‘COMPARATIVE EVALUATION OF EFFECT OF REPEATED MICROWAVE DISINFECTION ON THE SURFACE HARDNESS OF POLYETHERETHERKETONE (PEEK): *AN IN-VITRO STUDY’*

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IN

PROSTHODONTICS INCLUDING REMOVABLE, FIXED, MAXILLOFACIAL AND IMPLANTOLOGY

BRANCH I

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CONTENTS

LIST OF PHOTO PLATES

LIST OF TABLES

LIST OF GRAPH

LIST OF MATER CHART

LIST OF ABBREVIATIONS USED

No.	Abbreviation	Full form
1	PEEK	polyetheretherketone
2	PMMA	Polymethyl Methacrylate
3	PAEK	Polyaryletherketone
4	g/cm3	Gram per centimetre cube
5	^{0}C	Degree Celsius
6	%	Percentage
7	mm	Milimeter
8	i.e	That is
9	PMMA	Polymethyl Methacrylate
10	CAD/CAM	Computer Aided Designing and Computer Aided Machining
11	W	Wattage
12	min.	Minute
13	VHN	Vickers Hardness Number
14	HM	Martens Hardness
15	STL	Stereolithography/Standard Tessellation Language
16	ADA	American Dental Association
17	SH	Surface Hardness
18	MWC	Microwave Disinfection
19	HV	Vickers Hardness
20	gm	gram
21	ANOVA	Analysis of Variance
22	$N/mm.^2$	Newton per milimeter square
23	p value	Probability of happening of an event

INTRODUCTION

Prosthodontics is a speciality that deals with the replacement of missing teeth along with associated soft tissues and hard structures. These include removable or fixed prostheses. The demand for Prosthodontics has increased with increase in the years of survival of people due to advancement in the medications and treatment for certain illness of old age. With increase in the lifespan, concern towards oral health along with general health has also evolved. Considering the condition of the ridge and the available support from the surrounding structures, the patients is either provided with fixed, removable prosthesis or implant prosthesis. Apart from these, maxillofacial prosthesis is also a part of the specialty.

Prosthesis fabrication involves certain steps including patient's assessment, planning a treatment plan, making an impression to obtain its replica, pouring of impression with a gypsum product to obtain a positive replica, creating a prosthesis design as required, processing of prosthesis and finally delivery of the prosthesis to the patient.[1] This complete procedure involves different professionals like dental chair side assistant, laboratory technicians, dentists, other personnel including patients.

The use of resins as denture base materials was initiated by Dr. Leo Bakeland in 1909 by using phenol formaldehyde resin. Because of its outstanding esthetics, easy processing, relining, and repair techniques, PMMA is still considered the most preponderant denture base material. Thus, the combination of these desirable properties makes it the material that is being widely used. It is seen that when this material is used as a denture base material, it is not perfect for everything, especially its mechanical properties.[2]

Biocompatibility is a very essential requirement in all restorative materials, followed by physical and mechanical properties which guarantee proper structural and functional durability over extensive period of time. Hence now a days Polyetheretherketone (PEEK) has been introduced in dentistry for many purpose as it gives advance effect in dental materials.[3] PEEK is a semi-crystalline thermoplastic biomaterial. It belongs to the polymer group of Polyaryletherketones (PAEKs). It is characterized by ultra-high molecular weight of polyethylene. It has employed in industry as new material and used for medical purposes as biomedical material.[4] since last 20 yrs, it gets more attraction of interest towards implantable material for medical devices. It is available as granules which are to be pressed and circular disks of plank to be milled.

PEEK is a dominant material which has high chemical and mechanical resistance, also high-temperature stability exceeding 300^0C. In the field of trauma and orthopedics, it will be considered as a primary auxiliary for metallic constituents. PEEK has low elastic modulus, low density (1.32 g/cm3), high stability and insolubility, due to which it gives clinical advantages to considered as a dental implant biomaterial compared to Titanium. It causes less hypersensitivity and allergic reactions. It is radiolucent material and has a more aesthetic appearance than Titanium. Also, PEEK has a versatile foundation that can be custom-made to a particular purpose by changing its thickness or bulk and surface properties.(5)

With recurrent exposure towards the microorganisms containing salivary fluid and blood, the dental profession has become on a higher risk for certain infectious disorders or diseases as compared to the general population. The routine care provided to the patients puts the dentist at higher risk of acquiring diseases due to chances of cross-infection. The occupational potential for transmission of diseases is evident due to the fact that most of the pathogen from human micro-organism were separated from the secretions of oral cavity.

Dentistry is considered to be extremely hazardous. Infection hazard, psychological hazard, allergic reactions, physical hazards, mercury health hazards, ionizing radiation, non-ionizing radiation hazard are commonly found among the dentist and dental personnel. Among these infectious hazard is of utmost importance to prevent majority of diseases.(6) The transmission of microbial agents usually happens by direct contact with the infectious agent like blood and saliva, indirect contact with the infectious agents like through handling of contaminated items with blood and saliva, transfer of microorganisms via aerosol generation procedures and splatter of secretions of nasopharynx, blood and saliva directly over the intact or the broken mucosa of the skin. 67% of micro-organisms were found over the surface of dentures, crowns, impressions, wax patterns which were of carrying pathogenicity. Escherichia coli, Klebsiella oxytoca and Enterobacter cloacae were the commonly identified bacteria.(7) Moreover, the splash coming from the patient's oral cavity is difficult to get remarked further adding to the negligence of the risk potential.(8)

Certain life threatening diseases have been linked in the dental practice such as Hepatitis B virus, Herpes, Hepatitis C virus, Human Immunodeficiency virus and Pneumonia, Epstein-bar virus, varicella zoster, Human papilloma virus, upper respiratory tract pathogens like influenza A and B viruses, measles, mumps, rubella(9) and COVID 19. Viral infection is the result of infection spread due to cross contamination from prosthesis, impression material, handling of laboratory procedures etc.(10) 0.5% dentists per yeas are reported to be exposed to HIV during the dental treatment procedure provided to the patients.(9) Another study reported Hepatitis B virus infection of 6.1% among the dental personnel with 18% prevalence of lifetime exposure. Thus attention needs to be focused on the risk of infection involved due to inadequate sterilization of the equipment or dentist-patient contact with HBsAg carriers (11) and COVID-19 virus infection.

Literature throws light of various methods used for disinfecting the prosthesis so as to prevent the spread of microorganisms from patients to the dentist and further. According to the Council of Dental Therapeutics, there are four categories of disinfectant accepted which include; glutaraldehyde, chlorine solutions, iodophors and formaldehyde.(12) Glutaraldehyde is a saturated dialdehyde and works best when activated by using alkalinating agents. The chemical causes alteration of RNA, DNA and protein synthesis of microorganisms by its biocidal activity. The chlorine solutions have a broad spectrum of antimicrobial action against microorganisms that leave no toxic residue and remain unaffected by water hardness. They cause loss of nutrient uptake, loss of intracellular contents and inhibition of protein synthesis, DNA breakdown and decreased oxygen uptake by microorganisms. Iodophors have the ability to penetrate the cell walls causing lethal effect to the microorganisms by disrupting synthesis and structure of nucleic acid and protein. These are known to be mycobactericidal, bactericidal and virucidal in nature. Formaldehyde portrays its action by alkylating sulfhydryl and amino groups of proteins and ring nitrogen atoms of purine bases.(12)

Another concern which needs to be considered is the effect of these disinfectants on the denture material. Literature reports alteration of mechanical and physical properties of materials by subjecting them to disinfectants. The materials represented with brownish discoloration of acrylic materials and teeth along with irritation to oral mucosa due to release of certain toxins from disinfectant ingredients. Offensive odour was another drawback followed by corrosion of denture framework due to bleaching action of the disinfectants leading to decreased strength of the denture materials. Moreover, certain chemicals possessed cytotoxicity risk and thus were considered inappropriate for patients as well at chair side for the dentist for disinfection.(13)

Apart from these traditionally used methods, other alternative methods are microwave irradiation and photodynamic therapy..(14,15) The photodynamic therapy involves the use of photosynthesizer which is a photo active dye activated by a specific wavelength light in the presence of oxygen. This results in transfer of protons and electron from photo active dye to atmospheric oxygen which further results in highly toxic free radical that possess cell structures leading to inactivation of pathogens.(14) In case of microwave irradiation, electromagnetic waves of frequency close to television and aircraft radar are used to irradiate the microorganisms from the denture materials.(13) The clinical relevance microwave disinfection is that this procedure can be performed quickly and repeatedly, without the use of toxic, pungent, or allergenic chemicals. It is demonstrated that short period of microwave energy inhibits the growth of pathogenic microorganism. Hence microwave irradiation is most commonly used disinfected method for dentistry.(16)

Addition to the disinfectant, denture material too has a role to play in the physical and mechanical properties. The disinfection procedures cause changes in hardness of the material. Hardness is defined as “Resistance to indentation”. The surface hardness of a denture is based upon its ability to resist indentation or scratching.(17) Measurement of surface hardness of any material indicate up to what range the masticatory forces can be resisted.(18) The newer material i.e., PEEK which is semi crystalline and thermoplastic biomaterial having ultra-high molecular weight. It is highly biocompatible and solvent resistant making it different from the materials being traditionally used for denture. PEEK is introduced in dentistry as a dimensionally stable thermoplastic material.(19) Since microwave (MW) disinfection of PEEK material is not yet studied, this study aims to evaluate the effect of repeated cycle of microwave disinfection on the surface hardness of Polyetheretherketone material.

