COMPARISON OF MECHANICAL PROPERTIES, PHYSICAL PROPERTIES & BIOCOMPATIBILITY OF FOUR DIFFERENT DENTURE BASE RESINS - AN IN VITRO STUDY.

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INCLUDING CROWN AND BRIDGE AND IMPLANTOLOGY

CERTIFICATE

This is to certify that this dissertation entitled **"COMPARISON OF MECHANICAL PROPERTIES, PHYSICAL PROPERTIES & BIOCOMPATIBILITY OF FOUR DIFFERENT DENTURE BASE RESINS- AN IN VITRO STUDY."** is a genuine work done by ***Dr. JOSNA SUSAN JOY*** under my guidance during her post graduate study period between 2009-2012.

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R MEDICAL UNIVERSTY, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY IN PROSTHETIC DENTISTRY INCLUDING CROWN AND BRIDGE AND IMPLANTOLOGY - BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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ABSTRACT

Title:- *Comparison of mechanical properties, physical properties & biocompatibility of four different denture base resins- an in vitro study.*

Aims:- *To compare mechanical, physical property, compatibility between four heat cure denture base resins.*

Materials and Methods:- *the materials used in this study were SR Triplex-HOT (fiber reinforced heat cure resin), Sunflex (flexible heat cure resin), Trevalon-HI (high impact heat cure resin), DPI (conventional heat cure resin). The samples were tested for flexural strength, hardness, impact strength, water sorption and solubility, cytotoxicity in accordance with ISO specification 1567 for denture base resins.*

Results:- *The mean flexural strength varied from 93.82MPa for DPI to 140.95MPa for Sunflex. The mean hardness varied from 76.33kg/mm^2 for DPI to 85.33kg/mm^2 for SR-Triplex HOT. The mean impact strength varied from 7.99 kJ/m^2 for SR to 31.71 kJ/m2 for SU. The mean water sorption varied from 0.000401gm/mm^3 for SU to 0.000624gm/mm^3 for TR. The mean water solubility varied from 0.14gm/mm^3 for TR to 0.35gm/mm^3 for SR. Statistical analysis by One-way ANOVA showed that these were statistically significant between the denture base resins for each property tested with a two-tailed probability of value.*

Conclusion:-*The Sunflex denture base resin showed superior physical and mechanical properties, biocompatible to the oral tissues, can be selected as a suitable denture base material in daily clinical practice, thus fulfilling patient's requests.*

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Introduction

INTRODUCTION

Poly(methy1 methacrylate) polymers were introduced as denture base materials in 1937as vulcanite[62]. Artificial dentures should be made of a material which is strong, rigid & biocompatible in order to serve successfully for a reasonable length of time. Various materials like wood, ivory, ceramics, metals, metal alloys have been used in relatively thin sections in early years of dentistry[63]. Metal & metal alloys used in denture construction display excellent mechanical properties & can be used in relatively thin sections[62]. However it is easier & cheaper to construct prosthesis in non-metallic materials. Also, the color & texture of these materials resemble natural gum tissues making the prostheses less conspicuous in the mouth.

Materials such as vulcanite, nitrocellulose, phenol formaldehyde, vinyl plastics, and porcelain were used for denture bases. The acrylic resins were so well received by the dental profession that by 1946, 98% of all denture bases were constructed from methyl methacrylate polymers or copolymers. Other polymers developed since that time include vinyl acrylic, polystyrene, epoxy, nylon, vinyl styrene, polycarbonate, polysulfone-unsaturated polyester, polyurethane, polyvinylacetate-ethylene, hydrophilic polyacrylate, silicones, light-activated urethane dimethacrylate, rubber-

reinforced acrylics, and butadiene-reinforced acrylic[64]. Acrylic polymers have a wide variety of applications in prosthetic dentistry as artificial teeth, denture repair materials, facings in crown and bridge restorations, impression trays, record bases, temporary crowns, and obturators for cleft. But most of them had a number of disadvantages like increased water sorption, decreased strength & poor color stability. But even till date it's the most commonly, frequently used in dentistry.

There are other types of polymers & copolymers like acrylic-vinyl copolymers, epoxies, polycarbonates. Also flexible like vinyl copolymers, acrylic copolymers &hydrophyllic polymers are used as denture base materials.

Currently available denture base resins have drawbacks like high water sorption & solubility, cytotoxic effects of residual monomer on tissues but improved flexural strength, hardness, impact strength since they are reinforced[63]. Accordingly, an attempt was made to assess the mechanical properties & biocompatibility of 4 different denture base resins with their cross-linking agent added to the monomer, tetra-ethylene glycol dimethacrylate (TEGDMA)[65] as in common compared with commercially available denture base resin, DPI pink.

