ,CAD/CAM milled PMMA and PEEK respectively where subjected to 14 days of aging/conditioning.

IV. Thermocycling of the test samples: (Fig :34)

In the present invitro study thermocycling was done to simulate the intra oral conditions. All the samples of Group I (A) and (B), Group II (A) and (B), Group III (A) and (B) were subjected to thermocycling for 500 cycles and 1000 cycles respectively in a distilled water bath between 5º C and 55º C with the dwell time of 6 seconds and a dry time of 5 seconds using a thermocycling apparatus (Willytec, Germany) (Fig:14). Upon completion of thermocycling the samples were stored in distilled water in their respective container at room temperature, until they were subjected to flexural strength testing**.**

V. Evaluation of flexural strength of the samples: (Fig:35)

A total of sixty test samples (Group I (A) and (B), Group II (A) and (B), Group III (A) and (B)) were tested for flexural strength in a universal mechanical testing machine (Instron, model 3345) (Fig:15) at the Division of Polymeric Medical devices, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Bio Medical Wing, Thiruvananthapuram, Kerala, India.

Test samples were fixed to the sample fixture at the bench vice of the machine with the mono beveled chisel blade placed flat against the centre part of the test sample. The test samples were subjected to three point bending test at a crosshead speed of 0.75 mm/min until the fracture occurred in the universal testing machine (Instron, model 3345). Load deflection curves and ultimate load to failure were recorded and displayed by the computer software of the testing machine. The procedure was repeated for all the test samples and the breaking load values recorded. The breaking load values were recorded in newton (N) and flexural strength (Mpa) was calculated with these breaking load values using the formula,

$$S = 3FL / 2bd^2$$

where, S = Flexural strength / modulus of fracture in Mpa (Mega Pascals),

F = Load at the fracture point at which samples failed between load bearing edges,

L = Length of the support span (25 mm),

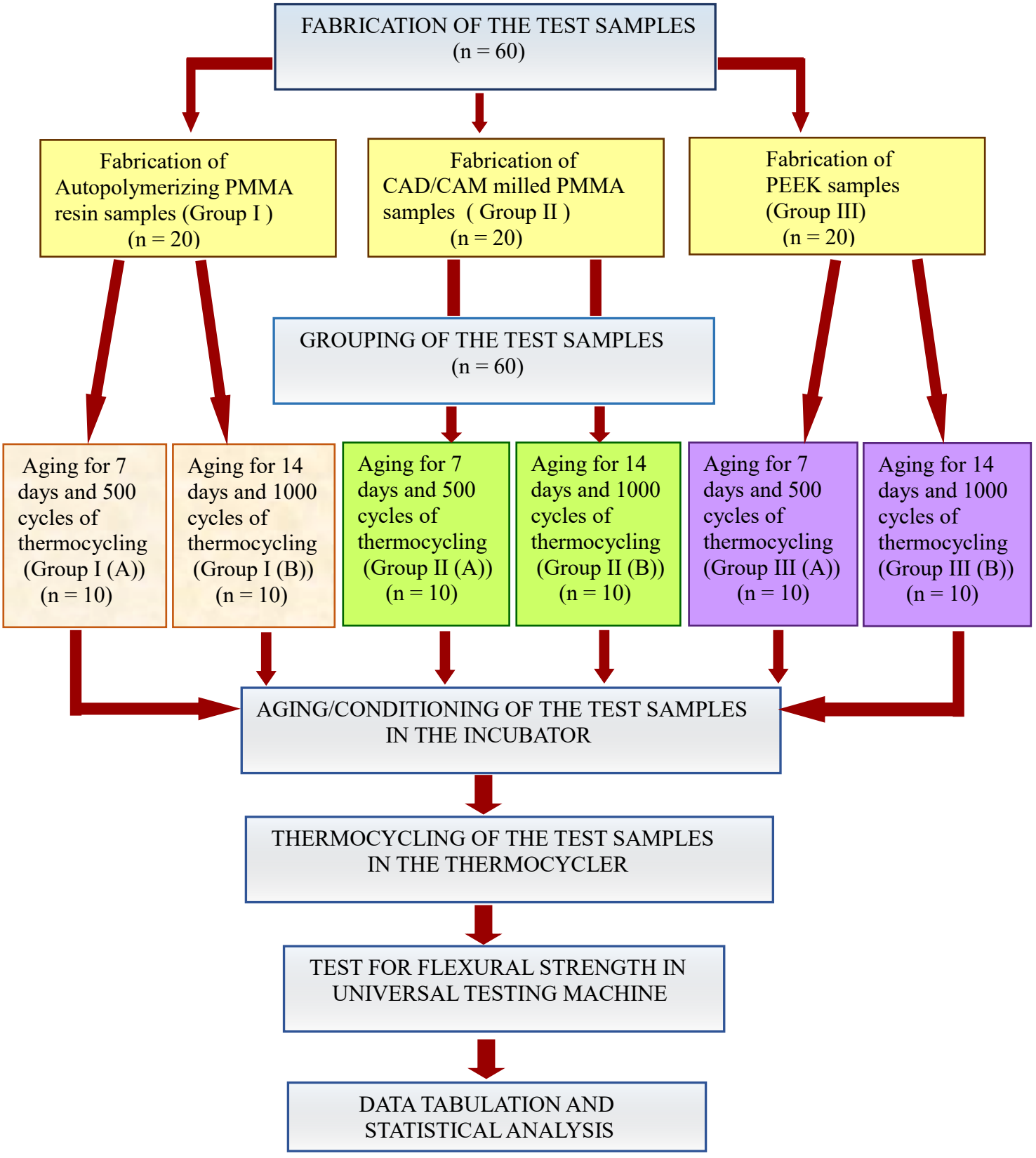
b = Width of the test sample (2mm),

d = Thickness of the test sample (2mm).

IX. Data tabulation and statistical analysis:

The flexural strength of all the sixty test samples were obtained in Megapascals (Mpa). The results obtained were tabulated and subjected to statistical analysis using the statistical software package SPSS 16 version (Chicago inc). Mean and standard deviation were estimated from the results obtained from each sample for each study group. The data were analysed with Student t test and pair–wise comparison of mean values was done by ANOVA (Analysis of Variance) test. Statistical significance was considered at 5% significance level.