AIM AND OBJECTIVES

AIM: -

To evaluate and compare the effect of repeated microwave disinfection on surface hardness of polyetheretherketone (PEEK).

OBJECTIVES: -

PRIMARY OBJECTIVE:

To evaluate the effect of repeated microwave disinfection on surface hardness of polyetheretherketone (PEEK).

OTHER OBJECTIVE 1:

To compare the effect of repeated microwave disinfection on surface hardness of polyetheretherketone (PEEK).

REVIEW OF LITERATURE

Azzarri MJ, Cortizo MS, Alessandrini JL (2003)[20] conducted a study on hardness and impact strength of microwave polymerised resin after different conditions of curing on the residual monomer. By using spectrophotometer, the released residual monomer was assessed up to 24 hr. they were observed the significant difference in the property of impact strength and hardness in the analysed condition. They concluded that optimisation of residual monomer can cause less cytotoxicity with best mechanical properties by proper selection of power and time of the curing resin.

Lai C-P, Tsai M-H, Chen M, Chang H-S, Tay H-H (2004) [21] conducted a study for examination of impact resistant denture material poly (methyl methacrylate) to examine the influence of microwave energy level with thickness of 10mm. Two resin blocks were processed in microwave flask at different temperatures. These variations in temperature were recorded with time during heating at 80, 160 and 240

W correspondingly. The results showed that minor changes occur in mean values of weight percentage and surface hardness, the porosity in microwave cure was more than the water bath cure. The conventionally cured specimen showed better hardness and flexural strength.

Godara A, Raabe D, Green S (2007)[22] conducted a study for micromechanical properties and structural integrity of thermoplastic polyetheretherketone (PEEK) composite which are reinforced by using carbon fibers (CF) due to sterilisation effect by indentation and nano-scratch test. The result revealed that any sterilisation that is steam or gamma radiation does not effect on hardness, elastic modulus and coefficient of friction. Very minor changes in the interphase of PEEK had seen. Hence they concluded that more significant influence seen in interphase zone due to sterilisation method of steam.

Machado AL, Breeding LC, Vergani CE, da Cruz Perez LE (2009)[23] conducted a study for evaluation of Vickers hardness and surface roughness affected by chemical and microwave disinfection of reline resins such as Kooliner, DuraLiner and heat-polymerized denture base resin like Lucitone. Parameters were evaluated after polymerisation which immersed in water or repeated microwave disinfection. The obtained results showed that the microwave disinfection increased the mean (SD) hardness of Kooliner and DuraLiner , whereas Lucitone remained unaffected. Hence the study concluded that repeated microwave disinfection increases the roughness of liner resin whereas microwave irradiation not affect the hardness of material.

Senna PM, Da Silva WJ, Faot F, Del Bel Cury AA (2011)[24] conducted a study for effect of microwave power on physical properties of PMMA denture resin.

Some sets of specimen were disinfected by water bath and another one by microwave energy by immersing in distilled water. Specimen was disinfected by microwave irradiation at different power for 3 minutes. It was found that repeated cycle of microwave irradiation increases the surface roughness and hardness. No significant change was noticed in flexural strength, crack propagation and impact strength. The conclusion of the study suggests that microwave disinfection of PMMA at power 450 to 650 W for 3 min is safe.

Campanha NH, Pavarina AC, Jorge JH, Vergani CE, Machado AL, Giampaolo ET (2012)(25) conducted a study to investigate Vickers hardness (VHN) of acrylic resin denture teeth affected by long term disinfection. In this study acrylic and composite resin denture teeth were disinfected for 7 days in 1% sodium hypochlorite and daily cycle of microwave sterilisation at 650 watts for 6 minutes. Also the specimen was maintaining in water while performing the disinfection procedure. The result found that microwave disinfection decreased hardness of acrylic teeth. While immersion in 1% hypochlorite shows no significant change on hardness. Hence the study concluded that hardness can be reduced by microwave disinfection.

Vasconcelos LR, Consani RLX, Mesquita MF, Sinhoreti MAC (26) prepared a microwave disinfection model and acrylic resin teeth was subjected for microwave disinfection cycle. The study reported that Micro-hardness decreases as the number of disinfection cycle increases compared to control group which was not disinfected by microwave.

Xin H, Shepherd DET, Dearn KD (2013)(27) conducted a study for investigation of effect of thermal ageing and sterilisation on strength of polyetheretherketone (PEEK). Specimens had been sterilised, aged and annealed. Specimens were tested to static and dynamic bending load. Result of the study showed that ageing and sterilisation had no significant change in yield strength. And the study concluded that dynamic test had no effect on hardness and fatigue strength after sterilisation.

Mathew M, Shenoy K, Tech M (2014)(28) conducted a study to investigate wear rate and Vickers Hardness of PMMA reinforced with polypropylene by varying the weight and ratio of reinforcing fibers. Wear rate was calculated by measuring the weight loss in pin on disc by monitor of friction and wear. The abraded microstructure observed through trinocular metallurgical model. The result of the study revealed that reinforcement of polypropylene fibers showed superior Vickers hardness and less wear rate. The authors concluded that the reinforcement of polypropylene fibers gave the better property of hardness while the wear rate showed no significant change.

Ji S, Sun C, Zhao J, Liang F (2015)(29) conducted a study for comparison of the mechanical property of machinable Polyetheretherketone (PEEK) and carbon-fibers reinforced PEEK by nano-indentation method. The result revealed that PEEK can present better uniformity, Young’s modulus variation and hardness for both the group with smaller change at experimental depth, due to its superior machinability.

Stawarczyk B, Eichberger M, Uhrenbacher J, Wimmer T, Edelhoff D, Schmidlin PR (2015)(30) conducted a study to for investigation of fracture load on three-unit reinforced polyetheretherketone composite (PEEK/C), influenced by different fabrication method. The fabricated samples were milled by CAD/CAM, pressed PEEK from pellets, and pressed from granular PEEK. Amongst these, CAD/CAM fabricated showed higher mean fracture load. While the granular had some plastic deformation without fracture. The study concluded that reliability and stability can be increased in pre pressed pellets of CAD/CAM.

Najeeb S, Zafar MS, Khurshid Z, Siddiqui F (2016)(3) reported a review for dental application and future aspects of PEEK in dentistry. Various online databases using keywords related to PEEK were carried out. The evidence publicized that PEEK has many applications in dentistry. PEEK can be used for dental implant which have less stress shielding effect compared to titanium, closely match the mechanical properties to alveolar bone. Also this material is applicable for fixed and removable prosthesis. The review concluded that as the mechanical properties of PEEK are very close to bone, it can be used in many area of dentistry.

Liebermann A, Wimmer T, Schmidlin PR, Scherer H, Löffler P, Roos M (2016)(31) conducted a study to investigate the mechanical properties of CAD/CAM polymerised material affected by different aging regimens/durations. Various specimens of PEEK were fabricated. The obtained result declared that storage media had no any significant change on water sorption and surface roughness. Physiological saliva revealed highest impact on solubility. PEEK had the lowest solubility and water sorption. PMMA showed lowest Martens hardness (HM) and indentation modulus compared to PEEK. Hence the study concluded that the hardness parameter of PMMA based materials were comparable with PEEK.

Heimer S, Schmidlin PR, Stawarczyk B (2016)(32) conducted a study for determination of surface roughness, surface energy of PEEK, PMMA based and composite material affected by individual laboratory and professional cleaning method. Various cleaning techniques were considered such as oral prophylaxis by soft, medium and hard toothbrush, lab cleaning system like Sun-Sparkle, ultrasonic bath and Al_2O_3-powder and Perio prophylaxis like perioscaler etc. Cleaning by air abrasion produced higher surface roughness. PMMA and PEEK presented lower Surface Free Energy after cleaning compared to composite and mentioned that all the methods except air abrasion can used to clean PEEK.