Aim of the Study

AIM OF THE STUDY

The aim of the study was :

1) To compare mechanical properties & physical properties of four different denture base resins

   (a) Flexural strength

   (b) Hardness

   (c) Impact strength

   (d) Water sorption

   (e) Water solubility

2) To compare biocompatibility of four different denture base resins

   (a) Cytotoxicity

Review of Literature

REVIEW OF LITERATURE

W.M.Amin et al (1981)[1] investigated four of the commonly used resilient denture lining materials of different chemical composition, physical forms and processing cycles. Scanning electron microscope examinations of the interface between the liners and the regular acrylic resin base materials were carried out in an attempt to assess the bonding of these materials to the denture base, and to evaluate the reliability of their use. The physical and mechanical bonding properties of the resilient lining materials to acrylic were studied. The effect of water on the liner/ denture base interface and on the liner's bonding properties to acrylics was investigated, and the validity of roughening the surface of the denture base prior to processing the liner was assessed.

V.T.Truong et al (1988)[2]transverse strength, hardness, water sorption, loss of mass by leaching and porosity were measured in accordance with Australian Standards on acrylic denture base resins cured by boiling water and microwave energy. The level of residual monomer measured by extraction in acetone and the degree of cross-linking by immersion in chloroform were also studied. Results indicated similar physical properties and identical microstructures in the resins cured by two methods. Using a

previously recommended microwave curing programme, porosity was observed in thick specimens with a cross-section 14 x 10 mm.however, the microwave programme can be optimized to prevent porosity without prolonging the curing time or sacrificing the physical properties of the resins by starting the curing process at low wattage.

Baker et al (1988)[3] did a study to develop an assay Gas-Liquid Chromatography Assay of monomeric MMA in saliva. This assay was then used to measure salivary levels of monomer released in vivo from oral acrylic baseplates worn by healthy dentate human volunteers. The duration and total amount of this release were investigated and the correlation between salivary monomer levels and free residual monomer concentrations n the baseplate at two depths determined. Monomer absorbed via the oral mucosa or elsewhere in the alimentary tract was sought in the blood and urine. For minimization of monomer release, autoploymerized appliances should be immersed for 24 hours in water before having worn.

W.FrankCaughman et al (1990)[4] evaluated the cytotoxic potential of resin luting agents on cultures of gingival fibroblasts and oral epithelial cells for direct microscopic cytotoxicity, cell morbidity, impaired adherence, and inhibition of macromolecular synthesis. Visible effects ranged from

severe toxicity with inadequately polymerized composite resin to no detectable morphological cell damage by a glassionomer cement, but inhibition of protein and RNA synthesis varied with the material and cell type. The glass ionomer cement demonstrated no morphologic damage, but exhibited inhibition of macromolecular synthesis in gingival fibroblasts. These results confirmed that in vitro metabolic assays are appropriate for examining the biologic effects of materials.

Lefebvre C A et al (1991)[5] compared biocompatibilities of 3 light-polymerized denture base resins using an in vitro epithelial cell culture system. The effect of varied lengths of polymerization of denture base resin on cell toxicity was examined. Specific formulation of the material and not to the type of polymerization effects oral epithelial cells.

Donna.L.Dixon et al (1992)[6]measured and compared linear dimensional changes of three denture base resins that occurred during processing and after storage n water for 30, 60, 90 days. Traid, Accelar 20, Lucitone 199 long and short-cured resins were studied. However, no significant differences occurred between the groups. After 90 days of water storage, the only resin that exhibited a shrinkage from the processed state was Accelar 20. All of the expansion or shrinkage changes were so small

that they were not statistically significant and should not be clinically detectable.

Barron D J et al (1993)[7]studied the biocompatibility of 3 commercial formulations of visible light-polymerized denture base resins, determined its effects on the RNA & DNA synthesis of oral epithelial cells in vitro. DNA synthesis is more sensitive to the toxic effects of the materials, which may relate to the ability to cause mucosal pathology. The cytotoxic effects may relate to the presence of unpolymerized resin constituents or polymerization by-products.

Hironori Tsuchiya et al (1994)[8] systematically conducted studies of substances leachable from acrylic resins, their cytotoxicity to cultured cells, and means of reducing their leaching. Under in vivo and in vitro conditions, formaldehyde and methyl methacrylate were significantly leached into human saliva and saliva-substitute buffer, especially from autopolymerized resins. Both leachable substances showed cytotoxic potentials in the range of their leaching concentrations. Formaldehyde was cytotoxic at lower concentrations than methyl methacrylate. Preleaching in water reduced subsequent leaching of both formaldehyde and methyl methacrylate, and the amount of reduction depended on an increase in the preleaching

temperatures. Immersion of acrylic resin dentures in hot water (50 ° C) before insertion is recommended, especially for autopolymerized resins used either for rebasing or as denture base materials, to minimize the risk of adverse reactions in patients who wear acrylic resin dentures.

Carol A.Lefebvre et al (1994)[9] examined the metabolic effects eluates from four light-polymerized denture base resins and one heat-polymerized denture base resin on oral epithelial cells in vitro. The eluate was cell culture medium that contained either or both of apparently nonpolymerized components and reaction products that diffused out of the resin samples. The fresh elautes inhibited cell metabolism, whereas the aged eluates stimulated then inhibited the response. Result that the components that leach out of the tested materials do so at different rates and have prolonged toxic effects on cells. Thus, soaking prostheses in water before insertion may be beneficial.