METHODOLOGY – OVERVIEW



Figures

ANNEXURE I

MATERIALS USED

Fig no.1: Petroleum Jelly

Fig no.2a: Autopolymerizing tooth powder

Fig no.2b : Cold cure monomer

Fig no.3: Distilled water

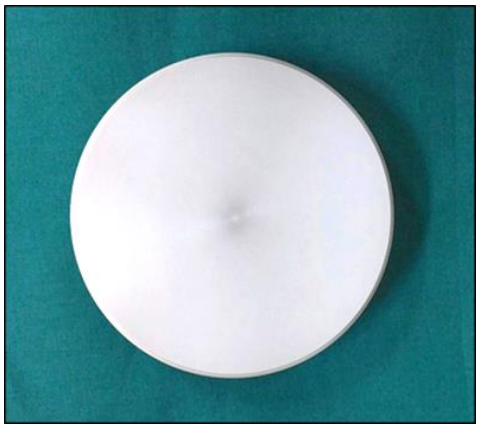


Fig no.4: Juvora PEEK blank

Fig no.5: Ruthinium PMMA blank

Fig no.6:Thread

Fig no.7: Gauze

INSTRUMENTS AND EQUIPMENTS EMPLOYED

Fig no.8: Digital Vernier caliper

Fig no.9: Incubator

Fig no.10: Pressure pot

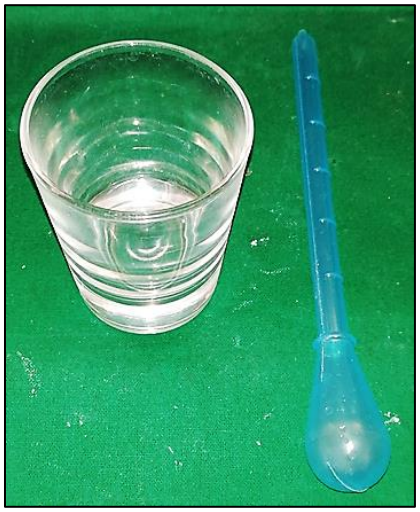


Fig no.11: Measuring bowl and Filler

Fig no.12: Plastic Petri dish

Fig no.13: Water distiller

Fig no.14: Automated thermocycling unit

Fig no.15: Universal Testing machine

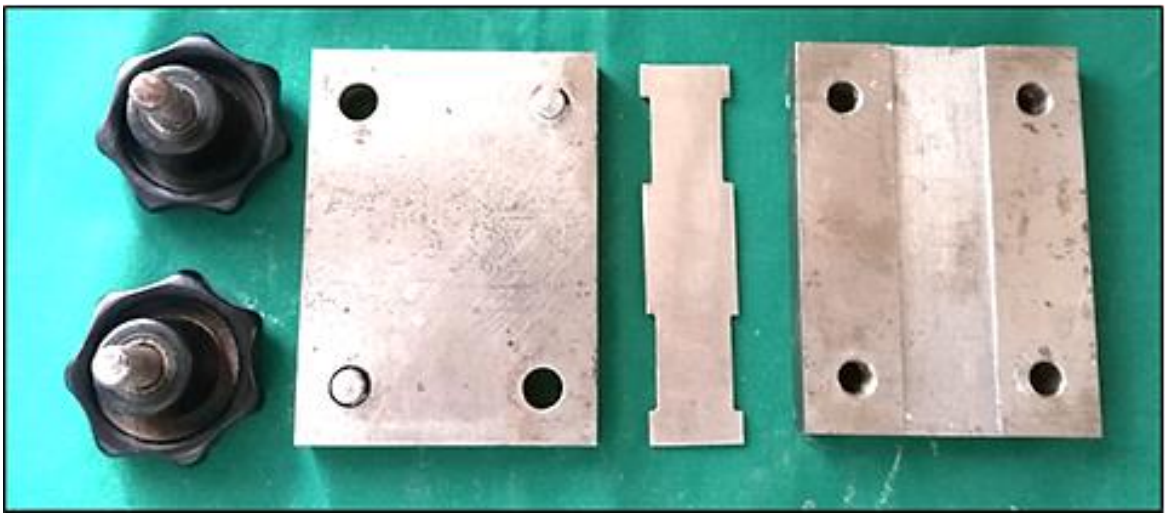


Fig no.16: Custom made stainless steel flask

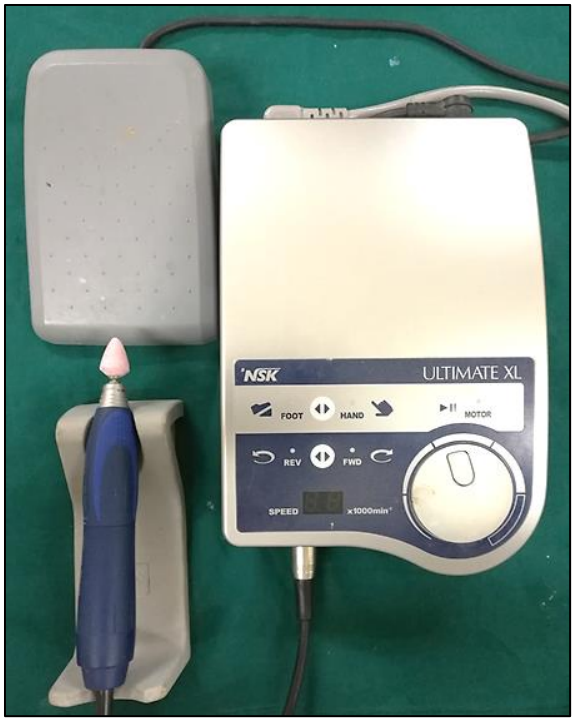


Fig no.17: Laboratory Micromoter

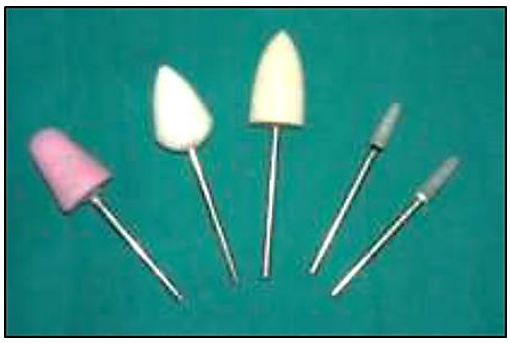


Fig no.18: Acrylic trimmers

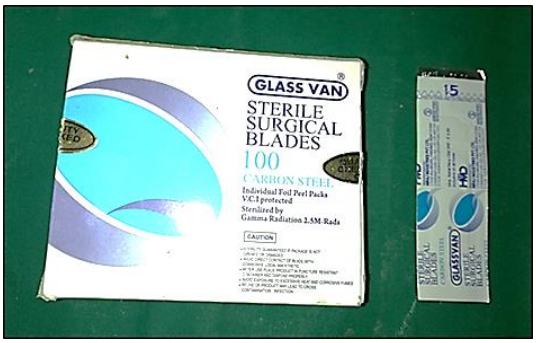


Fig no.19: Bard Parker blade no.15

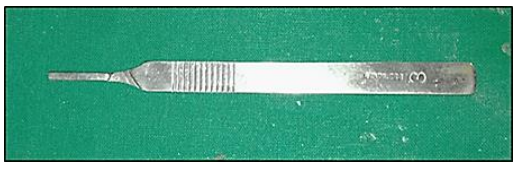


Fig no.20: BP blade handle

Fig no.21: Stainless steel scale

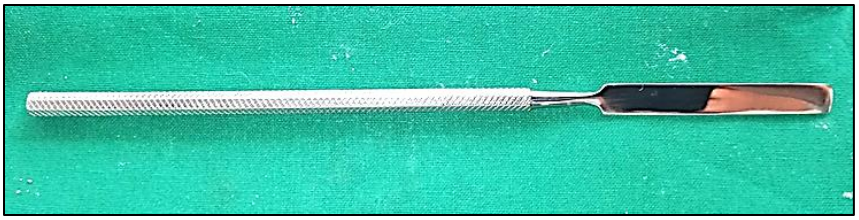


Fig no.22: Wide bladed spatula

Fig no.23: Wax carver

Fig no.24:MB COBRA MILL 5M milling machine

Fig no. 25:CORE TEC 350i milling machine

METHODOLOGY

I . FABRICATION OF THE TEST SAMPLES

I a. Fabrication of the Autopolymerizing PMMA resin samples

Fig no. 26:Fabrication of the Autopolymerizing PMMA resin samples

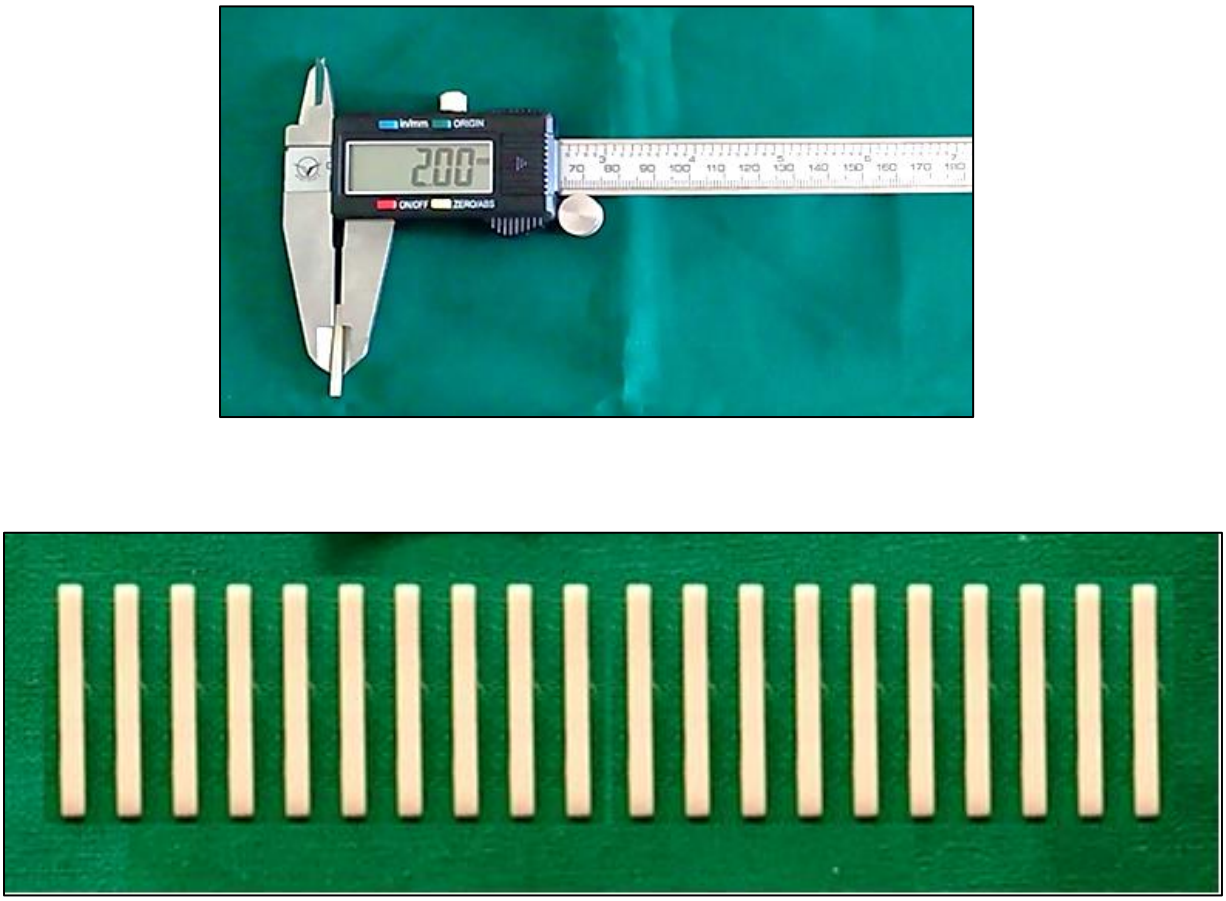


Fig no. 27: Autopolymerizing PMMA resin samples

I b. Fabrication of the CAD/CAM milled PMMA samples

Fig no.28:Fabrication of the CAD/CAM milled PMMA samples

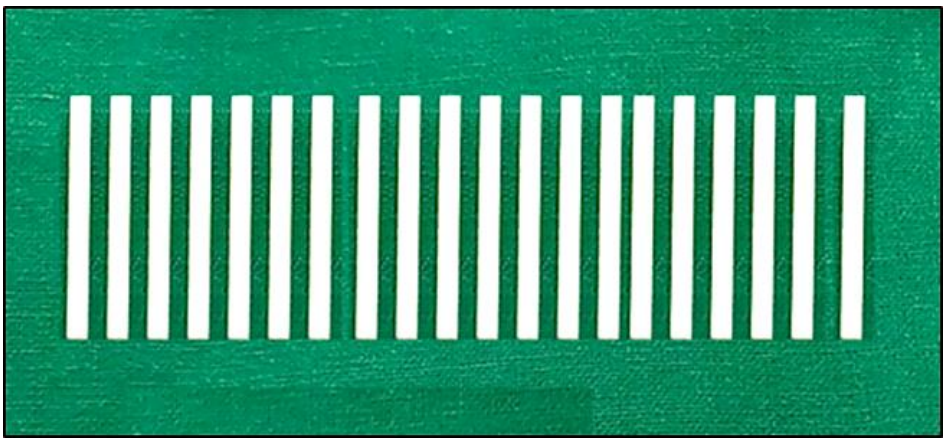


Fig no.29:CAD/CAM MILLED PMMA sample

I c. Fabrication of the PEEK samples

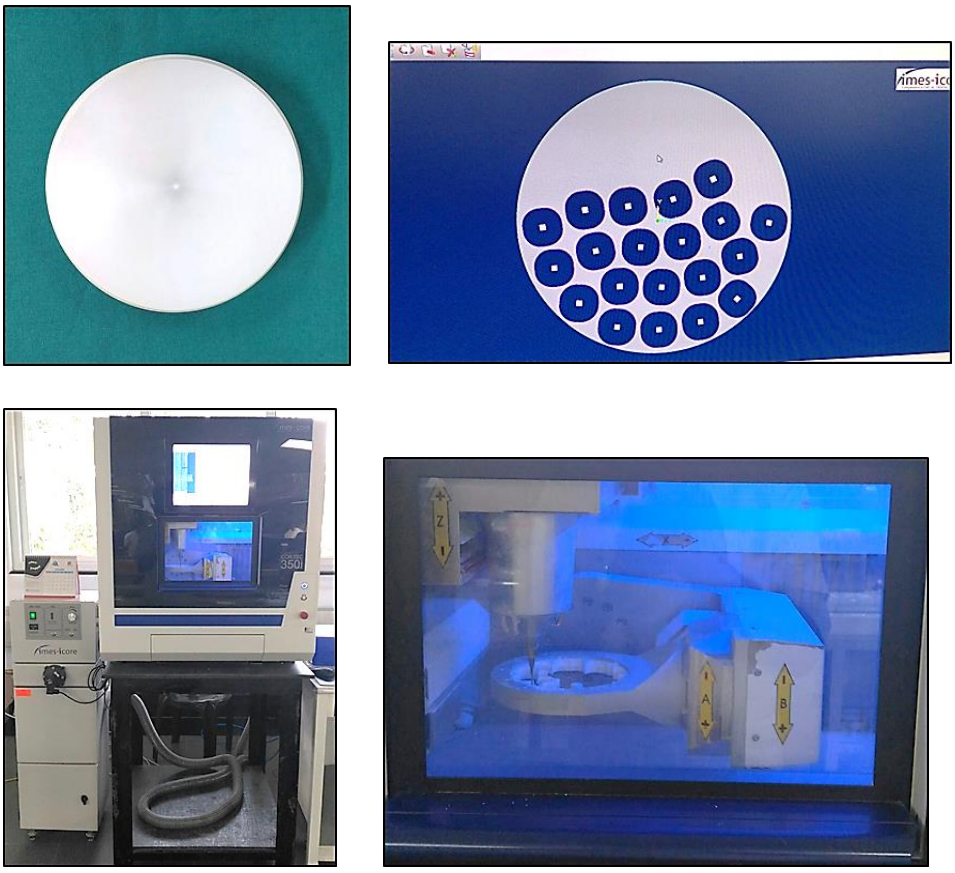


Fig no.30:Fabrication of PEEK samples

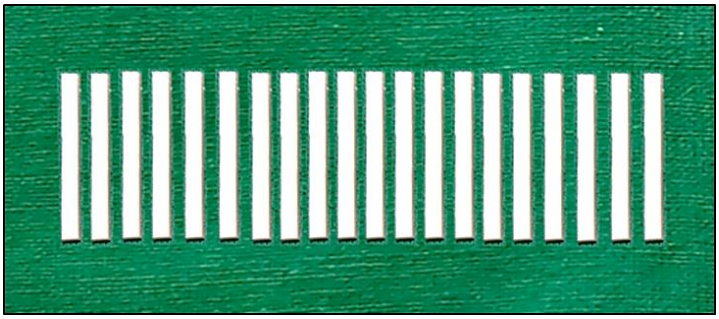


Fig no.31:CAD/CAM MILLED PEEK samples

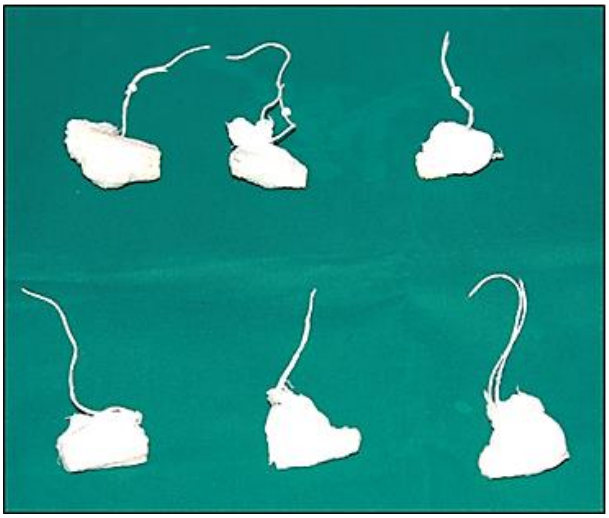
II.GROUPING OF THE TEST SAMPLES

Fig no.32:Grouping of the samples

III. AGING/CONDITIONING OF THE TEST SAMPLES

Fig no.33:Aging/conditioning of the samples in incubator

IV.THERMOCYCLING OF THE TEST SAMPLES



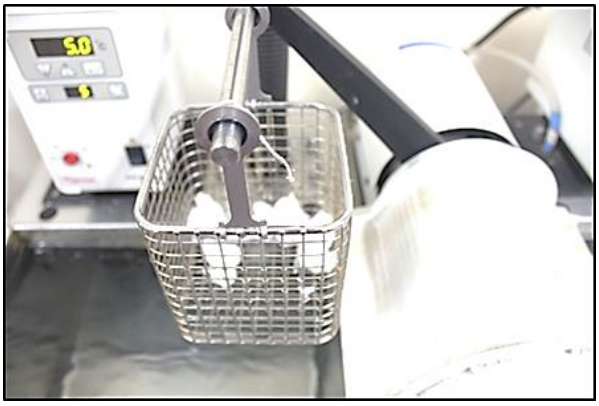
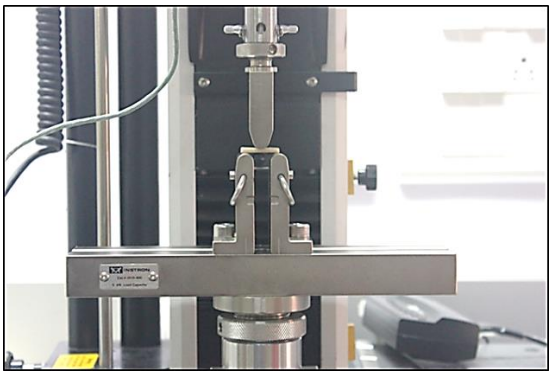
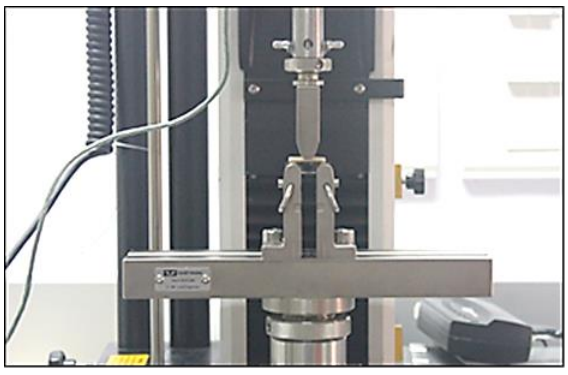
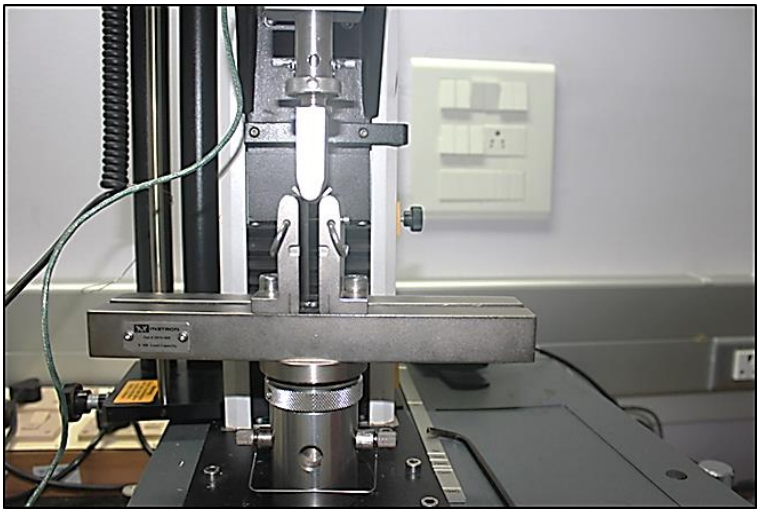


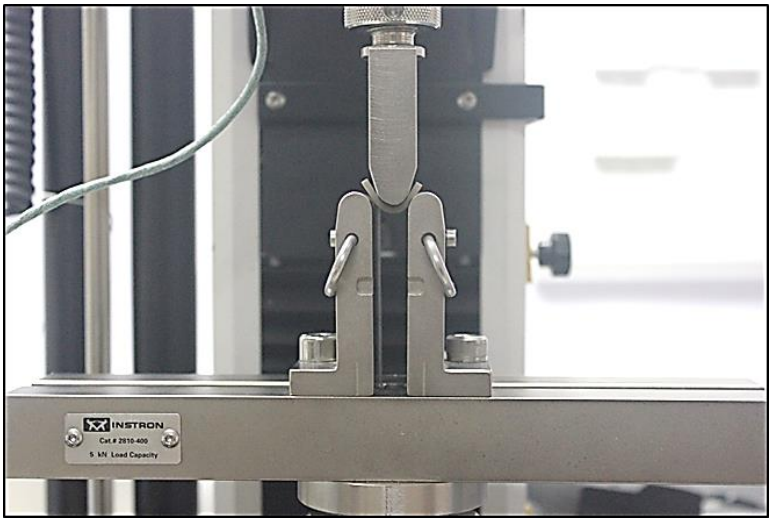
Fig no.34:Thermocycling of the samples

V. EVALUATION OF FLEXURAL STRENGTH IN UNIVERSAL TESTING MACHINE OF THE TEST SAMPLES









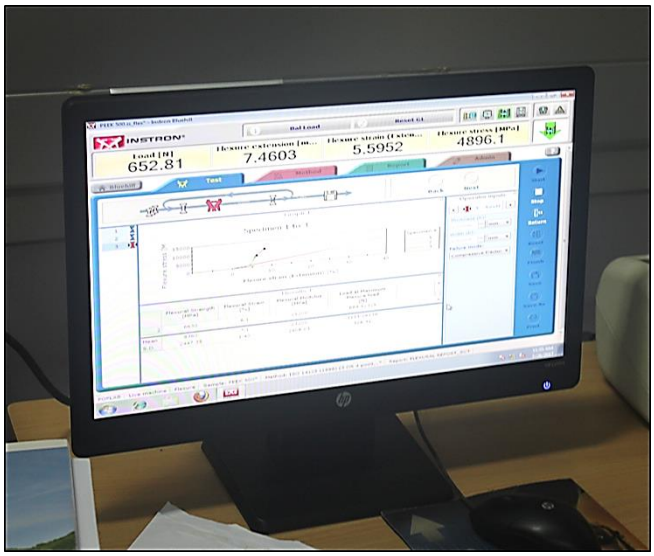


Fig no.35: 3 point bend test in universal testing machine

Results

RESULTS

The present in vitro study was conducted to compare and to evaluate the effect of aging and thermocycling on the flexural strength of the PEEK, CAD/CAM milled PMMA and Autopolymerizing PMMA resin.

Sixty test samples in total was fabricated of which twenty samples were fabricated using autopolymerising PMMA resin was designated as Group I, those twenty samples fabricated using CAD/CAM milled PMMA was designated as Group II and those twenty samples fabricated using PEEK. Group I (A) , Group II (A) and Group III (A) with ten samples each were subjected to 7 days of aging/conditioning and 500 cycles of thermocycling. Group I (B) , Group II (B) and Group III (B) with ten samples each were subjected to 14 days of aging/conditioning and 1000 cycles of thermocycling.

The test samples which were subjected to aging/conditioning and thermocycling were tested for flexural strength in the universal testing machine. The results were tabulated and subjected for statistical analysis.

Table 1 shows the basic values of flexural strength of Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling (Group I (A)).