Wimmer T, Gallus K, Eichberger M, Stawarczyk B (2016)(33) conducted a study to investigate the influence of specimen geometry and test configuration on body wear rate of CAD/CAM polymerised material. The evaluated CAD/CAM polymerised materials were thermoplastic PEEK, PMMA based material and nanohybrid composite (COMP). All the specimens underwent from thermomechanical loading opposing to enamel and stainless steel. PEEK had less material loss compared to CAD/CAM and COMP. Lateral force significantly showed higher material loss compared to axial load. This study concluded that PEEK had lower wear rate compared to resin based materials for lateral forces but comparable antagonist wear rate.

Awaja F, Cools P, Lohberger B, Nikiforov AY, Speranza G, Morent R (2017)(34) conducted a study to investigate biomedical device integration by using amorphous carbon/diamond like coatings to hermetically seal and biologically enhance PEEK. The hardness and thickness for coating of PEEK were controlled by H_2 and N_2 concentration. The thickness showed strong relation with hardness coating. Water impermeable to coating on PEEK showed strong bioactivity. It is viable for osteoblastic and fibroblastic cells without any toxicity. Hence, there was not any relation found between coatings and biological performance polymer.

Lümkemann N, Eichberger M, Stawarczyk B (2017)[(35)] conducted a study to examine Martens hardness of different PEEK qualities by using filler such as titanium dioxide (TiO_2), explicitly PEEK with 0%, PEEK with 20%, and PEEK with 30% after the impact of irradiation. Each specimen was fabricated and air abraded with aluminium oxide. Hardness parameter were measured initially and after irradiating by different wavelength. The authors concluded that impact of different irradiation affects the hardness of PEEK. The increase in TiO_2 in PEEK matrix can increase the hardness. However, these material showed lower hardness compared to human teeth.

Bodden L, Lümkemann N, Köhler V, Eichberger M, Stawarczyk B (2017)[(36)] conducted a study for investigation of mechanical, optical and thermodynamic properties of filled and unfilled PEEK and their impact by heating process. Different PEEK qualities were used by isostatic pressing. The determined tests included Martens-Hardness (HM), indentation test, melting temperature, Translucency, glass transition temperature etc. Specimen were exposed to quenching to evaluate the different parameters. After heating, the unfilled materials were more translucent and suspected that crystalline structure was melted and matrix stayed in amorphous state. Hence the possible explanation for the comparable value could be remaining amount of crystal that still stays in solid phase. The result of the study found that effect of quenching process increases translucency while the hardness was decreased significantly because of melted crystalline structures and the more remaining amorphous domains through quenching.

Ma R, Guo D (2017)[37] conducted a study for determination of mechanical properties of hydroxyapatite composite/ PEEK composite. For bioactivation of hydroxyapatite, silane coupling agents were used to modify the graft and to prepare the PEEK composite by hot press moulding. The result showed that silane coupling agent in hydroxyl apatite composite increase the tensile strength. Also in non-modified composite, no significant change in tensile strength was found. The inference of the study stated that nano-scale filler from bioactive PEEK substrate contribute towards growth of surrounding bone.

Kumar A, Yap WT, Foo SL, Lee TK (2018)[38] investigated hardness of PEEK material when subjected to repetitive cycles of 10 and 20 at 121°C of sterilization without presence of moisture. The maximum change in hardness was reported to be 7%. After 20 microwave irradiation cycles, the hardness increased to 48% which was followed by decrease in hardness until 17% after 40 microwave disinfection cycles. Post 40 cycles, the hardness remained stable in a range of 10.34-17.24%. This change was due to moisture absorption in polymer occurs through diffusion and capillary process which induce plastic deformation, which resulted in changed hardness. The effects of sudden cooling of the material had also been documented to affect the surface hardness. Due to faster cooling rate, more line and point defects may get induced in the material. This leads to a faster and deeper diffusion within the PEEK material with respect to moisture.

Jaiswal P, Pande N, Banerjee R, Radke U (2018)[18] conducted a study for determination of the surface hardness of PMMA material after repeated cycle of microwave disinfection. In this study, four groups were divided according to number of cycle like 0,1,3 and 5. The obtained result stated that there had no significant change after repeated microwave irradiation on surface hardness. The difference in surface hardness value between the groups because of reduction in residual monomer level due to leaching out monomer with increase in temperature. Inference of the study stated that microwave disinfection used regularly in dental practice disinfect the dentures.

Alsadon O, Wood D, Patrick D, Pollington S (2018)[39] conducted a study to compare the optical and mechanical properties between milled and Pressable PEEK. The study was concluded that Pressable and milled PEEK showed no significant difference in color values, flexural strength and hardness. This pressing protocol is time consuming method compared to CAD/CAM milling.

Niem T, Youssef N, Wöstmann B (2019)[40] conducted an in-vitro study to assess the capability for dissipation of destructive fracture energy of CAD-CAM restorative materials compared with a high-gold alloy to check the resiliency and toughness. Three groups of restoration were involved such as 3-unit fixed partial dentures, crowns and onlays and interim prostheses. The modulus of toughness, resiliency and elastic were determined. The obtained result showed the significant difference in modulus of resilience, toughness, the elastic recovery among the material. 3 unit FPD showed the highest value of toughness. All the material showed higher dissipation of energy by elastic and plastic deformation. Crown and onlays responsible for least able for restoration. As PEEK showed higher values for the modulus of resilience and better ability for dissipation of energy, compared IPS e.max CAD. The study concluded that, polymer-based CAD-CAM restorative materials had higher modulus of elastic and toughness compared to ceramic which dissipate destructive energy.

Bathala L, Majeti V, Rachuri N, Singh N, Gedela S (2019)(41) conducted a review for applications of PEEK in dentistry. They have mentioned that the PEEK material has superior as well as high mechanical properties and can be considered to be promising in future as an alternative to metals like Titanium and Zirconium. Therefore, it can be used in various treatments modalities: including dental implants, removable and fixed prosthesis, including orthopaedic medical specialities.

Klur T, Hasan I, Ottersbach K, Stark H, Fichte M, Dirk C (2019)(42) conducted a randomized controlled clinical trial, to investigate whether the high-performance polymer PEEK is equivalent alternative to cobalt chromium (Co-Cr) restorations, regarding comfort, stability and biocompatibility. The study concluded that, temporaries made by PEKK offer a good and stable alternative for restorations with Co-Cr. Also it showed a high aesthetic appearance compared to Co-Cr restoration.

Soni A, Smith J, Thompson A, Brightwell G (2021)(43) conducted a study on microwave induced thermal sterilisation. Microwave assisted thermal sterilisation (MATS) combines the energy from microwave along with hot water immersion. This was the successful sterilisation method accepted by Food and Drug Administration (FDA) to eliminate pathogen.

da Cruz MB, Marques JF, Peñarrieta-Juanito GM, Costa M, Souza JCM, Magini RS (2021)(44) conducted a study for investigation of mechanical characterisation of bioactive-modified PEEK dental implants. The discs of PEEK, PEEK with 5% hydroxyapatite (HA), PEEK with 5% beta-tricalcium phosphate (bTCP), and Ti6Al4V were produced. The test parameters included are water contact angle, surface roughness, hardness and shear bond strength. The results showed that all the tested samples presented similar roughness while Ti_6Al_4V samples have highest contact angle. Vickers hardness of different PEEK materials found similar. As the osteoblast adhesion was higher on pure PEEK whereas PEEK with HA promoted lowest cell attachment. So the study concluded that addition of 5% hydroxyapatite or beta calcium did not enhance the mechanical properties of PEEK.

Shrivastava SP, Dable R, Raj APN, Mutneja P, Srivastava SB, Haque M (2021)(2) conducted a study to evaluation of surface hardness and flexural strength between polyetheretherketone (PEEK) and heat-cured poly-methyl-methacrylate (PMMA). The flexural strength of PMMA was 84 MPa while PEEK showed 183 MPa. Whereas the hardness of PMMA was 24 VHN and PEEK was 19.4 VHN. The properties of PEEK such as solvent resistance, biocompatibility and modulus of elasticity were found similar to that of the bone. The results revealed that PEEK can be a potential material for denture base as it has superior mechanical properties compared with PMMA and also adequate flexural strength which provides prolong clinical longevity.

da Costa Valente ML, da Silva GG, Bachmann L, Marcondes Agnelli JA, Dos Reis C (2021)(45) conducted a study to evaluate the effect of before and after thermocycling, on the surface hardness and roughness, of polyether-ether-ketone (PEEK), for an implant-supported and retained removable partial prosthesis. The result found that there was no change in the surface roughness and hardness of PEEK, due to crystallinity of this material, which decreased after thermocycling. Thus, proved to be good mechanical and physical behaviour.