S. Ratanasathien et al (1995)[10] investigated the cytotoxicties of four dentin bonding components→ HEMA, Bis-GMA, TEGDMA and UDMA, interactive effects for three binary combinations of the dentin bonding components→ HEMA &Bis-GMA, Bis-GMA & TEGDMA, and TEGDMA &UDMA.The ranks of cytotoxicity of the dentin bonding components in

terms of TC50 values were as follows: Bis-GMA > UDMA > TEGDMA >>> HEMA (least toxic) after 24 and 72 hours exposures. The findings indicate that both exposure time and the interactions between the dentin bonding components may be important parameters in determining the cytotoxicity of dentin bonding agents *in vivo*.

A.Dooan (1995)[11] carried out curing of several commercial powder/ liquid mixtures of acrylic denture base materials at different temperatures and curing times. The level of residual monomer, tensile strength, percentage elongation before break and water absorption were measured.

Sheridan P J et al (1997)[12] et al did an in vitro study examining the effect of eluate from heat-activated, chemical activated, and microwave-activated denture base resins on cell viability of primary cultures of human gingival fibroblasts. Results indicated that all time periods tested, all three resins leached materials that were cytotoxic to the fibroblasts. Eluate from chemically activated resin disks was more cytotoxic than eluate from heat-activated and microwave-activated disks. In general, cytoxicity appeared to diminish as disk immersion time was increased. The greatest cytotxic effect on cell viability was observed with eluatesrecovred after 24 hours of disk

immersion, and the least cytoxic effect was observed with eluates recovered after 96 hours of immersion.

VarpuMMiettinen et al (1997)[13]determined the water sorption and solubility of heat-cured and chemical-cured glass fiber (GF) PMMA composite used in denture. Polymethacrylate (PMMA) absorbs water slowly over a period of time, primarily because of the polar properties of the resin molecules. The test specimens were fabricated from experimental, unidirectional, continuous GF reinforcement; GF concentration of the test specimens was approximately 11% weight. The results of this study suggest that the water sorption and solubility of unreinforced PMMA and PMMA reinforced with GF are in accordance with International Standards Organization specification No. 1567.

Takahashi Y et al (1998)[14] studied the effect of water sorption on the flexural strength at the proportional limit (F_s) of a denture base material relined with four different denture reline materials. The plasticizing effect of absorbed water molecules explains the general decrease in F_s of immersed relined specimens. The absence of a significant effect that water immersion had on some relined specimens under certain immersion conditions was explained by water sorption into the denture base achieving in an

equilibrium after a period of water immersion, and the resistance of some reline materials to the effect of water immersion.

Shim JS et al (1999)[15] determined the effects on methylmethacrylate (MMA) monomer concentration of a second heat-cure cycle introduced for the purpose of processing a denture soft-liner. Two denture-base resins (Lucitone199 and Trevalon) were selected. Concentrations of MMA monomer were determined by reversed-phase high performance liquid chromatography (HPLC) The HPLC method was suitable for determining the amount of residual monomer in the denture-base acrylic resin. A further (soft-liner) heat-cure cycle had a statistically significant effect on reducing residual monomer concentrations, and this may have an effect upon mechanical properties.

PekkaK.Vallittuet al (1999)[16] described and tested a novel system to use polymer-preimpregnated reinforcing fibers with commonly used multiphase acrylic resin. Continuous unidirectional & woven preimpregnated glass fibre reinforcements (Stick and Stick Net) were used to reinforce heat-curing denture base and autopolymerizing denture base polymers. A temporary fixed partial denture polymer was also reinforced with Stick reinforcement material. A 3-point loading test was used to

measure transverse strength and flexural modulus of the material and ultimate strain at fracture was calculated. Cross-sections of test specimens were examined with a SEM to evaluate degree of impregnation of fibers with polymer matrix. Quantity of fibers n test specimens was determined by combustion analysis. Novel glass fiber reinforcements may considerably enhance flexural properties of multiphase dental polymers, which is due to proper impregnation of fibers with polymer matrix. By using Stick or Stick Net reinforcement, the strain at fracture of the material can be modified.

GulayUzum et al (1999)[17] measured the effect of 5 fiber strengtheners on the fracture resistance of denture base resin material. Impact strength, transverse strength, deflection, and elasticity modulus values of a heat-polymerized denture base resin (Trevalon), reinforced with glass, carbon, thin Kevlar, thick Kevlar, and polyethylene fibers in woven form were studied. The impact strength of denture base acrylic resins was increased with fibers in woven form. Tested fibers did not have a significant effect on the transverse strengths. This will enhance the ability to repair the functional denture and also may reduce aspiration of denture fragments in the event of denture fracture by trauma or accident.

Debby M.S.Wong et al (1999)[18] investigated linear dimensional changes & water sorption of dentures processed by dry & wet heat with different rates of cooling. Water uptake of dry & wet heat-processed acrylic resin dentures after deflasking was in both cases low, and the dentures did not reveal significant differences in shrinkage at water saturation. Air oven-processed & water-bath processed acrylic resin dentures show similar dimensional changes at water saturation.