Table 2 shows the basic values of flexural strength of Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling (Group I(B)).

Table 3 shows the basic values of flexural strength of CAD/CAM milled PMMA after 7 days of aging and 500 cycles of thermocycling (Group II (A)).

Table 4 shows the basic values of flexural strength of CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling (Group II (B)).

Table 5 shows the basic values of flexural strength of PEEK after 7 days of aging and 500 cycles of thermocycling (Group III (A)).

Table 6 shows the basic values of flexural strength of PEEK after 14 days of aging and 1000 cycles of thermocycling (Group III (B)).

Table 7 shows the comparative evaluation of the mean flexural strength of Group I (A) and Group II (A) (Student 't' test).

Table 8 shows the comparative evaluation of the mean flexural strength of Group I (A) and Group III (A) (Student 't' test).

Table 9 shows the comparative evaluation of the mean flexural strength of Group II (A) and Group III (A) (Student 't' test).

Table 10 shows the comparative evaluation of the mean flexural strength of Group I (B) and Group II (B) (Student 't' test).

Table 11 shows the comparative evaluation of the mean flexural strength of Group I (B) and Group III (B) (Student 't' test).

Table 12 shows the comparative evaluation of the mean flexural strength of Group II (B) and Group III (B) (Student 't' test).

Table 13 shows the comparative evaluation of the mean flexural strength of Group I (A) and Group I (B) (Student 't' test).

Table 14 shows the comparative evaluation of the mean flexural strength of Group II (A) and Group II (B) (Student 't' test).

Table 15 shows the comparative evaluation of the mean flexural strength of Group III (A) and Group III (B) (Student 't' test).

Table 16 shows the comparative evaluation of the mean flexural strength of the Group I (A), Group II (A) and Group III (A) (ANOVA).

Table 17 shows the comparative evaluation of the mean flexural strength of the Group I (B), Group II (B) and Group III (B) (ANOVA).

Graph 1 shows the basic values of flexural strength of Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling. (Group I (A).

Graph 2 shows the basic values of flexural strength of Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling (Group I (B)).

Graph 3 shows the basic values of flexural strength of CAD/CAM milled PMMA after 7 days of aging and 500 cycles of thermocycling (Group II (A)).

Graph 4 shows the basic values of flexural strength of CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling (Group II (B)).

Graph 5 shows the basic values of flexural strength of PEEK after 7 days of aging and 500 cycles of thermocycling (Group III (A)).

Graph 6 shows the basic values of flexural strength of PEEK after 14 days of aging and 1000 cycles (Group III (B)).

Graph 7 shows the comparative evaluation of the mean flexural strength of Group I (A) and Group II (A).

Graph 8 shows the comparative evaluation of the mean flexural strength of Group I (A) and Group III (A).

Graph 9 shows the comparative evaluation of the mean flexural strength of Group II (A) and Group III (A).

Graph 10 shows the comparative evaluation of the mean flexural strength of Group I (B) and Group II (B).

Graph 11 shows the comparative evaluation of the mean flexural strength of Group I (B) and Group III (B).

Graph 12 shows the comparative evaluation of the mean flexural strength of Group II (B) and Group III (B).

Graph 13 shows the comparative evaluation of the mean flexural strength of Group I (A) and Group I (B).

Graph 14 shows the comparative evaluation of the mean flexural strength of Group II (A) and Group II (B).

Graph 15 shows the comparative evaluation of the mean flexural strength of Group III (A) and Group III (B).