Benli M, Eker Gümüş B, Kahraman Y, Yağcı Ö, Erdoğan D, Huck O (2021)(46) conducted a study for evaluation of commonly used dental polymers and their structural properties. The dental polymer used are poly-ethylene-terephthalate-glycol modified (PG), poly-methyl-methacrylate (PMMA), ethylene-vinyl-acetate(E), poly-carbonate (PC) and poly-ether-etherketone (PEEK). Result showed that PEEK and PMMA showed highest hardness followed by polycarbonate and poly-ethylene-terephthalate- glycol modified (PG). Lowest hardness belonged to ethylene acetate which displayed the most irregular surface. The study concluded that PEEK and PMMA polymers can be used for stress-containing treatments like denture base, provisional restoration, mouth guard or build up due to their superior mechanical properties.

Eraslan R, Colpak ED, Kilic K, Polat ZA (2021)(47) conducted the SEM study for investigation of hardness, biocompatibility, strength and fracture resistance of metal alloy like titanium, Co-Cr, Zirconia, PMMA and PEEK as substructure material for implant supported fixed prosthesis. The result showed that zirconia has highest hardness while lowest fracture resistance seen in PEEK and PMMA. In this study, Vickers hardness was similar between PEEK and PMMA. The result showed that most favourable biocompatible materials were PEEK and Zirconia.

Kwan JC and Kwan N (2021)(48) conducted an in-vivo study to evaluate provisional fixed dental prostheses (FDPs) of high performance polymer of PEEK retained by reciprocated guide surface in hexagonal shaped healing abutment during dental implant treatment. Patients required teeth replacement with implant in partially or fully edentulous cases were included. The provisional prosthesis was fabricated by lost wax technique using castable hex and PEEK granules. Very less amount of failure had seen in patient with provisional prosthesis. The result suggested that PEEK can be a suitable material during dental implant treatment for use in provisional FDPs.

MATERIAL AND METHOD

This study was carried out in the Department of Prosthodontics. All attempts were made to standardize the procedures throughout the study to minimize the effects of variable factors on the observations and the final results.

The material and method are subdivided into following groups:

A. Materials and Armamentarium

1. PEEK material used for fabrication of samples. (Color Plate I)
2. Instruments used for milling and fabrication of samples. (Color Plate I)
3. Instruments used for microwave disinfection. (Color Plate I)
4. Instrument used for testing of samples such as universal testing machine. (Color Plate I)

Materials and Armamentarium used:- Color plate I (Fig. 1, 2, 3, 4, 5)

Sr no.	Materials / Instruments	Manufacturer	Batch number
1.	PEEK material used for fabrication	Bredent breCAM. BioHPP	497897
2.	CAD/CAM Milling unit	Sirona Dental Systems GmbH Fabriksir. 31	6384700
3.	Microwave Disinfectant Unit	Samsung smart oven	-----
4.	Universal Testing Machine	Reichert Austria	363798
5.	Micro motor and Lab handpiece	Marathon	-----
6.	Beakers and bottles for storage of samples	------	------

B. Methodology

1. Formation of STL file
2. Preparation of samples
3. Microwave disinfection of the samples
4. Micro hardness testing of each group

METHODOLOGY:

Polyetheretherketone (PEEK) blank of 98 mm. x 10 mm. was used to fabricate the test samples. The size of the samples was decided on the basis of requirement of surface micro hardness test, as per ADA specifications. All samples were tested by using the Micro-Hardness Tester (Company Reichert, Austria SR. No. 363798).

The steps involved in the fabrication of the test samples are as follows:

1. STL (Standard Tessellation Language) file:- (Color plate II)

STL is a file format native to the stereolithographic CAD software created by 3D system. It is widely used for rapid prototyping, 3D printing and computer aided manufacturing. According to ADA specification no. 12, for micro hardness test, a disc block measuring 15 mm. in diameter and 5 mm. in thickness was used for preparing all the samples. This required sample size with its diagrammatic representation was sent to the software professionals (Fig.6). Accordingly, the final STL file was designed(Fig.7). The shape of each sample was in disc or circular form. This STL file was verified once again for a specific dimension and send to the laboratory for milling from the plank of PEEK.

2. Fabrication of samples:- (Color plate II & Color plate III)

Plank of PEEK material having dimensions of 98 mm. diameter and 10 mm. thickness was used for the fabrication of samples. Detail dimensions of each disc was adjusted in the milling software. In the milling machine system, fabrication of near about 15 samples was possible from one plank of PEEK material, accordingly these were adjusted in the software machine. PEEK plank was placed in the milling machine (Fig.8). Once the confirmatory command ordered by the software, the machine had started for milling to fabricate the samples. The milling machine has total 3 different textured burs, which was automatically used one after the other. During this procedure, there was formation of heat. So the inlet with coolant spray get activated at one end, at the same time discarded water was removed from the attached outlet, at another end (Fig.9). As per order by the software, the milling machine has the inbuilt arrangement to change the plank position, to fabricate samples with perfect dimensions and to get smooth finish. The excess material was accumulated in the base of the machine, which was discarded. Total time required for fabrication of one sample was 15 minutes. Accordingly, the subsequent millings were completed for remaining samples. The milled samples were not separated completely by the machine; rather all were attached at their corners in very thin portions (Fig.10). Finally, their attached ends were cut carefully using laboratory hand piece. In this way, total 60 samples were fabricated in the CAD CAM milling machine (Fig.11). They were divided into 4 groups for various cycles of microwave disinfection testing. All the samples were stored in distilled water in beaker at room temperature, till the surface hardness tests were performed (Fig.12).

There were total 60 samples divided into 4 groups of 15 samples each for surface hardness (SH) test.

1 MWC:- 1 cycle of microwave disinfection was referred at 650 watt for 3 minutes.

In this way, the Group 0, 1, 3 and 5 cycles of microwave disinfection were considered for the surface hardness testing.

1. Group SH- 0 MWC:- Samples without undergoing microwave disinfection (Control).
2. Group SH- 1 MWC:- Samples with 1 cycle of microwave disinfection.
3. Group SH- 3 MWC:- Samples with 3 cycles of microwave disinfection.
4. Group SH- 5 MWC:- Samples with 5 cycles of microwave disinfection.

CONTROL GROUP	EXPERIMENTAL GROUPS		
GROUP SH- 0 MWC	**GROUP SH- 1 MWC**	**GROUP SH- 3 MWC**	**GROUP SH- 5 MWC**
PEEK without microwave disinfection	PEEK with 1 microwave disinfection cycle	PEEK with 3 microwave disinfection cycle	PEEK with 5 microwave disinfection cycle
15 samples	15 samples	15 samples	15 samples
TOTAL SAMPLES = 60			

2. Microwave disinfection of the samples:- (Color plate III & Color plate IV)

Initially, the samples of control group i.e. without microwave disinfection, were stored in plastic beaker containing distill water for easy identification (Fig.13). For microwave disinfection cycles, samples were stored in glass beaker (Fig.14). The microwave oven, was set at 650 wattage (W) for 3 min referred as "one disinfection cycle of microwave irradiation."[49] Experimental group samples were disinfected one after the other, according to the number of cycle of microwave disinfection. Thus, for 1MWC, microwave oven was set at 650 W (Fig.15) for 3 minutes (Fig.16). This 1 cycle was repeated 3 times for 3 MWC and 5 times for 5 MWC without any break. After completion of MWCs, all the samples were again stored in the distilled water, till the micro-hardness tests were performed.

3. Surface Micro hardness test of the samples:- (Color plate IV)

All the samples were initially conditioned in incubator, immersed in distilled water at 37°C for 48 h, to simulate oral environment, before they were tested on

Universal testing machine. Later, the samples were transferred into the bottle containing distilled water where each group of testing was labelled (Fig.17).

The samples were tested using the Vickers hardness (HV) test method. For evaluation of surface hardness, the universal Micro Hardness Tester machine (Reichert Austria Make, Sr.No.363798, Load applied- 50 g, Reference Standard: ISO 6507) was used(Fig.18). This machine consists of indenting the test material with a diamond indenter, (Fig.19) in the form of a right pyramid with a square base and an angle of 136° between opposite faces subjected to a load of 0.05 kgf (50gmf). The load was applied for 10 - 15 seconds. After removal of the load, two diagonals of the indentation, left on the surface of each sample, was measured using a microscope and their average value was calculated. The area of the sloping surface of indentation was calculated. Average value of two diagonals was considered as a final value of diagonal. The hardness value (HV) quotient was obtained by dividing the kgf load by the square millimeter area of indentation.

The HV number was calculated in (HV) using the formula:

$$HV = (1.854 \times F) / d^2$$

Where, F = Load (kgf),

d = Arithmetic mean of the two diagonals, d1 and d2 mm.

Two readings were obtained for determining the hardness and finally the average value of these two readings was consider as a hardness value for particular sample of their respective group.