Jagger DCet al (2000)[19] investigated the effect of continuous poly (methyl methacrylate) fibres on the transverse strength and impact strength of poly (methyl methacrylate) denture base resin. The fibres were added in three arrangements, a single unidirectional (longitudinal in the length of the specimen) layer, two longitudinal layers and in cross poly form (a combination of an inferior longitudinal layer and a superior transverse layer). The results indicated that the transverse bend and impact strengths of poly (methyl methacrylate) denture base resin, were not significantly improved by the addition of poly (methyl methacrylate) fibres.

T.Kanie et al (2000)[20] determined the reinforcing effect of woven glass fibres on deflection, flexural strength, flexural modulus, impact strength of acrylic denture base polymer. The reinforcement in glass fiber

was effective in thin specimens, the reinforcing effect increased with the increase of the number of glass fibers in the case of thick specimens.

Syme VJ et al (2001)[21] determined the stiffness of representative cured autopolymerising dental acrylic resins by calculation of a secant modulus from measurements in tension of load and extension, and related to the powder/liquid mixing ratio. Also he compared impact strengths of autopolymerising, heat-cure and commercial resins. He found that while the stiffness of autopolymerising resins was unaffected by variations in powder/liquid mixing ratio, extension to failure was greater with lower powder/liquid ratios. The impact strength of autopolymerising resins was found to be greater than that of heat-cure resins, and offered a tentative explanation. These findings may help to explain the pattern of failure of acrylic resin denture bases.

F-X Reichl et al (2001)[22] investigated the effect of dental composite components TEGDMA (triethyleneglycoldimethacrylate), HEMA (hydroxyethylmethacrylate), $HgCl_2$ (mercuric chloride) and MeHgCl (methylmercury chloride) on the release of lactate dehydrogenase (LDH) from alveolar epithelial lung cells in vitro. The toxic effect of $HgCl_2$ and MeHgCl from the L2 cells was about 100-700 fold higher than of the dental

composite components. A significant time dependant increase of toxicity was observed with TEGDMA, HEMA and MeHgCl.

Fu-Mei Huang et al (2001)[23] determined the cytocompatibilty of three different extracts of denture base resins and to compare the cytotoxic effect of these materials on a human oral epithelial KB cell line and primary human oral fibroblasts derived from buccal mucosa. The eluates from self-cured, heat-cured, light-cured denture base resins were cytotoxic to primary human buccal fibroblast cultures and KB cells. Self-cured resin was the most toxic denture base material among the chemicals tested in all cultures. The influence of the cytotoxicity depended on the materials tested and the cell culture system used. The use of both permanent and primary cells is recommended for a better screening of the cytotoxic effects of denture base resins.

Mohammed SohailMemom et al (2001)[24] compared the impact and transverse strengths and the flexural moduus of three denture base polymers. The investigation included a relatively new microwave-polymerized polyurethane-based denture material processed by an injection-molding technique, a conventional microwave-polymerized denture material, a heat-polymerized compression-molded poly(methyl methacrylate) (PMMA)

denture material. Impact strength was determined using Charpy-type impact tester. The transverse strength & the flexural modulus were assessed with a 3-point bending test. He concluded that in terms of the impact & flexural strengths, the new microwave-polymerized, injection-molded, polyurethane-based polymer offered no advantage over the existing heat- and microwave-polymerized PMMA- based denture base polymers. However it has a rigidity comparable to that of the microwave-polymerized PMMA polymer.

Yau WF et al (2002)[25] measured the pressure and temperature changes of acrylic resin during processing, to record the highest temperature reached when fast cured in boiling water and determined the elevated boiling point of monomer under high pressure. The highest temperature reached by heating of resin during processing is well below the elevated boiling point of monomer. Monomer therefore does not boil in clamped denture flasks under sufficient pressure. Thus adequate clamp pressure prevents gaseous porosity irrespective of curing cycle used.

Jagger DC et al (2002)[26]investigated transverse and impact strength of five "high strength" acrylic resin denture base materials. A conventional heat-cured acrylic resin was used as a control. Specimens were prepared as specified in the International Standard Organization (ISO 1567: 1988) and

British standards for the Testing of Denture Base Resins (BS 2487: 1989) and the British Standard Specification for Orthodontic resins (BS 6747: 1987) for transverse bend and impact testing. The impact strength was measured using a Zwick pendulum impact tester and the transverse bend strength measured using a Lloyds Instruments testing machine. The results showed that Metrocryl Hi, Luctitone 199 and N.D.S. Hi all had an impact strength which was significantly higher than the control. For the modulus of rupture, there was a significant difference between Sledgehammer and the other groups. There was no significant difference between the other groups and the control. For the modulus of elasticity, Sledgehammer produced the highest value followed by the control. The remaining four materials had a modulus of elasticity less than the control.

Uzun G et al (2002)[27]compared fracture resistance of six commercially available acrylic resin denture base materials through impact and transverse strength tests. Namely, three rapid heat-polymerised resins (QC 20, Meliodent and Trevalon), two high-impact strength resins (Trevalon Hi and Lucitone 199) and a strengthened injection-moulded acrylic resin (SR Ivocap plus). High-impact resins can be recommended to increase the impact strength of denture base. If the cause of fracture is mechanical or

anatomical, strengthened acrylic resins and conventional acrylic resins have similar fracture resistance.