Graph 16 shows the comparative evaluation of the mean flexural strength of the Group I (A) , Group II (A) and Group III (A).

Graph 17 shows the comparative evaluation of the mean flexural strength of the Group I (B), Group II (B) and Group III (B).

Graph 18 shows the overall comparative evaluation of the mean flexural strength of Group I (A) and (B), Group II (A) and (B) and Group III (A) and (B).

TABLES

TABLE:1 Basic values of flexural strength of Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling (Group I (A)).

SAMPLE NO:	FLEXURAL STRENGTH (Mpa)
1	274
2	263
3	243
4	213
5	235
6	228
7	265
8	240
9	223
10	265
Mean / Standard Deviation (S.D)	244.90/ 20.79

INFERENCE:

The maximum flexural strength is **274 Mpa**.

The minimum flexural strength is **213 Mpa**.

The mean flexural strength is **244.90 Mpa**.

TABLE: 2 Basic values of flexural strength of Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling (Group I(B)).

SAMPLE NO:	FLEXURAL STRENGTH (Mpa)
1	218
2	242
3	200
4	189
5	195
6	180
7	209
8	165
9	225
10	208
Mean / Standard Deviation (S.D)	203.10 / 22.44

INFERENCE:

The maximum flexural strength is **242 Mpa**.

The minimum flexural strength is **200 Mpa**.

The mean flexural strength is **203.10 Mpa**.

TABLE: 3 Basic values of flexural strength of CAD/CAM milled PMMA after 7 days of aging and 500 cycles of thermocycling (Group II(A)).

SAMPLE NO:	FLEXURAL STRENGTH (Mpa)
1	255
2	237
3	277
4	268
5	240
6	243
7	242
8	214
9	244
10	285
Mean / Standard Deviation (S.D)	250.50 / 21.12

INFERENCE:

The maximum flexural strength is **285 Mpa**.

The minimum flexural strength is **214 Mpa**.

The mean flexural strength is **250.50 Mpa**

TABLE: 4 Basic values of flexural strength of CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling (Group II (B)).

SAMPLE NO:	FLEXURAL STRENGTH (Mpa)
1	265
2	190
3	191
4	231
5	213
6	270
7	191
8	206
9	195
10	253
Mean / Standard Deviation (S.D)	220.50 / 31.95

INFERENCE:

The maximum flexural strength is **270 Mpa**.

The minimum flexural strength is **206 Mpa**.

The mean flexural strength is **220.50 Mpa**

TABLE: 5 Basic values of flexural strength of PEEK after 7 days of aging and 500 cycles of thermocycling (Group III (A)).

SAMPLE NO:	FLEXURAL STRENGTH (Mpa)
1	6700
2	6630
3	6330
4	6290
5	6410
6	6758
7	6836
8	6681
9	6950
10	6702
Mean / Standard Deviation (S.D)	6628.70 / 218.04

INFERENCE:

The maximum flexural strength is **6950 Mpa**.

The minimum flexural strength is **6290 Mpa**.

The mean flexural strength is **6628.70 Mpa.**

TABLE: 6 Basic values of flexural strength of PEEK after 14 days of aging and 1000 cycles of thermocycling (Group III (B).

SAMPLE NO:	FLEXURAL STRENGTH (Mpa)
1	4170
2	4060
3	3730
4	3320
5	3550
6	3667
7	3407
8	4127
9	4193
10	3381
Mean / Standard Deviation (S.D)	3760.50 / 348.93

INFERENCE:

The maximum flexural strength is **4193 Mpa**.

The minimum flexural strength is **3320 Mpa**.

The mean flexural strength is **3760.50 Mpa.**

TABLE: 7 Comparative evaluation of the mean flexural strength of Group I (A) and Group II (A) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group I (A)	244.90	20.79	0.558*
Group II (A)	250.50	21.12	

***p > 0.05; statistically not significant.**

INFERENCE: On comparison of the mean flexural strength of Group I (A) and Group II (A) using Student 't' test shows no statistical significance.

TABLE: 8 Comparative evaluation of the mean flexural strength of Group I (A) and Group III (A) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group I (A)	244.90	20.79	< 0.001*
Group III (A)	6628.70	218.04	

***p< 0.05; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group I (A) and Group III (A) using Student 't' test shows statistical significance, indicating Group III (A) greater than Group I (A).

TABLE: 9 Comparative evaluation of the mean flexural strength of Group II (A) and Group III (A) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group II (A)	250.50	21.12	< 0.001*
Group III (A)	6628.70	218.04	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group II (A) and Group III (A) using Student 't' test shows statistical significance.

indicating Group III (A) greater than Group II (A).

TABLE : 10 Comparative evaluation of the mean flexural strength of Group I (B) and Group II (B) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group I (B)	203.10	22.44	0.176*
Group II (B)	220.50	31.95	

***p > 0.05 ; statistically not significant.**

INFERENCE: On comparison of the mean flexural strength of Group I (B) and Group II (B) using Student 't' test shows no statistical significance**.**

TABLE: 11 Comparative evaluation of the mean flexural strength of Group I (B) and Group III (B) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group I (B)	203.10	22.44	< 0.001*
Group III (B)	3760.50	348.93	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group I (B) and Group III (B) using Student 't' test shows statistical significance, indicating Group III (B) greater than Group I (B).

TABLE: 12 Comparative evaluation of the mean flexural strength of Group II (B) and Group III (B) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group II (B)	220.50	31.95	< 0.001*
Group III (B)	3760.50	348.93	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group II (B) and Group III (B) using Student 't' test shows statistical significance, indicating Group III (B) greater than Group II (B).

TABLE: 13 Comparative evaluation of the mean flexural strength of Group I (A) and Group I (B) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group I (A)	244.90	20.79	< 0.001*
Group I (B)	203.10	22.44	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group I (A) and Group I (B) using Student 't' test shows statistical significance, indicating Group I (A) greater than Group I (B).

TABLE: 14 Comparative evaluation of the mean flexural strength of Group II (A) and Group II (B) (Student 't' test)

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group II (A)	250.50	21.12	< 0.023*
Group II (B)	220.50	31.95	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group II (A) and Group II (B) using Student 't' test shows statistical significance, indicating Group II (A) greater than Group II (B).

TABLE: 15 Comparative evaluation of mean flexural strength of Group III (A) and Group III (B) (Student 't' test).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
Group III (A)	6628.70	218.04	< 0.001*
Group III (B)	3760.50	348.93	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of the mean flexural strength of Group III (A) and Group III (B) using Student 't' test shows statistical significance, indicating Group III (A) greater than Group III (B).

TABLE: 16 Comparative evaluation of mean flexural strength of Group I (A) ,Group II (A) and Group III (A) (ANOVA).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
GROUP I (A)	244.90	20.79	< 0.001*
GROUP II (A)	250.50	21.12	
GROUP III (A)	6628.70	218.04	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of mean flexural strength of Group I (A), Group II (A) and Group III (A) using ANOVA test shows statistical significance, indicating Group III (A) is highest followed by Group II (A) and Group I (A).

TABLE: 17 Comparative evaluation of mean flexural strength of Group I (B) ,Group II (B) and Group III (B) (ANOVA).

GROUPS	MEAN FLEXURAL STRENGTH (Mpa)	STANDARD DEVIATION (S.D)	'p' value
GROUP I (B)	203.10	22.44	< 0.001*
GROUP II (B)	220.50	31.95	
GROUP III (B)	3760.50	348.93	

***p < 0.05 ; statistically significant.**

INFERENCE: On comparison of mean flexural strength of Group I (B), Group II (B) and Group III (B) using ANOVA test shows statistical significance, indicating Group III(B) is highest followed by Group II (B) and Group I (B).

OBSERVATION:

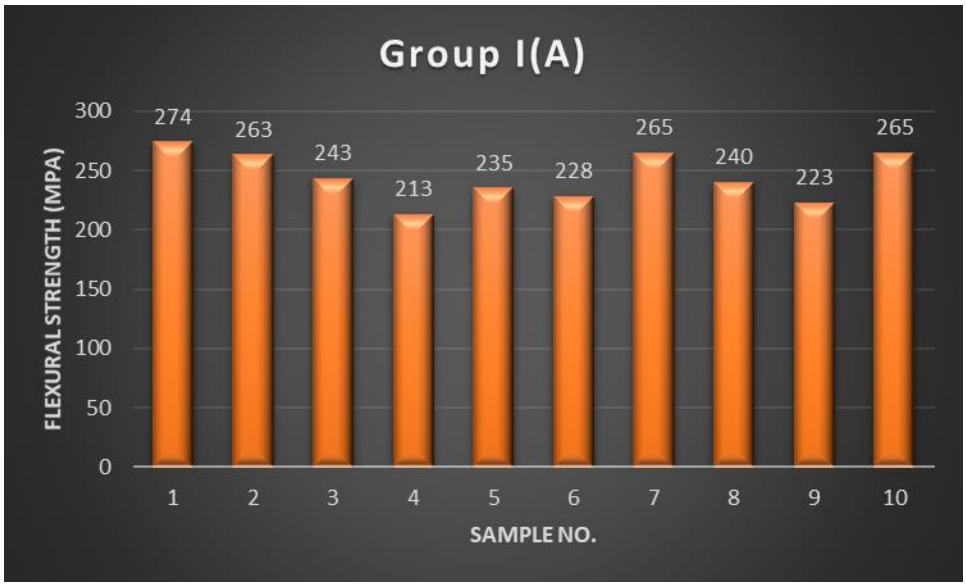
In the present in-vitro study ,from the above results it is observed that the mean flexural strength of the provisional materials compared were in the descending order : **Group III (A) > Group III (B) > Group II (A) > Group II (B) > Group I (A) > Group I (B)**

which implies that the mean flexural strength of PEEK after 7 days of aging and 500 cycles of thermocycling was the highest followed by PEEK after 14 days of aging and 1000 cycles of thermocycling, CAD/CAM milled PMMA after 7 days of aging and 500 cycles of thermocycling, CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling, Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling and the least mean flexural strength was exhibited by Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling .

ANNEXURE II

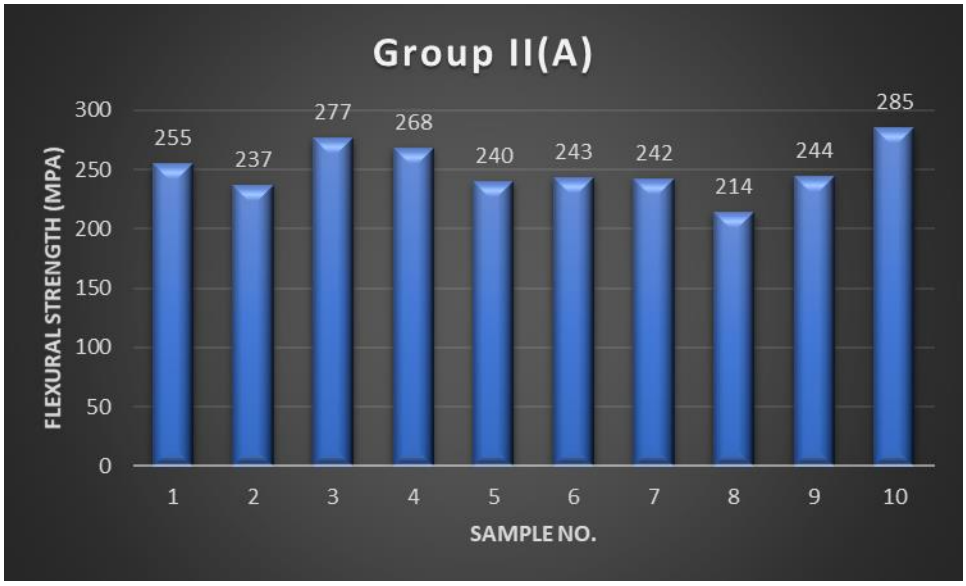
GRAPHS

Graph: 1 Basic values of flexural strength of Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling. (Group I (A)).