COLOR PLATE I

Fig. 1:- Plank/disc of PEEK material

Fig. 2:- Microwave Oven for disinfection

Fig. 3:- CAD-CAM milling unit

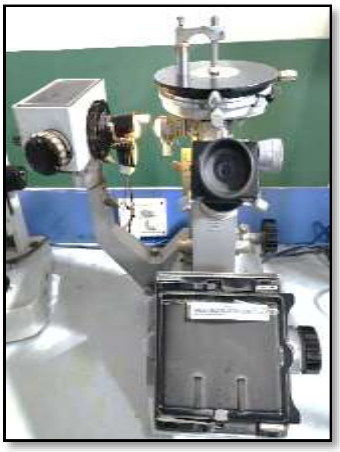

Fig. 4:- Universal Micro Hardness testing Machine

Fig.5:- Micro motor and handpiece

COLOR PLATE II

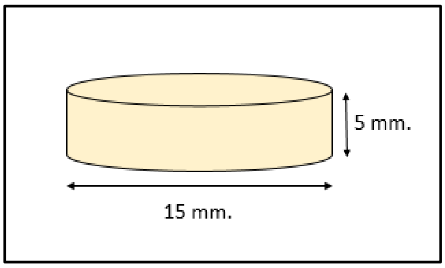

Fig. 6:- Diagrammatic representation of sample

Fig. 7:- STL file of dimension 15 mm. X 5 mm.

Fig. 8:- Plank of PEEK placed in machine for milling

Fig. 9:- Milling by using bur and water spray for coolant

Fig. 10:- Milled samples attached in thin portion was cut manually

COLOR PLATE III

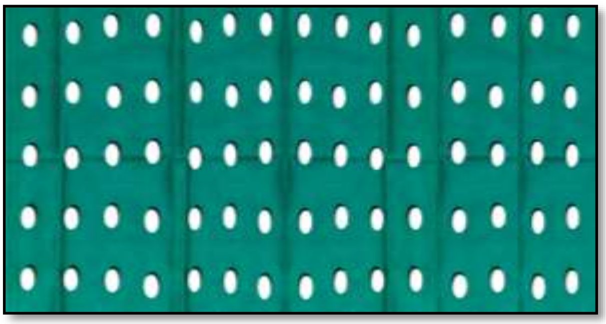

Fig. 11:- Total 60 Fabricated samples.

Fig. 12:- Four groups suggest without microwave disinfection, 1 cycle of microwave disinfection, 3 cycle of microwave disinfection, 5 cycle of microwave disinfection.

Fig.13:- Samples kept in plastic beaker (without microwave disinfection)

Fig.14:- Samples kept in glass beaker for microwave disinfection

COLOR PLATE IV

Fig.15:- Microwave set at 650 watts for disinfection

Fig.16:- Microwave set at 3 minutes for disinfection

Fig.17:- Samples kept in bottle filled with distilled in which white color denotes without microwave disinfection and colored box labelled for number of microwave disinfection cycle

Fig.18:- Sample kept in hardness testing machine

Fig.19:- Testing of samples by 50 gm load gives micro-indentation

RESULTS

The present study was conducted to evaluate the difference in surface hardness of PEEK material without microwave disinfection with that of PEEK material undergoing 1 microwave cycle, 3 microwave cycles and 5 microwave cycles for disinfection.

CONTROL GROUP	**EXPERIMENTAL GROUPS**		
GROUP SH- 0 MWC	**GROUP SH- 1 MWC**	**GROUP SH- 3 MWC**	**GROUP SH- 5 MWC**
PEEK without microwave disinfection	PEEK with 1 microwave disinfection cycle	PEEK with 3 microwave disinfection cycle	PEEK with 5 microwave disinfection cycle
15 samples	15 samples	15 samples	15 samples
TOTAL SAMPLES = 60			

One-way ANOVA was applied to assess the difference between the groups followed by post hoc test. The results were obtained as follows:-

Table 1:- This represents the mean surface hardness in groups Group SH-0 MWC, Group SH-1 MWC, Group SH-3 MWC and Group SH-5 MWC Group. In Group SH-0 Control, the mean surface hardness was 15.88 N/mm.^{2} with standard deviation of 1.33. The minimum and maximum surface hardness was 14.7 N/mm.^{2} and 18.9 N/mm.^{2}. In Group SH-1 MWC, the mean surface hardness was 17.02 N/mm.^{2} with standard deviation of 1.04. The minimum and maximum surface hardness was 15.41 N/mm.^{2} and 18.80 N/mm.^{2} In Group SH-3 MWC, the mean surface hardness was 23.30 N/mm.^{2} with standard deviation of 1.13. The minimum and maximum surface hardness was 21.69 N/mm.^{2} and 25.35 N/mm.^{2} In Group SH-5 MWC, the mean surface hardness was 24.48 N/mm.^{2} with standard deviation of 1.81. The minimum and maximum surface hardness was 22.88 N/mm.^{2} and 27.96 N/mm.^{2}

Table 1:- Mean hardness in control and the intervention groups

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Group SH-0 MWC Control	15	14.7	18.9	15.88	1.33
Group SH-1 MWC	15	15.41	18.8	17.02	1.04
Group SH-3 MWC	15	21.69	25.35	23.30	1.13
Group SH-5 MWC	15	22.88	27.96	24.48	1.81

Graph1:- Represents the bar diagram with surface hardness in all the four groups. The x-axis represents the groups i.e., Group SH-0 Control, Group SH-1 MWC, Group SH-3 MWC and Group SH-5 MWC and the y-axis represents the mean surface hardness.

Graph 1- Bar diagram representing mean hardness in control and intervention groups

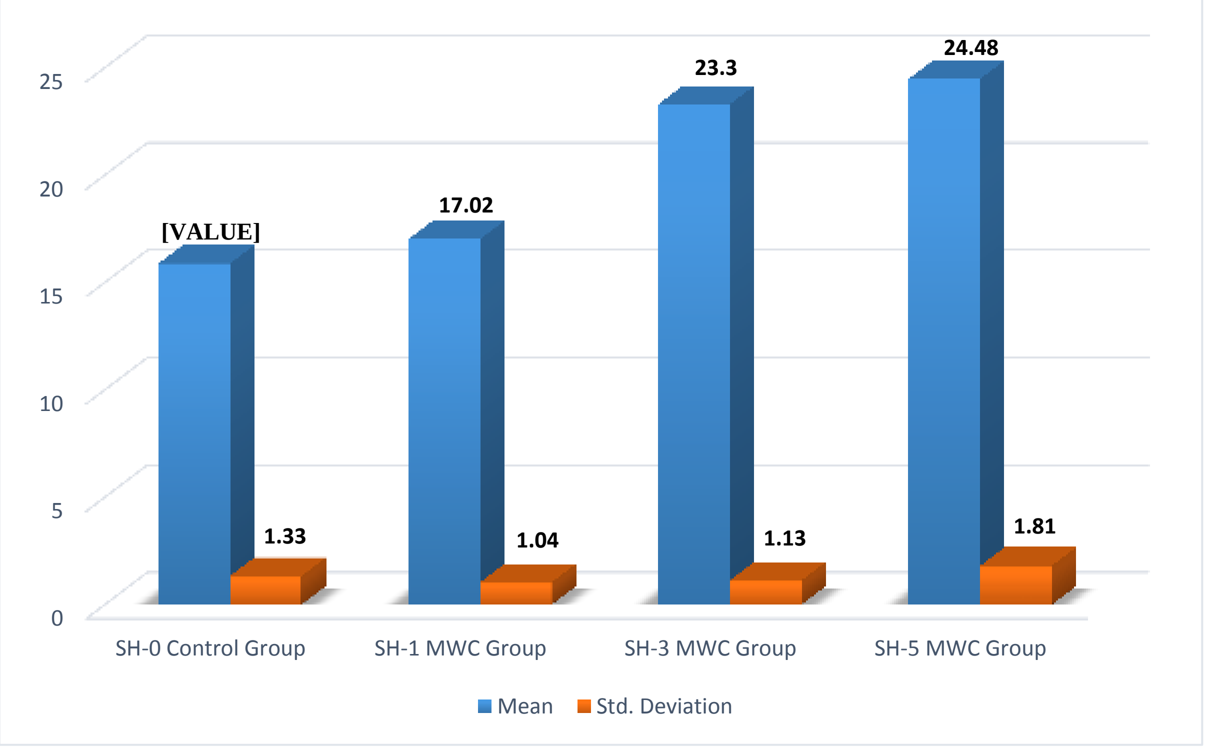

Table 2:- It represents difference in mean surface hardness between Group SH-0 Control, Group SH-1 MWC, Group SH-3 MWC and Group SH-5 MWC. After applying One-way ANOVA test the F value was 153.392. There was a significant difference in the surface hardness between the groups with $p<0.0001$.