JanainaHabib Jorge et al (2003)[28] reviewed the literature published from 1973 to 2000, acrylic resins have shown to be cytoxic as a result of substances that leach from the resin. The primary eluate is residual monomer which is responsible for mucosal irritation and sensitization of tissues. It helped to assess biologic effects , enabled a comparison among the different polymerization methods assisting the clinician in selecting a material with minimal cytotoxicity.

Zappini G et al (2003)[29] determined the fracture toughness of denture base resins and to compare the results with impact strength measurements. Seven heat-polymerized denture base resins were chosen for the study: 5 high impact (GC Luxon, Injectall IPF HI-I, Ivocap Plus, Lucitone 199, Trevalon HI) and 2 conventional (Major Base 2 and Probase Hot). He concluded specimen geometry and testing configuration influenced the impact strength measurements. The fracture toughness method seems to be more suitable than impact strength measurements to demonstrate the effects of resin modifications. The differences between conventional and so-called

"high-impact" denture base resins are more clearly demonstrated with fracture toughness measurements.

Marco Antonio Compagnoni et al (2004)[30] studied the effect of different microwave polymerization cycles on the porosity of a denture base resin designed for microwave polymerization. Within the limits of this study, a denture base resin specifically designed for microwave polymerization tested was not affected by different polymerization cycles. Porosity was similar to the conventional heat-polymerized denture resin tested.

Sung-Hun Kim et al (2004)[31] measured the impact strength of maxillary complete dentures fabricated with high-impact acrylic resin & to evaluate the effect of woven E-glass fibre-reinforcement on the impact strength of the complete dentures. He concluded that impact strengths of maxillary complete dentures with high-impact acrylic resin increased by a factor greater than 2 when reinforced with woven E-glass fiber.

Pfeiffer P et al (2004)[32]did an invitro study by comparing the amount of residual monomer, quantity of water sorption, and water solubility of 4 denture base materials Sinomer, Polyan, Promysan, Microbasepurpoted to be hypoallergenic with those of a polymethyl methacrylate-based (PMMA)

heat-polymerizing acrylic resin- Paladon 65 according to ISO 1567:2000. The residual MMA monomer concentrations were determined by gas chromatography (GC). The tested denture base materials fulfilled the requirements regarding water sorption and solubility. The tested hypoallergenic denture base materials exhibited significantly lower residual monomer content than PMMA. Promysan and Microbase showed no detectable residual MMA.

Juliana Saab Rahal et al (2004)[33] studied influence of polishing methods on water sorption and solubility of denture base acrylic resins. Groups of heat-cured, microwave cured were submitted to mechanical polishing- pumice slurry, chalk powder, soft brush, felt cone in a bench vise; or chemical polishing- heated monomer fluid in a chemical polisher. Mechanical polishing promoted significantly lower solubility of acrylic resins; initially water sorption values were higher of chemical polished samples, however, after 4 weeks all groups were similar.

Sunitha N Shamnur (2004)[34]hard and soft undercuts are frequently encountered in the fabrication of prosthesis in partially as well as completely edentulous arches. Though alteration of denture prosthesis, relining by flexible relining material will serve the purpose but the flexible denture base

materials stands in superior position compared to other options. Sunitha reviewed the various commercially available flexible denture base materials and highlights then indications and special instructions in wearing and maintenance of the same.

C Y K Lung et al (2005)[35] stated that residual monomer [MMA]R in denture base acrylic continues to be of concern. The response surface of concentration vs. time and temperature for the equilibrium of methyl methacrylate (MMA) and it's polymer (PMMA) allows a prediction of the time to the minimum at any temperature for a closed system. He decided to determine whether this prediction applies to normal denture base processing, whether optimum conditions could be identified. Residual monomer is inevitable for all PMMA-based products no matter what the curing conditions are. He suggested that overnight processing at 95^0C should be adopted to minimize [MMA]R and save energy.

Peter Pfeiffer et al (2005)[36] did an in vitro study comparing flexural strength and flexural modulus of 4 hypoallergenic denture base materials with flexural strength/ modulus of a PMMA heat-polymerizing acrylic resin . The following denture base resins were examined: Sinomer, Polyan, Promysan, Microbase, Paladon 65. Specimens of each material were tested

for flexuralstrength and flexural modulus according to ISO 1567:1999. Flexural modulus of Promysan was significantly higher than the PMMA material. Microbase and Sinomer exhibited significantly lower flexural strength and flexural modulus, respectively, than PMMA. The other did not differ significantly from the control group.

Andrea Azevedo et al (2005)[37]evaluated indirectly the degree of conversion of 2 hard chair-side reline resins & one heat-cured acrylic resin by measuring the surface hardness. The effect of immersion in water on this property was also analyzed. In general, the hardness of the materials evaluated increased during dry storage and decreased after immersion in water.