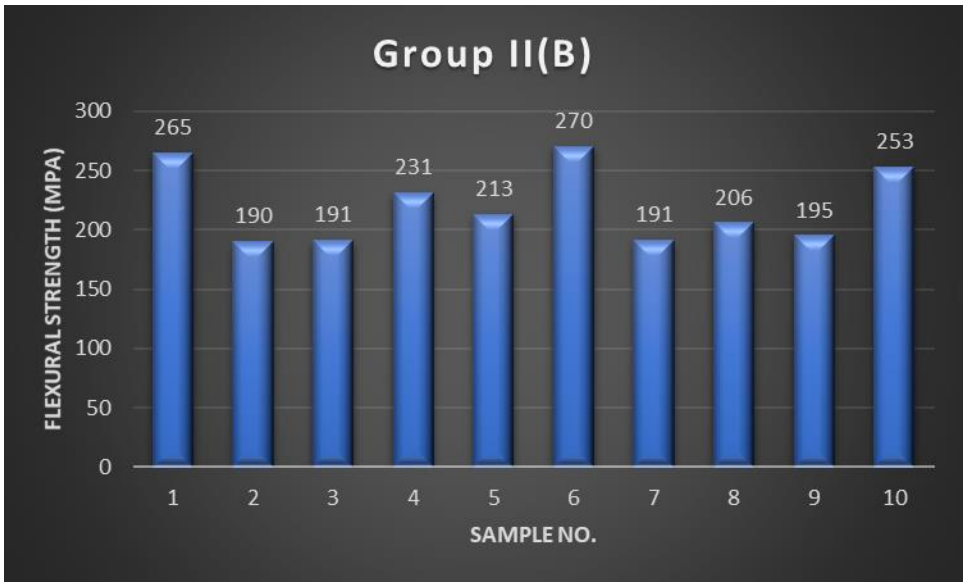


Graph : 2 Basic values of flexural strength of Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling (Group I(B).

Graph: 3 Basic values of flexural strength of CAD/CAM milled PMMA after 7 days of aging and 500 cycles of thermocycling (Group II (A)).



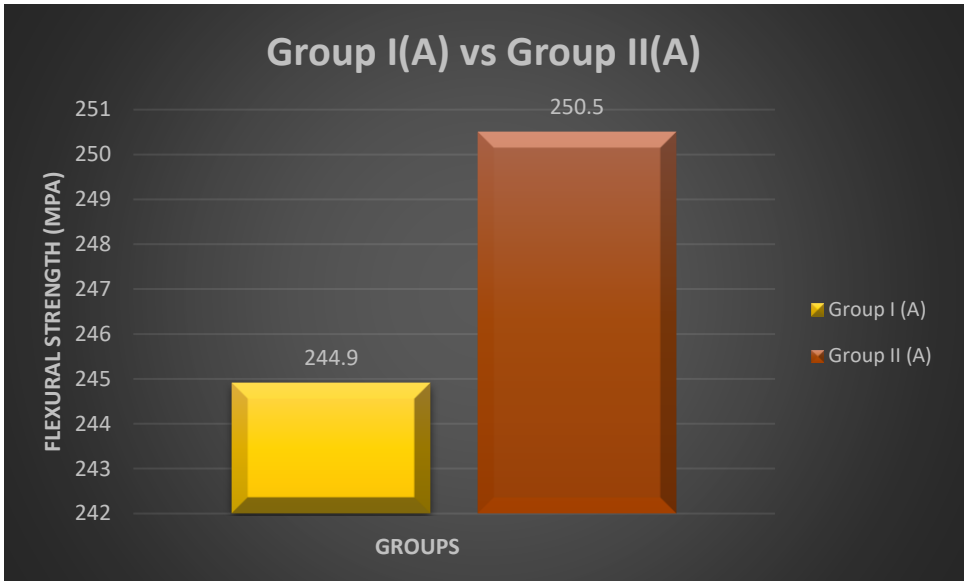
Graph: 4 Basic values of flexural strength of CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling (Group II (B)).



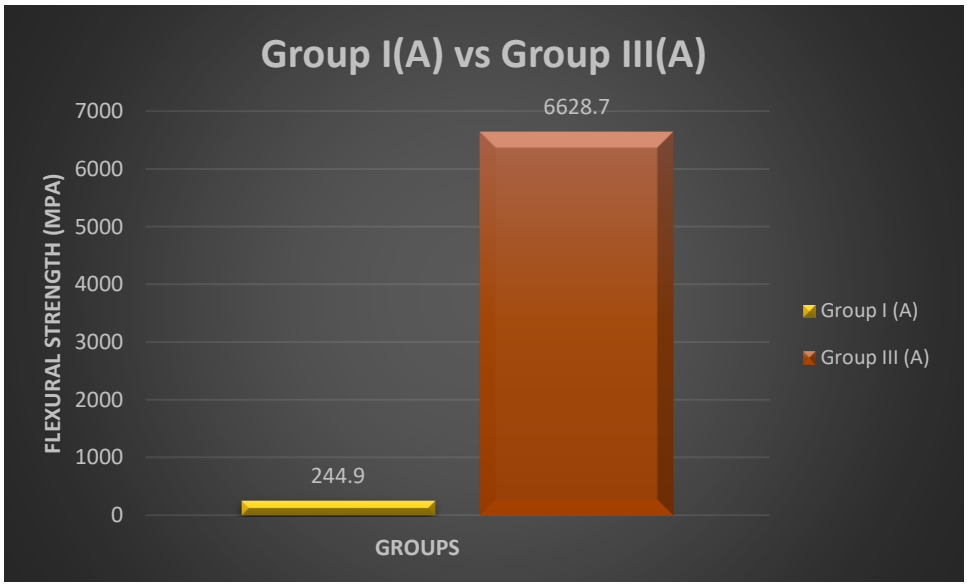
Graph: 5 Basic values of flexural strength of PEEK after 7 days of aging and 500 cycles of thermocycling (Group III (A)).

Graph: 6 Basic values of flexural strength of PEEK after 14 days of aging and 1000 cycles (Group III (B)).

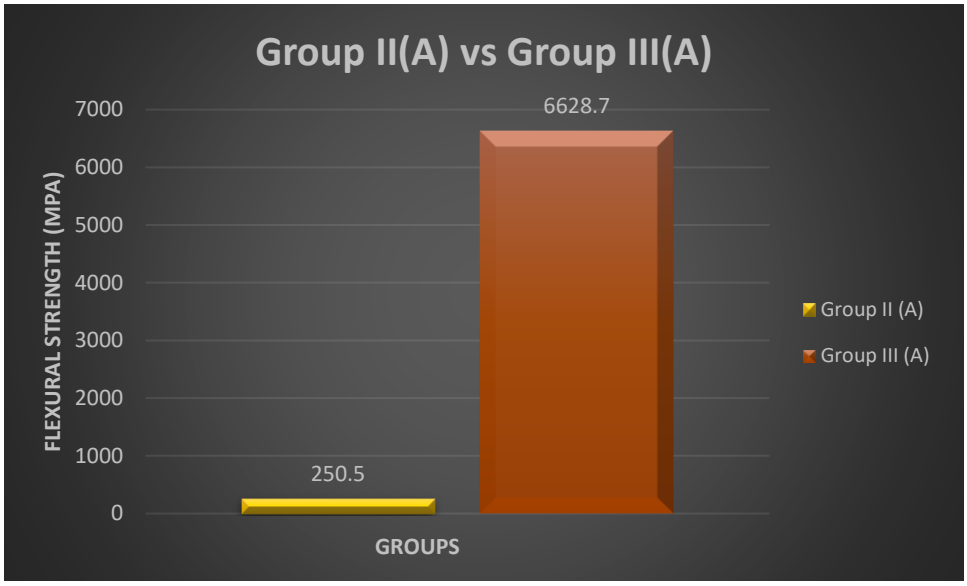
Graph: 7 Comparative evaluation of the mean flexural strength of Group I (A) and Group II (A).



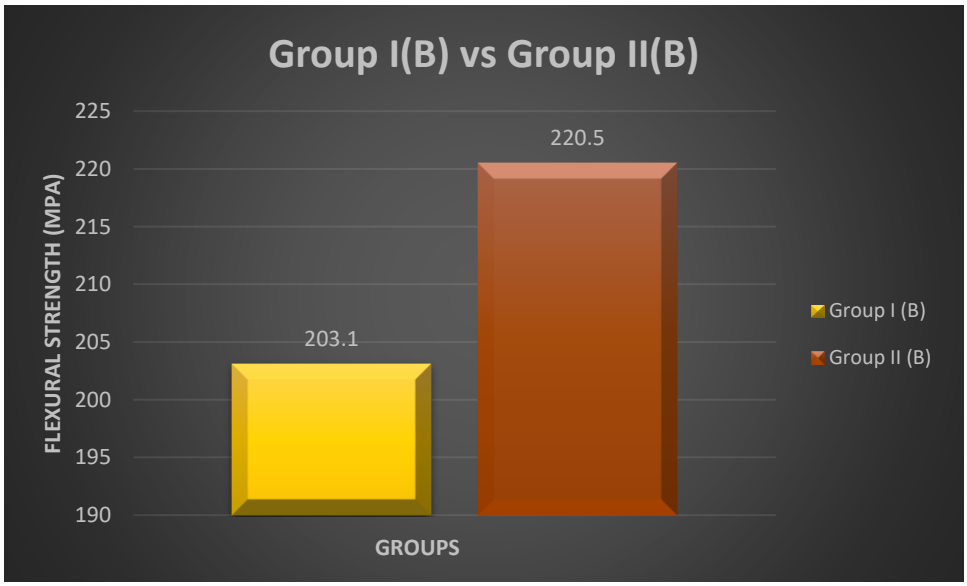
Graph: 8 Comparative evaluation of the mean flexural strength of Group I (A) and Group III (A).



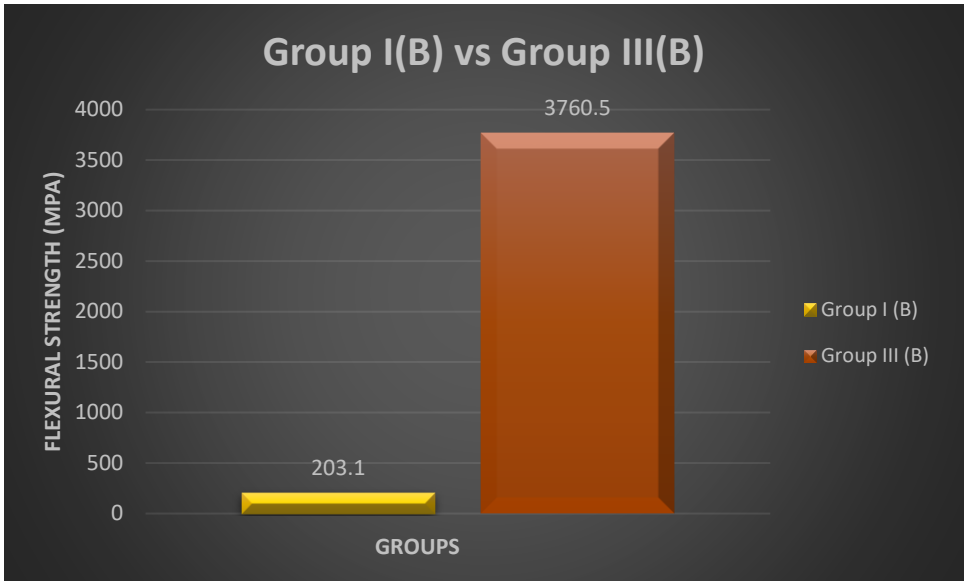
Graph: 9 Comparative evaluation of the mean flexural strength of Group II (A) and Group III (A).