Table 2:- Difference in the hardness between the groups

Groups	**Mean**	**F**	**Significance (p)**
Group SH-0 MWC Control Group	15.88	153.392	**< 0.0001***
Group SH-1 MWC	17.02		
Group SH-3 MWC	23.30		
Group SH-5 MWC	24.48		

**Significance at p<0.05*

A statistical significant difference is present in the hardness between Group SH-0, Group SH-1 MWC, Group SH-3 MWC and Group SH-5 MWC.

Table 3:- It determines exactly which groups are presenting with the difference in mean surface roughness, post hoc Tukey test was applied. The table represents the groups showing significant difference in mean surface hardness. A significant difference in mean surface hardness was present between: Group SH-0 and Group SH-3 with mean difference of 7.41 and p<0.0001, Group SH-0 and Group SH-5 MWC with mean difference of 8.59 and p=<0.0001, Group SH-1 MWC and Group SH-3 with mean difference of 6.28 and p<0.0001, Group SH-1 MWC and Group SH-5 MWC with mean difference of 7.45 and p<0.0001.

Table 3:- Post hoc Tukey test

Groups		Mean Difference	Significance (p)
Group SH-0 MWC Control Group	Group SH-1 MWC	1.13400	.114
	Group SH-3 MWC	7.41933	**<.0001***
	Group SH-5 MWC	8.59200	**<.0001***
Group SH-1 MWC	Group SH-0 MWC	1.13400	.114
	Group SH-3 MWC	6.28533	**<.0001***
	Group SH-5 MWC	7.45800	**<.0001***
Group SH-3 MWC	Group SH-0 MWC	7.41933	**<.0001***
	Group SH-1 MWC	6.28533	**<.0001***
	Group SH-5 MWC	1.17267	.096
Group SH-5 MWC	Group SH-0 MWC	8.59200	**<.0001***
	Group SH-1 MWC	7.45800	**<.0001***
	Group SH-3 MWC	1.17267	.096

**Significance at* $p<0.05$

A statistical significant difference is present between –

Group SH-0 MWC Control Group and Group SH-3 MWC

Group SH-0 Control Group and Group SH-5 MWC

Group SH-1 MWC and Group SH-3 MWC

Group SH-1 MWC and Group SH-5 MWC

Hardness: Group SH-5 MWC > Group SH-3 MWC > Group SH-1 MWC > Group SH-0 MWC Control Group

No statistical significant difference in surface hardness was present between: Group SH-0 Control Group and Group SH-1 MWC, Group SH-3 MWC and Group SH-5 MWC with $p>0.05$.

Overall, the results of the study reveal that there is a significant difference in surface hardness between the groups. The highest surface hardness was present with Group SH-5 MWC followed by Group SH-3 MWC and Group SH-1 MWC. The Group SH-0 MWC Control Group showed the least surface hardness. The results indicate that the microwave disinfecting cycles affect the surface hardness of PEEK material. With increase in number of cycles, the surface hardness of PEEK material increases.

DISCUSSION

With increase in the lifespan of people the poor health conditions have also increased. As the age advances, the dental health of a person is expected to be deteriorating with decrease in the support from the periodontium. As a result of this, tooth loss is one of the major concerns in elderly group. Moreover, knowing the connection of oral health and general health, replacement of the lost teeth among this age group becomes an utmost priority. Complete dentures consisting of artificial teeth and a denture base that are fabricated to restore the normal functions like, occlusion, aesthetic, oral function and assist in pronunciation of words.

Considering the importance of dentures in this age group the longevity and stability of dentures is crucial. To overcome the disadvantages of older denture base materials, various modifications have been introduced with respect to material and technique in which the dentures are fabricated. Polyetheretherketone (PEEK) is one such invention having properties in parallel to other existing materials in dentistry.

With respect to esthetics especially color matching, PEEK provides good precision because of high performance polymer. With less weight the material provides improved comfort to the patients. As the denture is subjected to range of shear and compressive forces, the wear resistance of PEEK material is found to be satisfactory. Moreover, the material is biocompatible and possesses less fear of irritation to the tissues. One of the major problems with dentures is that the roughness of denture base material, that promotes formation of plaque on the surfaces of denture. Denture plaque is a structured community of microorganisms that is surrounded by self-produced polymeric matrix. The structure is adherent to living and inert surfaces. Streptococcus, Staphylococcus, Lactobaccilus, Candida, Actinomyces, Enterobacter and Pseudomonas are the commonly associated species with denture plaque. These microorganisms cause local irritation to the tissues beneath. The effects of microorganisms not just stay confined to the patients but become a potential source of contamination from patient to the dentist as well as laboratory person. In a study reported by **Powell et al (1990)** [(50)], 67% of the dental material sent from the clinic was found to be contaminated with opportunistic pathogens. Thus, keeping the dentures clean eradicated disease spread to patients, dentist and laboratory technician.

In this regard, disinfecting solutions do help in making the prosthesis surface clean to some extent but they cause detrimental effects on the acrylic resin. Chemical agents like aldehyde compounds, chlorine, iodophors have been reported in the literature. Apart from these, immersion of dentures in 2% alkaline glutaraldehyde, 3% aqueous formaldehyde, 1% sodium hypochlorite, 3.78% sodium perborate, 4% chlorhexidine proved to be effective in reducing microorganism contamination over the denture surfaces. Though these methods disinfect the dentures but they also alter the physical and mechanical properties of denture materials. The studies have reported the detrimental effect of these solutions on surface roughness, hardness and transverse strength. Moreover, the color stability also gets significantly affected resulting in poor esthetics.[51]

With the focus on a method that will disinfect the denture material and prevent contamination and at the same time retain its mechanical and physical properties, microwaving the dentures have emerged as an effective method. The study conducted by **Rohrer SC and Bulard SC (1985)**[52] reported that the dentures contaminated with fungi and aerobic bacteria were sterilized in 10 minutes by microwaving at an irradiation of 720W. Similarly, **Webb BC et al (1988)**[53] demonstrated a 6 minutes of microwaving at 350W to be more effective in inactivating the microorganisms than soaking the denture in the disinfecting solution. **Buergers et al (2008)**[54] also mentioned in their study a significant decrease in Candida albicans from the denture surface after irradiating for 6 minutes with 800W. In addition to this, irradiation with 650W for 6 minutes provided denture surface free from colonization of staphylococcus aureus, Candida albicans, bacillus subtilis and pseudomonas aeruginosa.[55]

With the evidence of effectiveness of microwave disinfection denture surfaces, it is equally important to understand the effects of microwaving of the physical and mechanical properties of the material. The present study provided the effect of repeated microwave disinfection on the surface hardness of Polyetheretherketone (PEEK) material, when subjected to 1, 3 and 5 microwave disinfection cycles. All the samples were divided creating four different groups viz. Group SH-0 MWC (control/

without microwave disinfection), Group SH- 1 MWC, Group SH-3 MWC and Group SH-5MWC respectively. After the micro wave disinfection, surface hardness test was performed on universal testing machine. Surface hardness (SH) value was calculated by using formula and tabular format was sent for statistical analysis.

The statistical data revealed the mean surface hardness in all the groups. The mean surface hardness and standard deviation of Group SH-0 MWC was 15.88 ± 1.33. For Group SH-1 MWC it was 17.02 ± 1.04, for Group SH-3 MWC 23.30 ±1.13 and for Group SH-5 MWC it was 24.48 ±1.81. This analysis indicated a significant difference in the surface hardness after microwave disinfection. Mean surface hardness difference in the groups were also evaluated. Between Group SH-0 MWC Control and Group SH- 1 MWC it was **1.14**, Group SH-0 MWC Control and Group SH- 3 MWC it was **7.42**, Group SH-0 MWC Control and Group SH- 5 MWC it was **8.59**. Mean difference between Group SH-1 MWC and Group SH- 3 MWC it was **6.28**, Group SH-1 MWC and Group SH- 5 MWC it was **7.45**, Group SH-3 MWC and Group SH- 5 MWC it was **1.17**. Thus the highest mean difference in surface hardness value was seen between Group SH-0 MWC Control and Group SH- 5 MWC, followed by Group SH- 3 MWC and Group SH-1 MWC. This evaluation suggests increase surface hardness of Group SH- 5 MWC followed by Group SH- 3 MWC and Group SH- 1 MWC. The surface hardness of Group SH- 0 MWC was least.