Thomas R MengJr et al (2005)[38] determined the Izod impact strength, the flexural strength, the flexural modulus, the yield distance for four premium denture resins. Flexural strength, flexural modulus, yield distance were determined by testing the specimens to failure using a three-point test fixture. Izod impact strength was determined using an Izod tester on un-notched specimens generated from the flexural test. Fricki Hi-I, Probase Hot, Sledgehammer Maxipack were statistically similar for the Izod impact strength and flexural strength tests performed. Flexural modulus had an

inverse relationship to the impact strength, flexural strength, and yield distance.

Nabawy A. Alrobeigy et al (2005)[39] compared the water sorption and solubility of four different types of acrylic resins using injection molding technique in comparison with heat-cured acrylic resin using compression molding technique. All injection processed resins less water sorption than the compression processed resin (control group). No significant difference was noted in the water sorption of all injection processed resins. Microwave polymerized acrylic resin (Acron MC) showed significant increase in the solubility value than other tested acrylic denture base resins.

I.H. Tacir et al (2006)[40] examined the reinforcing effect of glass fibers on the fracture resistance and flexural strength of acrylic denture base resins. Flexural strength was tested using a 3-point universal testing machine. Within the limitations of this study, the flexural strength of heat-polymerized PMMA denture resin was improved after reinforcement with glass fibers. It may be possible to apply these results to distal extension partial and complete denture bases.

Dong Hee Lee et al (2006)[41] studied the possibility that apoptosis as well as mutagenicity induced by resin monomers are mediated by oxidative

stress. A range of dilutions of three resin monomers GMA, TEGDMA, HEMA were used. Their cytotoxic effects were measured by a colorimetric functional assay (MTT). Resin monomer-induced apoptosis was further confirmed by flow cytometry (staining with both annexin V-FITC and PI). All monomers exhibited a dose-dependant cytotoxic effect, and the ranking of the cytotoxicity based on TC50 was GMA > TEGDMA > HEMA. The resin monomer-induced cytotoxicity was significantly decreased by co-treatment with N-acetylcystein (NAC), an antioxidant. These findings suggested that glutathione depletion and oxidative stress are responsible for GMA, TEGDMA, HEMA-induced mutagenicity and apoptosis.

Rune Becher et al (2006)[42] evaluated aqueous extracts of freshly cured components Freedom and F2000, and constituents identified in the extracts, GDMA, TEGDMA and HEMA for their ability to induce necrosis and apoptosis in primary rat alveolar macrophages and the J744A1 macrophage cell line. Cytotoxicity and necrosis were assayed by MTT test and fluorescence microscopy. Apoptosis was assayed by fluorescence microscopy and flow cytometry. He found that TEGDMA was more cytotoxic than HEMA using the MTT test and fluorescence microscopy, whereas HEMA caused a greater accumulation of apoptotic cells seen by fluorescence microscopy and flow cytometry. As an apoptotic response

elicits inflammatory response in the surrounding tissues than a necrotic process, the role of cell death pattern could be important for the evaluation of the biocompatibility of dental materials.

JanainaHabib Jorge et al (2006)[43]investigated using 3H-thymidine incorporation test, the effect of microwave and water-bath polymerization heat treatments on the cytotoxicity of two base acrylic resins. The results showed that the components leached from the resins were cytotoxic to L929 cells, except for the specimens heat treated in water bath. Compared to the group with no treatment, water-bath decreased the cytotoxicity of the denture base acrylic resins. The in vitro cytotoxicity of the tested denture base materials was not influenced by microwave post-polymerization heat treatment.

Fernanda Faot et al (2006)[44] evaluated the impact strength & fracture morphology of denture base resin acrylic resins processed by microwave energy & hot water bath. 20 specimens measuring 65 x 10 x 2.5 mm were fabricated from each of 4 acrylic resins were processed. Fractures were classified as brittle or intermediate. Within the limitations of this study, it was observed that impact strength in microwave-polymerized acrylic resins varies according to the period of irradiation. Acrylic resins exhibited a

high number of brittle fractures, irrespective of the processing technique. This study suggests that the polymerization cycle can influence the impact strength of the microwave acrylic resins studied.

Jon E. Dahl et al (2006)[45]evaluated the in vitro biocompatibility of denture base relining materials using cell culture tests and a test for irritation mechanisms. Many dental materials elicit cytotoxic response, but this does not necessarily reflect the long-term risk for adverse effects as the oral mucosa is generally more resistant to toxic substances than a cell culture.

Yu R Y et al (2006)[46]evaluated the biocompatibility of polymethyl methacrylate denture base resin containing silver-supported antimicrobial agent STR-1 nanometer level in vitro. The PMMA denture base resins containing silver- supported antimicrobial agents STR-1 nanometer level at concentrations of 5 g/l and 10 g/l exhibit good biocompatibility.

Jorge J.H et al (2007)[47] evaluated the effect of two post-polymerization treatments and different cycles of polymerization on the cytotoxicity of two denture base resins. The resins tested were Lucitone 550 and QC 20. Lucitone 550 was processed by long/ short cycle. The resin disc QC 20 was processed by reverse/ normal cycle. The long cycle increased the

cytotoxicity of Lucitone 550 and water-bath post-polymerization reduced the cytotoxicity of Lucitone 550 processed by long cycle.