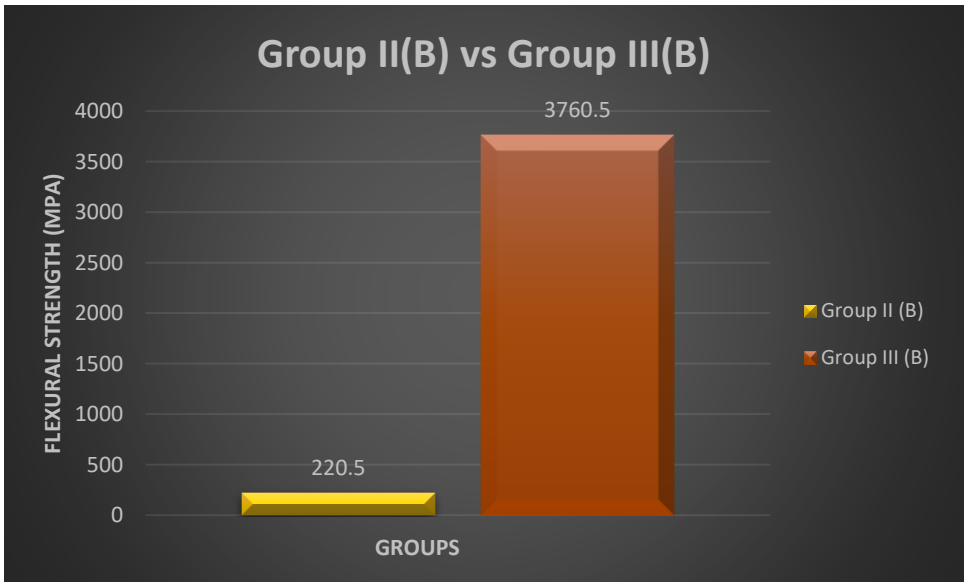
Graph: 10 Comparative evaluation of the mean flexural strength of Group I (B) and Group II (B).



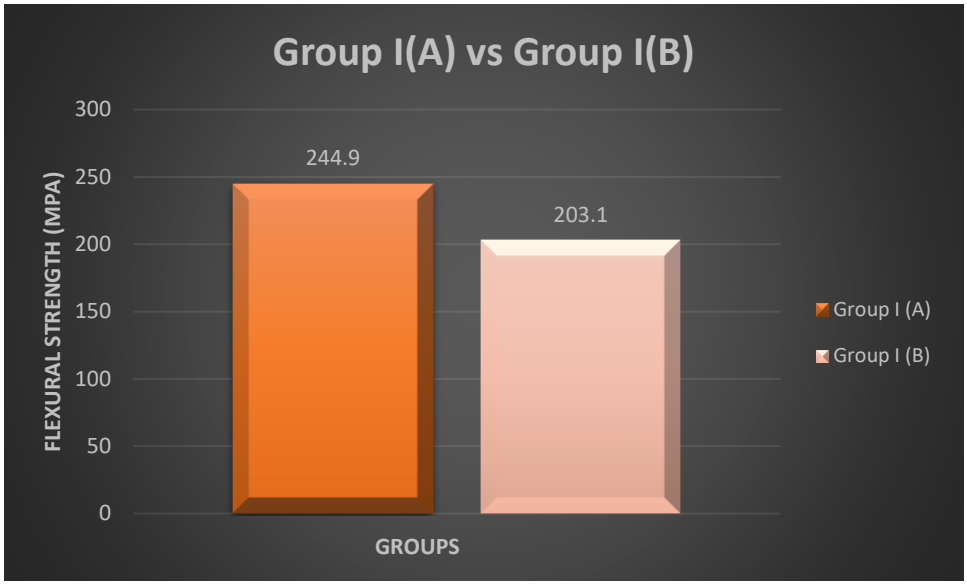
Graph: 11 Comparative evaluation of the mean flexural strength of Group I (B) and Group III (B).



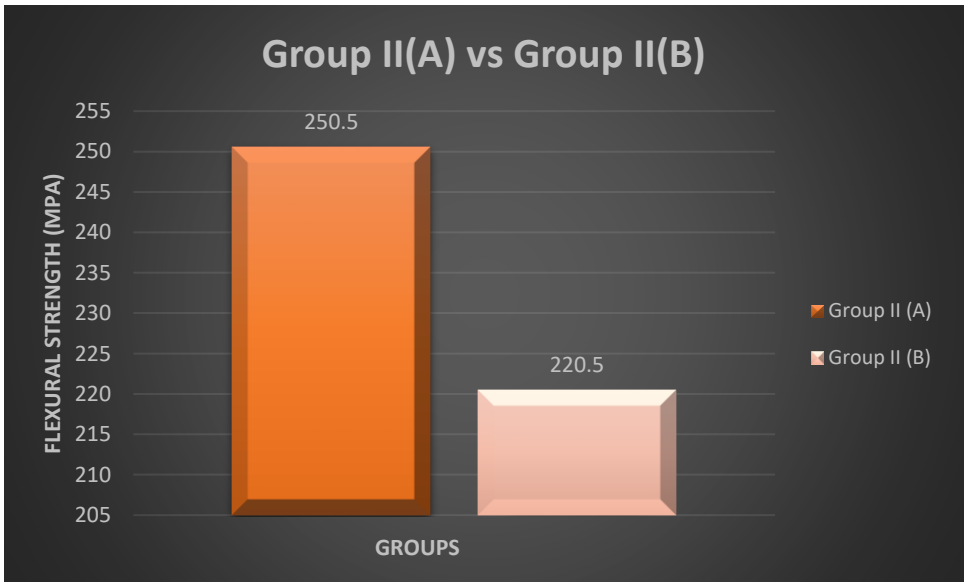
Graph: 12 Comparative evaluation of the mean flexural strength of Group II (B) and Group III (B).



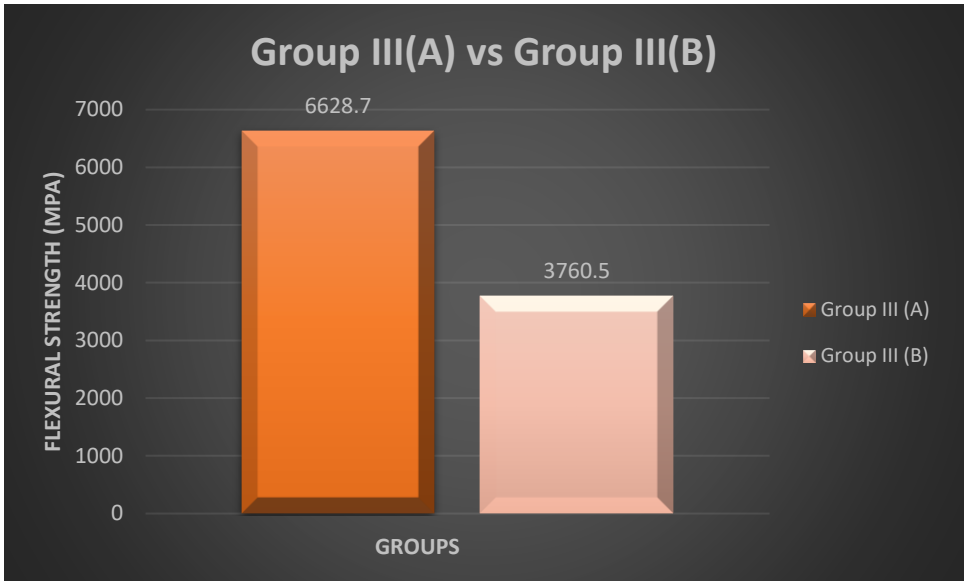
Graph: 13 Comparative evaluation of the mean flexural strength of Group I (A) and Group I (B).



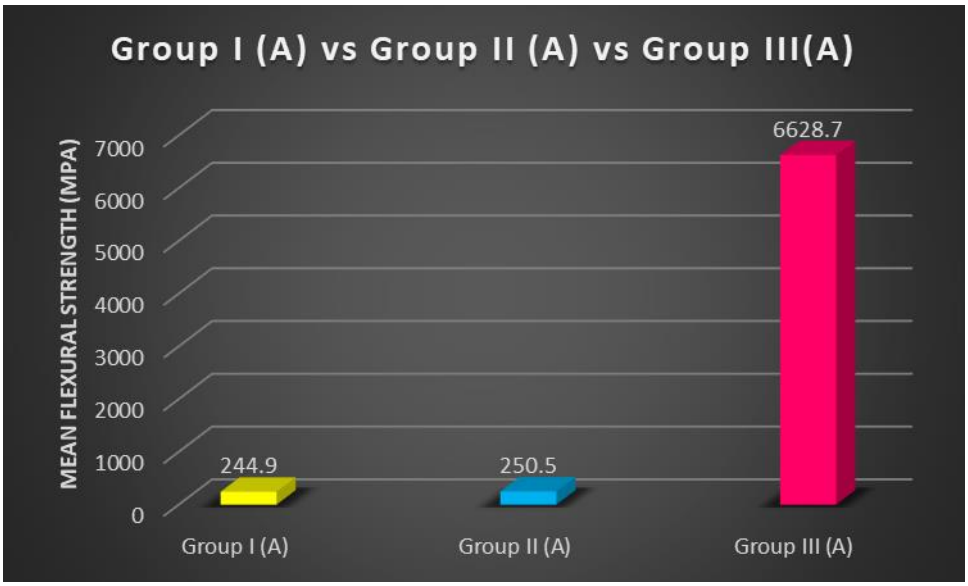
Graph: 14 Comparative evaluation of the mean flexural strength of Group II (A) and Group II (B).



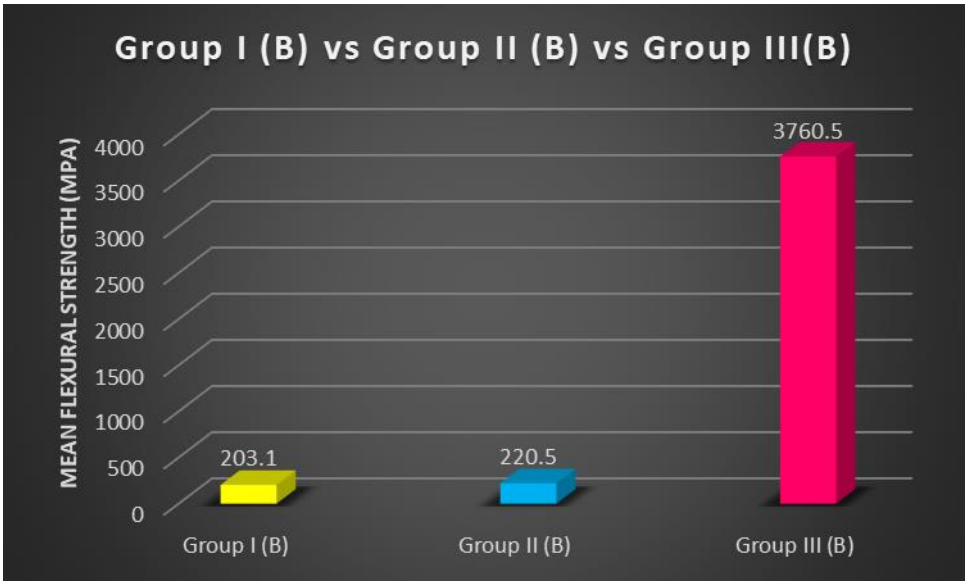
Graph: 15 Comparative evaluation of the mean flexural strength of Group III (A) and Group III (B).