Many investigators had done disinfection of PEEK material by different methods. A study by **Godara A et al (2007)**[(22)] where the effect of gamma radiation or steam sterilization on thermoplastic matrix composite polyetheretherketone (PEEK), reinforced with carbon fibers was evaluated. The average values of hardness of the bulk matrix region for the sterilized specimens were very similar to reference specimen. The presence of fibers can also impose restrictions on the normal plastic-flow deformation mechanism of the matrix, hence inducing an increase in the hardness values within the proximity of the fiber surface. Whereas study done by **Bodden L et al (2017)** [36] though not related to microwave disinfection, but the effect of heating / quenching process on the PEEK material demonstrated that the Martens hardness of PEEK material significantly decreased. It was suspected that the crystalline structure of PEEK melted and the matrix stayed in amorphous state through quenching. An increase of the indentation modulus affects the stiffness of the material, making it less flexible and more translucent.

Also study done on PMMA by **Arima et al (1996)**[56], showed that the changes in surface hardness of the material is greatly influence by the chemical composition. As with the addition of cross-linking agents, the solubility of the material decreases. Similarly, **Machado et al (2009)**[23], evaluated the effect of microwave disinfection on Vickers hardness of the material was determined on different types of PMMA. They found increase in the mean hardness of the reline resin materials while the hardness of heat polymerised resin remained unchanged. They explained this change in hardness was due the amount of unreacted monomer in the specimens was reduced during the disinfection procedures.

In addition, microwave irradiation causes rearrangement of the polymer chains and the extent of distortion of the material by the nature of polymerization process. This traps the stresses within the poly-matrix which are then released during microwave disinfection, resulting an increase in surface hardness.[24]

Prechtel et al (2019)[57] in their study mentioned that the method of fabrication can also affect the surface hardness of PEEK materials. The PEEK restorations can be fabricated by CAD/CAM milling, which is a subtractive method or by 3D printing which is an additive method. CAD/CAM Milled specimens showed higher hardness than 3D printed. This fact was explained by the standardized conditions of manufacturing by CAD/CAM milling, where a controlled crystallization process of the thermoplastic material take place. Whereas in 3D printed samples, the filament was melted in the extruder and subjected to a more or less controlled crystallization, after the printing process, which was influenced by factors like temperature management and cooling procedure.

In the present study also all the samples were made by CAD-CAM milling process, by standardised software procedures, this automatically eliminated fabrication error. There was least mean difference between Group SH-0 MWC and Group SH-1, when compared to other groups (Group SH-3 MWC and Group SH-5). This was due to temperature change during microwave disinfection process, where the diffusion coefficient was increased, while the equilibrium absorption remained same. Thus, as the microwave disinfection cycle increased, there may lead to change in hardness, due to moisture absorption in polymer through diffusion and capillary process which induce plastic deformation. As the higher level of water gets absorbed, the process facilitated the plasticizing effect on the material surface, leading to moderately lesser surface hardness as compared to remaining two groups (Group SH-3 MWC and Group SH-5 MWC).

In Group SH-3 MWC and Group SH-5 MWC, with increased microwave cycles, there was further increase in temperature. Moreover, the vibrations caused by microwave irradiation lead to vibration of the water molecules within the water bath, thereby resulting in friction. At the same time, with faster moisture diffusion the material likely showed faster rate of hardening. Another reason might be due to further increase in the temperature, which may lead to heating induced deformation in crystallinity and microscopic structures, resulting in increased hardness of the PEEK samples in these groups.

Group SH-0 MWC and Group SH-1MWC showed statistically significant differences with Group SH-3 MWC and Group SH-5 MWC. (**p value < 0.05**) However, there were no statistically differences seen between Group SH-0 MWC and Group SH-1 MWC as well as Group SH-3 MWC and Group SH-5MWC (**p value > 0.05**). Therefore, this material can be disinfested by either of the microwave disinfection cycle viz. 1 cycle of microwave disinfection or with 3 cycles of microwave disinfection or with 5 cycles of microwave disinfection. This may not make much difference during regular use of PEEK in clinical conditions.

Within the limitation of the study, following conclusion can be drawn:

1. PEEK material can be disinfected safely by using microwave.
2. Restorations fabricated by PEEK materials can be disinfected by repeated microwave disinfection method, up to 650 W for 3 min.
3. Repeated microwave disinfection increases the surface hardness of PEEK material. this material can be disinfested by either by 1 cycle of microwave disinfection or with 3 cycles of microwave disinfection or with 5 cycles of microwave disinfection process.

Clinical Implications:-

The microwave disinfection is less time taking and easy procedure for disinfection of dental prosthesis. The newer PEEK material successfully used in the day to day clinical practice, can also be disinfected repeatedly by using either of the cycle of microwave disinfection. Even though the hardness of PEEK increased with the increased number of microwave disinfection cycles, it is an appropriate material to fabricate the prosthesis, to withstand or resist the heavy masticatory forces.

Limitations of the study:-

There were some limitations in this study, being an in-vitro study it could not replicate all the conditions present in the oral environment. The hardness value was checked in the laboratory by applying straight perpendicular load. However, intraorally masticatory forces are different and are multi directional.

Scope for further studies:-

1. Other parameters for mechanical properties and color stability can be evaluated after microwave disinfection.

2. Samples fabricated by additive method i.e. 3D printing can also be evaluated.

SUMMARY

The present investigation was done with an aim to evaluate and compare the effect of repeated microwave disinfection on surface hardness of polyetheretherketone (PEEK).

Microwave disinfection is now a days easy and less time consuming procedure which is used more commonly. As PEEK is having high melting temperature of 343^0c, it can be disinfected by microwave irradiation. The present study performed to compare the surface hardness of PEEK with and without the microwave disinfection.

Total 60 samples of PEEK were milled and fabricated by using CAD/CAM milling unit. These were divided into 4 groups of 15 samples in each. The included groups were Group SH-0 MWC, Group SH-1 MWC, Group SH-3 MWC and Group SH-5 MWC. Microwave oven set at 650 Watt for 3 minutes was considered as 1 cycle of microwave disinfection. This one cycle repeated for 3 times and 5 times for

Group SH-3 MWC and Group SH-5 MWC respectively. Every time samples were stored in distilled water to simulate the oral environment. After disinfection, each group was tested for surface micro hardness test, on universal testing machine. Hardness value was calculated by using the formula:

$$HV = (1.854 \times F) / d^2$$

Where, F = Load (kgf),

d = Arithmetic mean of the two diagonals, d1 and d2 mm.

Two readings were obtained for determining the hardness and finally the average value of these two readings was considered as a final hardness value, for particular sample of their respective group. Final readings of hardness value was send for statistical analysis.

The result revealed statistically significant differences between each group. PEEK samples with 5 cycles of microwave disinfection showed highest surface hardness value whereas those without microwave disinfection showed least surface hardness value.

The order of calculated surface hardness value was Group SH-5 MWC > Group SH-3 MWC > Group SH-1 MWC > Group SH-0 MWC Control Group.

The study concluded that

1. PEEK material can be disinfected safely by using microwave.

2. The microwave disinfection method can be used repeatedly for disinfecting the dentures up to 650 W for 3 min.

3. Repeated microwave disinfection can increase the surface hardness of PEEK material.

4. This material can be disinfested by either of the microwave disinfection cycle viz. 1 cycle of microwave disinfection or with 3 cycles of microwave disinfection or with 5 cycles of microwave disinfection. This may not make much difference during regular use of PEEK in clinical conditions.

CONCLUSION

The aim of the study was to evaluate and compare the effect of repeated microwave disinfection on surface hardness of polyetheretherketone (PEEK).

Within the limitation of the study, following conclusion can be drawn:

1. PEEK material can be disinfected safely by using microwave.
2. The microwave disinfection method can be used repeatedly for disinfecting the dentures up to 650 W for 3 min.
3. Repeated microwave disinfection can increase the surface hardness of PEEK material.
4. This material can be disinfested by either of the microwave disinfection cycle viz. 1 cycle of microwave disinfection or with 3 cycles of microwave disinfection or with 5 cycles of microwave disinfection. This may not make much difference during regular use of PEEK in clinical conditions.