SuleymanHakan Tuna et al (2008)[48] evaluated 10 acrylic resin-based materials were evaluated: 2 heat cure acrylic resins and eight self-cure acrylic resins. In this study, the method recommended by ISO for measuring water sorption and solubility was used. The water sorption was determined according to increase in mass per unit volume. Also water solubility was determined according to loose of mass from polymers. According to tests performed in this research, each acrylic resin displayed various water sorption and water solubility values. The results of the water sorption & solubility of both self-cured and heat-cured acrylic resins were in accordance with the ISO specification. No correlation found between water sorption & solubility values.

Ana M. Diaz-Arnold et al (2008)[49] evaluated static and dynamic flexure properties of a variety of acrylic resins utilized in the fabrication of prostheses : (1) heat-polymerized plymethyl methacrylate (PMMA), powder-liquid type, and (2) a newly introduced, visible light-polymerized urethane dimethacrylate dough type. The visible light- polymerized urethane dimethacrylate resin (Eclipse) showed greater flexure strength than all

PMMA heat-polymerized resins for both static & cyclic groups. Yet the Eclipse material had lower load limits, and demonstrated brittle type behavior and greater standard deviations. The heat-polymerized PMMA materials did not significantly differ from each other after static or cyclic testing.

Zissis A et al (2008)[50] investigated the release of residual monomer from different denture materials (three heat polymerizing, one auto polymerizing) and one hard liner were subjected to residual monomer determination using gas liquid chromatography. Heat polymerized denture base acrylic resins released insignificant amounts of residual monomer during the storage period, whereas both the auto polymerized denture base resin and the hard liner released significant amounts of residual monomer during the initial storage time period but insignificant ones during the remainder of the storage period.

DalalA et al (2009)[51] tested the effect of different curing cycles on the tensile strength of the bond between one brand of cross-linked acrylic resin teeth and three heat cured denture base acrylic resins. There were differences in the tensile bond strength between the three heat cured denture base acrylic resins and the three curing cycles used. The bond strength of the acrylic

resin denture base material made by the same manufacturer as the cross-linked acrylic resin denture teeth was higher. The bond strength following the short cycle was lowest in all cases, individual differences between curing cycles failed to reach statistical significance.

Fernando Faot et al (2009)[52] evaluated the impact and flexural strength and analyzed the fracture behavior of acrylic resins. Impact strength was evaluated in notched specimens (50 x 6 x 4 mm) and flexural strength in unnotched (64 x 10 x 3.3 mm) using 3-point bend test. Within the limits of this study, the Impact 2000 showed improved mechanical properties with high capacity of stress absorption & energy dissipation before the fracture.

Ana Lucia Machado et al (2009)[53]evaluated the effect of microwave and chemical disinfection on the Vicker's hardness (VHN) and surface roughness of 2 hard chairside reline resins and 1 heat-polymerizing denture base resin. Disinfection by immersion in sodium perborate or microwave irradiation did not adversely affect the hardness of all materials evaluated. The effect of both disinfection methods on the roughness varied among materials.

Melilli D et al (2009)[54]compared the cytoxicity of 4 types of resins used for manufacturing denture bases. The autopolymerized resin showed

the major cytoxicity; the light-polymerized resin, instead, showed an optimal biocompatibility due to the absence of free monomer from it's chemical composition.

Jorge J Het al (2009)[55]evaluated the effect of microwave postpolymerization heat treatment and water storage time on the cytotoxicity of denture base and acrylic resins. Microwave irradiation may be considered an alternative to reduce the cytotoxicity of Tokuyama Rebase II.

Carolina de Andrade Lima Chaves et al (2010)[56] evaluated the cytotoxic effect of the monomers IBMA, 1,6-HDMA, DBP, MA, BA on L929 cells including hard chair-side reline resins. Cytotoxic effects were assessed using MTT and 3 H-thymidine assays. The differences observed in the cytotoxicity of these compounds, along with other properties, may assist the dental practitioners in the selection of reline materials with improved service life performance and low risk of adverse reactions in patients who wear relined dentures.

AylaArikan et al (2010)[57] compared transverse strengths of pink & white acetal resins to transverse strengths in increasing durations of water storage. The results of this study indicated that transverse strength values of PMMA were within the ISO specification limit. Water storage time (50

hours, 30, 60, 180 days) had no statistically significant effect on the transverse strength and deflection of PMMA. Acetal resin suffered from permanent deformation, but did not break in the three-point bending test. Acetal resin showed significant increase in deflection as the water storage time was increased from 50 hours- 180 days. All materials tested demonstrated deflection values in compliance with ISO specification No.1567.

Rahul Bholaet al (2010)[58]reviewed, an attempt was made to combine the material properties of the polymers used in dentistry mainly PMMA. Depending on type of polymerization, PMMA resins may leach 0.1-5% of the residual monomer and additives, mainly MMA and formaldehyde, contributing to localized allergies.