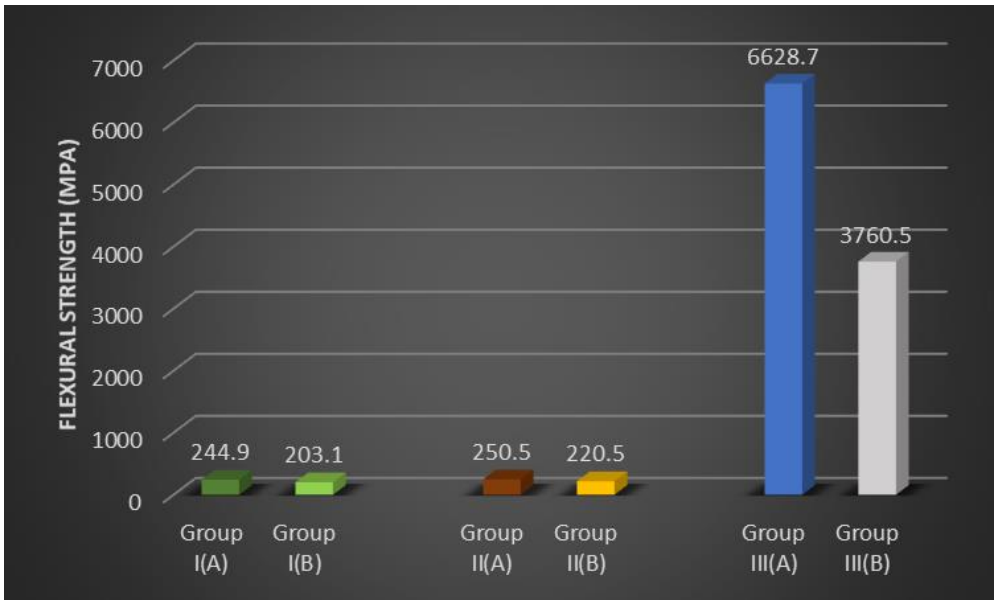
Graph: 16 Comparative evaluation of the mean flexural strength of Group I (A) , Group II (A) and Group III (A).



Graph: 17 Comparative evaluation of the mean flexural strength of Group I (B) , Group II (B) and Group III (B).



Graph: 18 Overall comparative evaluation of the mean flexural strength of Group I (A) and (B),Group II (A) and (B) and Group III (A) and (B).



Discussion

DISCUSSION

Provisional restorations / Interim restorations / transitional restorations plays a vital role in the fixed prosthodontic treatment. These restorations are designed such that they enhance the esthetics, function and stabilization for the fixed prosthesis for a transitional period of time[14,27,47,50]. During the period in the oral cavity provisional restoration must accomplish several functions such as acting as a shield for the pulpal tissues of the prepared tooth against biochemical, biologic and thermal injuries. Provisional restorations can also be used for the alteration of the vertical dimensions, irregular occlusal plane correction and alteration of the gingival tissue contour[28,47].

The provisional restorative materials should possess the following ideal properties, such as adequate retention, good marginal adaptation, resistance to dislodgement during normal mastication, non- irritant to the pulpal tissue and other tissues, durable, dimensionally stable, non-porous, aesthetically acceptable, maintain positional stability and occlusal function, low exothermic reaction, colour stability, easy for fabrication, repair and retrieval, low incidence of allergic reactions (localized), short setting time, favorable for routine home care maintenance, and should have a plaque and stain resistant surface (highly polished surface). But, the provisional restorations for a long term maintenance is considerably difficult for both the dentists and the patient [27,28,40,43,47,52]. Repairing procedures of these restorations can be time consuming. The breakage of the provisional restorations may lead to functional, esthetic problems and tooth movement. And therefore, an appropriate material used for fabrication of the provisional restoration is considered to be critical in fixed partial prosthesis and full mouth rehabilitation cases[27].

The technique used and the material used depends on variable demands of the treatment and requirements [43,47,52].

Many provisional restorative materials are commercially available, but no single interim material has been proved to be ideal for all the clinical situations. By understanding carefully the composition and mechanical properties of these materials available, selection of the suitable material suiting the clinical situation can be done[27].

If the provisional/ interim restorations are expected to function for an extended period of time or when additional treatment is required before the completion of definitive treatment for example like during the dental implants prosthetic phase and reconstructive procedures, in cases of parafunctional habits like bruxism, for in cases of evaluating the change in vertical dimension, for the assessment of the results of endodontic and periodontal therapies ,an improved mechanical properties play an significant role[14]. The material of choice for the long -term and long-span interim prosthesis was Cast metal restorations [30].

Provisional/ interim restorations must also provide an environment that is conducive for the periodontal health maintenance. Provisional/interim restorations which have a poorly adapted margins, are overcontoured or undercontoured and those having a rough or porous surfaces might cause gingival tissue inflammation, overgrowth or recession. Faulty placement of the contour or over contouring of the restoration causes greater hazard to the health of the periodontium than the lack of contouring in the restoration since both sub gingival and supra gingival plaque accumulation is enhanced. This might lead to a unpredictable outcome and unfavorable gingival tissue architecture which might compromise the final restoration success.

Most commonly used material to fabricate the custom interim restoration are acrylic resins which are usually available as powder and liquid. In 1936, Poly methyl methacrylate (PMMA) resins were introduced and in the early 1940's it was available as a room temperature polymerizing methacrylate which was later improved for the field of dentistry as a self-curing prosthetic and restorative resin[6]. The acrylic based resins is mainly composed of polymeric materials based on PMMA. These are most commonly used provisional/ interim material nowadays for both single-unit and multiple-unit restorations. The advantages of poly methyl methacrylate (PMMA) resins are relatively inexpensive with ease of handling, excellent polish and good marginal adaptation. The major disadvantage of these materials is the exothermic reaction, polymerization shrinkage, low wear resistance, low strength and poor colour stability, objectionable odour, short working time, hard to repair and radiolucent and also causes pulpal irritation as a result of excess free monomers [32,39,41,47] and PMMA resins are affected moderately by the free eugenol from the zinc oxide eugenol luting cement which reduces the surface hardness and strength causing softening of the newly added resin. Thus, making the linings or repairs unsuccessful [43].

It was in the 1980's CAD/CAM technique gained popularity due to its various applications in the field of dentistry. There are various studies for the use of CAD/CAM milled materials as the provisional restorations for fixed prosthesis. The advantages of the CAD/CAM milled provisional restorations have good biocompatibility, favorable mechanical properties,and reduces the chair side time. In addition to these, according to Rocca et al., over the last two decades as the CAD/CAM technique has evolved, the instrumentation- the hardware has become less expensive, software is easier to use,

fabrication is faster, and the milled restorations are more accurate in the anatomic form, marginal fit and occlusal/interproximal contacts. In addition, the location and the pontic extension over the soft tissue of the residual ridge can also be virtually determined. New provisional/interim restoration can be fabricated through the second milling process with the preset data. And also, definitive prosthesis fabrication can be done by simulating the shape of the provisional restoration. Hence, the CAD/CAM technique is becoming more popular for the tooth-colored indirect restoration fabrications[14].There are many studies in evaluating the flexural strength of CAD/CAM milled PMMA of different manufacturers and their use as long term provisional restoration.

In recent times Poly-ether-ether-ketone (PEEK) has been used in various purposes in medical field . PEEK was introduced to the field of dentistry in the year 1992 and now been used increasingly in prosthetic dentistry. Advantages of PEEK includes excellent mechanical properties with a high level of biological compatibility, almost non-existence material fatigue, the bone- like elasticity, the lack of metal, plaque resistance and the low specific weight . The material is supplied as industrially-manufactured milling blanks for CAD/CAM – supported processing [49,53,56,64,65] . Various applications of PEEK are as a removable partial denture framework, implant material, metal- and ceramic-free crowns, bridges and for the patients who are allergic to titanium. Due to its tooth like white colour it provides appropriate aesthetics. PEEK is an excellent biomaterial for short-term applications, like temporary abutments and healing caps [13,17,20,34,46]. But, there are not much studies in the use of PEEK as a provisional restorative material for full mouth rehabilitation for long term use.

Hence, in the present in- vitro study was conducted to compare and evaluate the flexural strength of commonly used Autopolymerizing provisional resin (PMMA) (Group I), CAD/CAM milled PMMA (Group II) and CAD/CAM milled PEEK (Group III) after being subjected to aging and thermocycling.

The tests for flexural strength are essentially a test in which a bar is supported at each end, which is subjected to three point flexure. These tests for flexural strength evaluates the compressive stress at the point of load application and tensile and shear stress at the point of resistance, similar to the stresses produced by long- span prosthesis. Flexural strength can be determined using Universal Testing Machine by three point bend test. The determination of the flexural strength of provisional restorative materials using 3 point bend test has been documented in various studies. The flexural strength of provisional restorative materials is influenced by food components, saliva and beverages and interactions between these materials. When subjected to various temperature regulations, changes occur to a material and it should be assessed for a long-term usage. One such process which causes aging of the material is known as thermal cycling which simulates/ mimicking the changes in oral environment [35,61]. Hence, the changes which occur to the material when subjected to different temperature changes must be assessed when the material is used in the long run. A total of 10,000 cycles of thermocycling represent one year on clinical usage. Hence, 1000 cycles and 500 cycles represents the material studied is subjected to stresses equivalent to its clinical usage of 1.2 months (36 days) and 0.6 months (18 days) respectively. Usually , mouth is subjected to a temperature range between −8°C and +81°C, and thus the resulting temperatures on the construction surfaces between 5°C and 55°C [15]. Studies conducted by Yao et al., Lang et al., and Nejatidanesh et al.,

supported the use of thermocycling process to age the material. For partially simulating the oral environment, test samples were stored in artificial saliva and thermocycled (5°C to 55°C) before subjecting to standard three point bending test in universal testing machine [35,61]. pH of the distilled water is 7 which is similar to that of the pH of the saliva 7 and artificial saliva 6.98, hence in the present study the test samples were stored in the distilled water for aging/ conditioning of the samples.

In the present study the total of sixty samples were fabricated, twenty in each group. Autopolymerizing PMMA resin (Group I), CAD/CAM milled PMMA (Group II) and PEEK (Group III). These groups were sub divided based on the number of days of aging and number of thermocycles the samples were subjected to, as

Group I (A) – Autopolymerizing PMMA resin subjected to aging for 7 days and 500 cycles of thermocycling.

Group I (B) – Autopolymerizing PMMA resin subjected to aging for 14 days and 1000 cycles of thermocycling.

Group II (A) – CAD /CAM milled PMMA subjected to aging for 7 days and 500 cycles of thermocycling.

Group II (B) - CAD /CAM milled PMMA subjected to aging for 14 days and 1000 cycles of thermocycling.

Group III (A) - PEEK subjected to aging for 7 days and 500 cycles of thermocycling.

Group III(B) - PEEK subjected to aging for 7 days and 500 cycles of thermocycling.

After the Grouping of the test samples they were placed separately in plastic Petri dish, ten samples in each petri dish. The distilled water obtained from the water distiller was used. The test samples in the each petri dish filled with distilled water obtained from the water distiller and was labelled. These plastic petri dishes were placed in incubator maintained at 37^0 C temperature and subjected to aging/conditioning. The Group I (A), Group II (A) and Group III (A) test samples of Autopolymerizing PMMA resin, CAD/CAM milled PMMA and PEEK respectively where subjected to 7 days of aging/conditioning. The Group I (B), Group II (B) and Group III (B) test samples of Autopolymerizing PMMA resin, CAD/CAM milled PMMA and PEEK respectively where subjected to 14 days of aging/conditioning.

All the samples of Group I (A) and (B), Group II (A) and (B), Group III (A) and (B) were subjected to thermocycling to simulate the intra oral conditions for 500 cycles and 1000 cycles respectively in a distilled water bath maintained between 5º C and 55º C with the dwell time of 6 seconds and a dry time of 5 seconds using a thermocycling apparatus. Various studies have reported that thermocycling decreased the flexural strength of the provisional restorative materials. Upon completion of thermocycling the samples were stored in distilled water in their respective container at room temperature, until they were subjected to flexural strength testing in the order of autopolymerising resin, CAD/CAM milled PMMA followed by PEEK. The test samples were then subjected to three point bending test at a crosshead speed of 0.75 mm/min until the fracture occurred in the universal testing machine.