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TABLES

Table 1:- Mean hardness in control and the intervention groups

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Group SH-0 MWC Control	15	14.7	18.9	15.88	1.33
Group SH-1 MWC	15	15.41	18.8	17.02	1.04
Group SH-3 MWC	15	21.69	25.35	23.30	1.13
Group SH-5 MWC	15	22.88	27.96	24.48	1.81

Table 2:- Difference in the hardness between the groups

Groups	Mean	F	Significance (p)
Group SH-0 MWC Control Group	15.88	153.392	**< 0.0001***
Group SH-1 MWC	17.02		
Group SH-3 MWC	23.30		
Group SH-5 MWC	24.48		

**Significance at p<0.05*

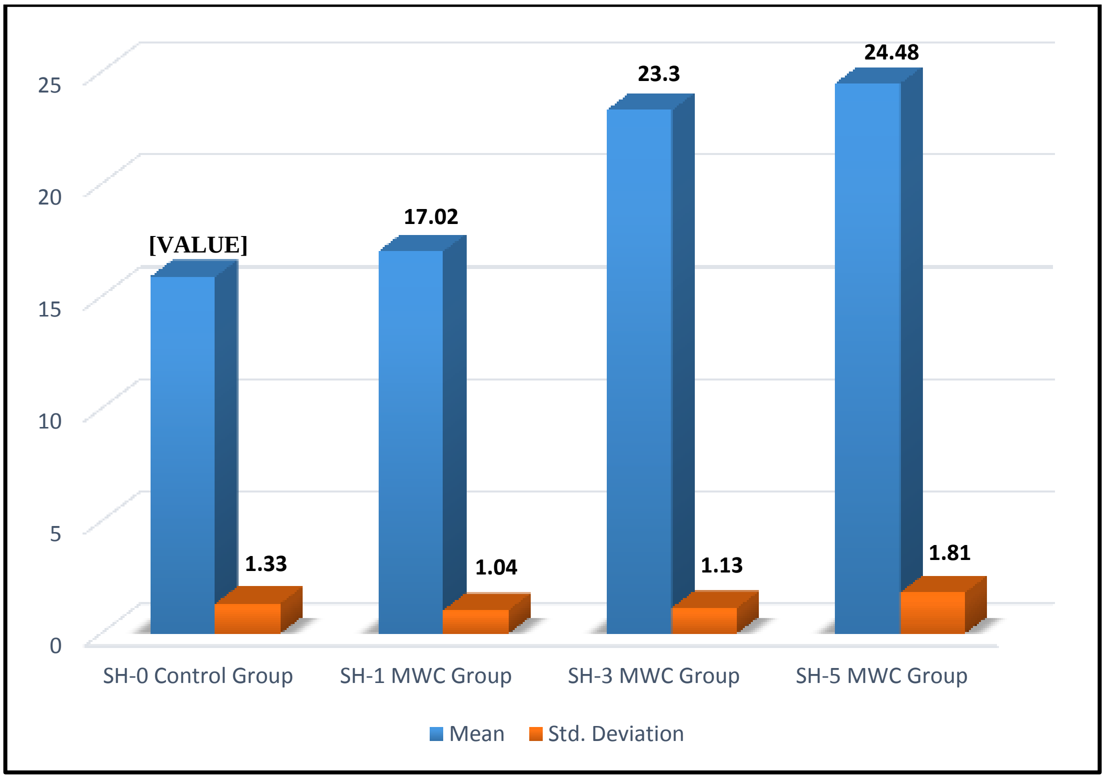
Table 3:- Post hoc Tukey test

Groups		Mean Difference	Significance (p)
Group SH-0 MWC Control Group	Group SH-1 MWC	1.13400	.114
	Group SH-3 MWC	7.41933	**<.0001***
	Group SH-5 MWC	8.59200	**<.0001***
Group SH-1 MWC	Group SH-0 MWC	1.13400	.114
	Group SH-3 MWC	6.28533	**<.0001***
	Group SH-5 MWC	7.45800	**<.0001***
Group SH-3 MWC	Group SH-0 MWC	7.41933	**<.0001***
	Group SH-1 MWC	6.28533	**<.0001***
	Group SH-5 MWC	1.17267	.096
Group SH-5 MWC	Group SH-0 MWC	8.59200	**<.0001***
	Group SH-1 MWC	7.45800	**<.0001***
	Group SH-3 MWC	1.17267	.096

*Significance at $p<0.05$

GRAPH

Graph 1- Bar diagram representing mean hardness in control and intervention groups



MASTER CHARTS

Master chart 1:- Hardness value of 4 groups

Sample No	Group SH-0 MWC control group Hardness 50gm load HV N/mm^2	Group SH-1 MWC Hardness 50gm load HV N/mm^2	Group SH-3 MWC Hardness 50gm load HV N/mm^2	Group SH-5 MWC Hardness 50gm load HV N/mm^2
1.	18.9	18.8	23.73	27.96
2.	15.79	16.14	22.8	23.94
3.	15.75	17.97	25.35	23.32
4.	15.38	16.01	22.05	22.96
5.	15.95	17.05	22.38	24.38
6.	15.27	15.69	22.38	27.05
7.	15.41	16.16	21.87	23.29
8.	18.05	18.28	23.39	23.81
9.	14.7	17.74	24.44	22.88
10.	14.84	16.37	24.65	23.21
11.	15.37	17.28	22.99	22.93
12.	17.98	18.29	21.69	23.8
13.	14.8	16.86	24.39	27.11
14.	14.77	15.41	23.25	23.49
15.	15.3	17.22	24.19	27.01

Master Chart 2:- Hardness Value of Group SH- 0 MWC

Group SH-0 MWC control group Hardness 50gm load				
Sr No	Sample ID	Micro hardness in N/mm^2		
		Reading 1	Reading 2	**Average**
1.	No.1	18.19	19.62	**18.90**
2.	No.2	15.10	16.48	**15.79**
3.	No.3	15.30	16.20	**15.75**
4.	No.4	14.95	15.82	**15.38**
5.	No.5	15.50	16.40	**15.95**
6.	No.6	15.20	15.34	**15.27**
7.	No.7	15.32	15.51	**15.41**
8.	No.8	18.17	17.93	**18.05**
9.	No.9	14.68	14.72	**14.70**
10.	No.10	14.76	14.93	**14.84**
11.	No.11	15.31	15.43	**15.37**
12.	No.12	18.11	17.86	**17.98**
13.	No.13	14.83	14.77	**14.80**
14.	No.14	14.98	14.56	**14.77**
15.	No.15	15.23	15.38	**15.30**

Master Chart 3:- Hardness Value of Group SH- 1 MWC

Group SH-1 MWC control group Hardness 50gm load				
Sr No	Sample ID	Micro hardness in N/mm^2		
		Reading 1	Reading 2	**Average**
1.	No.1	18.29	19.32	**18.80**
2.	No.2	15.70	16.58	**16.14**
3.	No.3	18.32	17.63	**17.97**
4.	No.4	16.14	15.89	**16.01**
5.	No.5	17.56	16.54	**17.05**
6.	No.6	15.58	15.81	**15.69**
7.	No.7	16.25	16.07	**16.16**
8.	No.8	18.25	18.32	**18.28**
9.	No.9	17.65	17.83	**17.74**
10.	No.10	16.32	16.43	**16.37**
11.	No.11	17.14	17.42	**17.28**
12.	No.12	18.23	18.35	**18.29**
13.	No.13	16.98	16.74	**16.86**
14.	No.14	15.35	15.47	**15.41**
15.	No.15	17.32	17.12	**17.22**

Master Chart 4:- Hardness Value of Group SH- 3 MWC

Group SH-3 MWC control group Hardness 50gm load				
Sr No	Sample ID	Micro hardness in N/mm^2		
		Reading 1	Reading 2	**Average**
1.	No.1	23.22	24.25	**23.73**
2.	No.2	22.16	23.45	**22.80**
3.	No.3	24.75	25.96	**25.35**
4.	No.4	21.54	22.57	**22.05**
5.	No.5	21.92	22.84	**22.38**
6.	No.6	22.32	22.45	**22.38**
7.	No.7	21.98	21.76	**21.87**
8.	No.8	23.43	23.35	**23.39**
9.	No.9	24.65	24.24	**24.44**
10.	No.10	24.43	24.87	**24.65**
11.	No.11	22.87	23.11	**22.99**
12.	No.12	21.65	21.74	**21.69**
13.	No.13	24.32	24.46	**24.39**
14.	No.14	23.19	23.31	**23.25**
15.	No.15	24.23	24.15	**24.19**

Master Chart 5:- Hardness Value of Group SH- 5 MWC

Group SH-5 MWC control group Hardness 50gm load				
Sr No	Sample ID	Micro hardness in N/mm^2		
		Reading 1	Reading 2	**Average**
1.	No.1	27.37	28.56	**27.96**
2.	No.2	23.11	24.78	**23.94**
3.	No.3	22.78	23.86	**23.32**
4.	No.4	22.50	23.43	**22.96**
5.	No.5	23.90	24.87	**24.38**
6.	No.6	27.12	26.98	**27.05**
7.	No.7	23.15	23.43	**23.29**
8.	No.8	23.78	23.84	**23.81**
9.	No.9	22.98	22.78	**22.88**
10.	No.10	23.17	23.25	**23.21**
11.	No.11	22.99	22.87	**22.93**
12.	No.12	23.78	23.82	**23.80**
13.	No.13	27.06	27.17	**27.11**
14.	No.14	23.57	23.42	**23.49**
15.	No.15	27.11	26.92	**27.01**