Within limitations of the study ,after analyzing the data the mean flexural strength of the provisional materials compared were in the descending order :

Group III (A) > Group III (B) > Group II (A) > Group II (B) > Group I (A) > Group I (B)

As per the American National Standards Institute (ANSI) / American Dental Association(ADA) Specifications no.27 and International Organization for Standardization (ISO 4049) ,when a bar of a material is subjected to three point bend test, a minimum strength of 50 Mpa should be possessed by a provisional fixed prosthesis [5]. All the test specimens tested in this study had flexural strength values more than 50 Mpa, by which we infere that all the materials used in this study can comfortably be used for the fabrication of provisional restorations.

Autopolymerizing PMMA resins are most commonly used in the clinical situation as a provisional restorative material. They are mono functional, low molecular weight linear molecules which exhibit decreased rigidity and strength. Lack of time available for the cold cure monomer in self-cure resin to wet the autopolymerizing polymer beads, might be the reason for decreased flexural strength. Thus, a less homogenous polymer is produced and the material when subjected to themal cycling deforms under stresses unlike other materials [6,35].

The CAD-CAM milled CAD/CAM milled PMMA showed higher flexural strength than the autopolymerizing resin. The manufacturer of the CAD/CAM milled PMMA stated that the material included highly cross-linked PMMA and was cured under idealized conditions. The cross-linking consists of methacrylic acid ester-based polymers. According to Edelhoff et al ., these high-density polymers based on highly cross-linked resins are manufactured in an industrial process, which exhibits superior qualities. A

research conducted by Alt et al., investigated the influence of fabrication method, storage condition, and use of different materials, on the fracture strength of provisional 3-unit FDPs using CAD/CAM technologies and resin-based blanks cured under optimal conditions and concluded that CAD/CAM specimens exhibited increased mechanical strength and had less porosity within the restoration. Thus, it can be proposed that it was due to these optimal curing conditions, the CAD/CAM milled PMMA specimens showed the higher flexural strength than Autopolymerizing PMMA resin. Thus, the CAD/CAM PMMA material is a more convenient temporary material than the other PMMA groups made by direct techniques.

On comparison with Autopolymerizing PMMA resin and CAD/CAM milled PMMA , PEEK showed the highest of flexural strength.

After subjecting to 14 days of aging and 1000 cycles of thermocycling, the flexural strength of the test samples was less when compared to the samples subjected to 7 days of aging and 500 cycles of thermocycling samples in all the three groups indicating the long term use of the interim prosthesis, indicating that the flexural strength has decreased during the long run of the prosthesis.

Within limitations of the study PEEK subjected to 7 days of aging and 500 cycles of thermocycling (Group III (A)) had a highest flexural strength on overall comparison followed by the PEEK subjected to 14 days of aging and 1000 cycles of thermocycling (Group III(B)). Thus, suggesting that even though the flexural strength decreases with prolonged time of usage, the PEEK is a suitable material for the use a provisional restoration for full mouth rehabilitation cases and the patients requiring a long

term interim restoration before the definitive prosthesis. But the main concern is the economical factor.

The present in vitro study has some limitations. Although the study was designed in an attempt to simulate in-vivo conditions, it still had limitations in replicating clinical conditions accurately. Another aspect in clinical situations is that an immediate load is placed on the interim prosthesis once it is cemented into place but in this experiment a load was not applied until 7 days &14 days of distilled water storage. There are further investigation required for evaluating the other properties like color stability, marginal adaptability, micro-hardness, and absorption to assess the superiority and efficiency of PEEK as a long term interim/provisional restoration and help the clinician to choose the PEEK over other materials.

Conclusion

CONCLUSION

The following conclusions were drawn based on the results obtained in the present in vitro study, which was conducted to compare and evaluate the effect of aging/conditioning and thermocycling on the flexural strength of PEEK , CAD/CAM milled PMMA and Autopolymerizing PMMA resin.

1. The flexural strength of Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling (Group I (A)) shows a mean value of 244.90 Mpa.

2. The flexural strength of Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling (Group I(B)) shows a mean value of 203.10 Mpa.

3. The flexural strength of CAD/CAM milled PMMA after 7 days of aging and 500 cycles of thermocycling (Group II (A)) shows a mean value of 250.50 Mpa.

4. The flexural strength of CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling (Group II (B)) shows a mean value of 220.50 Mpa.

5. The flexural strength of PEEK after 7 days of aging and 500 cycles of thermocycling (Group III (A)) shows a mean value of 6628.70 Mpa.

6. The flexural strength PEEK after 14 days of aging and 1000 cycles of thermocycling (Group III (B)) shows a mean value of 3760.50 Mpa.

7. On overall comparison the mean flexural strength of the test samples, PEEK after 7 days of aging and 500 cycles showed the highest mean flexural strength (Group III (A), mean value- 6628.70 Mpa), followed by PEEK after 14 days of aging and 1000 cycles of thermocycling (Group III (B), mean value- 3760.50 Mpa), followed by CAD/CAM milled

PMMA after 7 days of aging and 500 cycles of thermocycling (Group II (A), mean value - 250.50 Mpa) , followed by Autopolymerizing PMMA resin after 7 days of aging and 500 cycles of thermocycling (Group I (A), mean value - 244.90 Mpa) followed by CAD/CAM milled PMMA after 14 days of aging and 1000 cycles of thermocycling (Group II (B), mean value -220.50 Mpa) and Autopolymerizing PMMA resin after 14 days of aging and 1000 cycles of thermocycling (Group I(B) , mean value - 203.10 Mpa) showed the least mean flexural strength.

8. The student 't' test revealed the following inferences,

- The mean flexural strength of Group II (A) (250.50 Mpa) is higher than Group I (A) (244.90 Mpa) , but the difference is statistically not significant ('p' value > 0.05).
- The mean flexural strength of Group III (A) (6628.70 Mpa) is higher than Group I (A) (244.90 Mpa), and the difference is statistically significant ('p' value < 0.05).
- The mean flexural strength of Group III (A) (6628.70 Mpa) is higher than Group II (A) (250.50 Mpa), and the difference is statistically significant ('p' value < 0.05).
- The mean flexural strength of Group II (B) (220.50 Mpa) is higher than Group I (B) (203.10 Mpa) , but the difference is statistically not significant ('p' value > 0.05).
- The mean flexural strength of Group III (B) (3760.50 Mpa) is higher than Group I (B) (203.10 Mpa), and the difference is statistically significant ('p' value < 0.05).

- ❖ The mean flexural strength of Group III (B) (3760.50 Mpa) is higher than Group II (B) (220.50 Mpa), and the difference is statistically significant (‘p’ value < 0.05).
- ❖ The mean flexural strength of Group I (A) (244.90 Mpa) is higher than Group I (B) (203.10 Mpa), and the difference is statistically significant (‘p’ value < 0.05).
- ❖ The mean flexural strength of Group II (A) (250.50 Mpa) is higher than Group II (B) (220.50 Mpa), and the difference is statistically significant (‘p’ value < 0.05).
- ❖ The mean flexural strength of Group III (A) (6628.70 Mpa) is higher than Group III (B) (3760.50 Mpa), and the difference is statistically significant (‘p’ value < 0.05).

9. The ANOVA test revealed the following inferences,

- ❖ The mean flexural strength of Group III (A) (6628.70 Mpa) is higher than Group II (A) (250.50 Mpa) and Group I (A) (244.90 Mpa), and the difference is statistically significant (‘p’ value < 0.05).
- ❖ The mean flexural strength of Group III (B) (3760.50 Mpa) is higher than Group II (B) (220.50 Mpa) and Group I (B) (203.10 Mpa), and the difference is statistically significant (‘p’ value < 0.05).

Thus the present in vitro study concludes, that the mean flexural strength of CAD/CAM milled PEEK is greater than the CAD/CAM milled PMMA and the Autopolymerizing PMMA resin after subjecting to aging/conditioning and thermocycling. But the mean flexural strength of CAD/CAM milled PEEK after subjecting to 14 days of

aging/conditioning and 1000 cycles of thermocycling reduced approximately by 44% when compared to the PEEK samples which were subjected to 7 days of aging/ conditioning and 500 cycles of thermocycling, but it was not in the case of CAD/CAM milled PMMA and Autopolymerizing PMMA in which the mean flexural strength reduced approximately by 12% and 18% respectively.

Summary

SUMMARY

The present in vitro study was conducted to compare and evaluate the effect of aging/conditioning and thermocycling on the flexural strength of the PEEK , CAD/CAM milled PMMA and Autopolymerizing PMMA resin as provisional restoration for full mouth rehabilitation.

A total of sixty samples were fabricated for the present study. The grouping of the samples was done based on the material used for the fabrication of the samples with twenty samples each and designated as Group I (Autopolymerizing PMMA resin), Group II (CAD/CAM milled PMMA) and Group III (PEEK).These test samples were again sub-grouped based on the aging/ conditioning and the number of thermocycling cycles as Group I (A), Group I(B) ,Group II (A), Group II (B) , Group III (A) and Group III (B). Group I (A) were the autopolymerizing PMMA resin samples which were subjected to 7 days of aging/conditioning and 500 cycles of thermocycling. Group I (B) were the Autopolymerizing PMMA resin samples which were subjected to 14 days of aging/ conditioning and 1000 cycles of thermocycling. Group II (A) were the CAD/CAM milled PMMA samples which were subjected to 7 days of aging/conditioning and 500 cycles of thermocycling. Group II (B) were the CAD/CAM milled PMMA samples which were subjected to 14 days of aging/ conditioning and 1000 cycles of thermocycling. Group III (A) were the CAD/CAM milled PEEK samples which were subjected to 7 days of aging/conditioning and 500 cycles of thermocycling. Group III (B) were the CAD/CAM milled PEEK samples which were subjected to 14 days of aging/ conditioning and 1000 cycles of thermocycling.

All the sixty test samples after grouping were subjected to aging / conditioning by storing in distilled water at 37^{O} C in the incubator for the respective days and subjected to thermocycling in the thermocycling unit for the respective number of cycles. These test samples were tested for the flexural strength using the 3- point bending test in the Universal Testing Machine. The basic and mean values of flexural strength of all the test samples of all the groups were tabulated and subjected to statistical analysis.

The mean flexural strength values for all the test groups were compared and found to be statistically significant. The mean flexural strength of the PEEK samples subjected to 7 days of aging/conditioning and 500 cycles of thermocycling (Group III (A)) was the highest followed by PEEK samples subjected to 14 days of aging/conditioning and 1000 cycles of thermocycling (Group III (B)) followed by CAD/CAM milled PMMA samples subjected to 7 days of aging/conditioning and 500 cycles of thermocycling (Group II (A)) followed by CAD/CAM milled PMMA samples subjected to 14 days of aging/conditioning and 1000 cycles of thermocycling (Group II (B)) followed by Autopolymerizing PMMA resin samples subjected to 7 days of aging/conditioning and 500 cycles of thermocycling (Group I (A)) and Autopolymerizing PMMA resin samples subjected to 14 days of aging/conditioning and 1000 cycles of thermocycling (Group I (B)) was the least.

Group III (A) > Group III (B) > Group II (A) > Group II (B) > Group I (A) > Group I (B)

The present study revealed that the PEEK subjected to aging/conditioning and thermocycling showed the maximum flexural strength compared to the CAD/CAM

milled PMMA and the Autopolymerizing PMMA resin. Hence, PEEK can be given as a provisional restorative material for full mouth rehabilitation cases as long- span and long- term provisional material compared to the CAD/CAM milled PMMA and Autopolymerizing PMMA resin.

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