Hamanaka et al (2011)[59]investigated the mechanical properties of injection-molded thermoplastic denture base resins. Four injection-molded thermoplastic resins and as a control, a conventional heat-polymerized polymethyl methacrylate (PMMA) were used in this study. The flexural strength at the proportional limit (FS-PL), the elastic modulus, Charpy impact strength of the denture base resins were measured according to International Organization for Standardization ISO 1567:1999. All of the

injection-molded thermoplastic resins had significantly lower FS-PL, lower elastic moduli; and higher or similar impact strength compared to the conventional PMMA.

Materials And Methods

MATERIALS AND METHODS

The heat-cure denture base resins used in this study were:

i) SR Triplex-HOT (fiber reinforced denture base resin)

ii) Sunflex (Flexible denture base resin)

iii) TrevalonHI (High impact denture base resin)

iv) DPI Heat Cure (Conventional denture base resin)

The materials used, powder:liquid ratio, batch no., manufacturer are given in table below:-

TABLE I

MATERIALS USED IN THE STUDY

Materials used	Powder: liquid ratio	Batch no.	Manufacturer
SR Triplex-HOT	23.4 g polymer : 10ml monomer	Powder N27615 Liquid N16926	IvoclarVivadent AG FL-9494 Schaan/ Liechtenstein
Sunflex	Single component	O60511B	IvoclarVivadent, United States
Trevalon HI	Powder/Liquid Ratio: 24g/10ml	Powder TH 100503 Liquid TH L100402	Dentsply India Pvt.Ltd.
DPI Heat Cure	24 gm powder: 10ml liquid	Powder 7111 Liquid 5117	Dental Products of India, Bombay Burmah Trading Corporation Ltd. Mumbai

METHODS

The mechanical properties and physical properties studied were:

a) Flexural strength

b) Hardness

c) Impact strength

d) Water sorption & solubility

The biocompatibility studied was:

a) Cytoxicity

A total of 100 samples were prepared from four denture base resins to test the mechanical, physical property& biocompatibility. 5 samples were made for each material to test each property.

FLEXURAL STRENGTH

Specimens for SR, TR, DPIwere prepared as per manufacturer's instructions by compression-molding method.The specimenswere made as per ISO specification 1567: 2000. The wax block of dimension of 65mm x 10.5mm x 4mm[50]were invested in conventional metal denture flasks. After dewaxing, a layer of undiluted alginate mould seal was painted uniformly on

the mold. The manipulation, packing, and curing of the denture base resins was done according to the manufacturer's instructions. All specimens were polymerized in a thermostatically controlled water bath UNIDENT Acrylizer (UNIDENT INSTRUMENTS, INDIA PVT. LTD; NEW DELHI-10005).Following deflasking, the specimen strips were wet-grinded in sequence using 320,400, 600 grit silicon carbide paper , polished with wet buff & pumice, polished with dry buff & pumice.The final dimensions of specimens were 64 ± 0.03 mm long x 10 ± 0.03 mm wide x 3.5 ± 0.03 mm depth. Each specimen was individually measured by use of a vernier caliper. All specimen were stored in distilled water at room temperature for 7 days before testing.

Specimens for SU were fabricated using injection molding technique where resin was supplied in a single-paste form in a plastic catridge. Wax strips of dimensions 64mm x 10mm x 2.5 mm were invested in specially designed flask. After dewaxing, flask was reassembled. Flask was placed into carrier that maintains pressure on the assembly during resin introduction & processing. Then resin was injected into mold cavity. Specimens were acrylized in water bath, bench cooled, deflasked, trimmed, polished, finished. All specimen were stored in distilled water at room temperature for 7 days before testing.

Test was carried out using anUniversal Testing Machine- Instron machine (Model 3365) using the three-point bend test method. The dimensions of each specimen were entered into the program for computation.

Specimen was centered on the two wedges which were 50mm apart (span length). The loading wedge (upper central loading) 5kN was set to move at a crosshead speed of 10 mm/min & engage the centre of the specimen until it fractured[25]. The load at break was noted & flexural strength was calculated using the formula :

$$Fs = 3Pml / 2bh^2$$ [21]

Pm = maximum load

l = span length

b = width of the test specimen

h = thickness of the test specimen

HARDNESS

Hardness was tested with SHORE DUROMETER. Specimens of dimension 12 mm x 12mm x 3 mm[55]were prepared using wax block & gypsum molds as in the previous experiment. After processing according to

manufacturer's instructions, the specimens were removed, trimmed and hand polished in sequence using 320, 400, 600 grit silicon carbide paper.All specimen were stored in distilled water at room temperature for 7 days before testing.

Shore Durometer (Model SHR-D, Blue Steel, Engineering Pvt. Ltd, India) was pressed on the pressed on the specimen & the gauge directly gave the reading. Shore Durometer was pressed at 6 different points on the specimens and averaged for each sample. The less the indenter of the Shore Durometer penetrates the specimen, the higher the reading and greater the hardness.

IMPACT STRENGTH

The specimen preparation & the test were carried out in accordance with the conditions laid down in ISO specification 1567. Specimens of size 65 mm x 10mm x 2.5 mm[44] were prepared by packing acrylic resin in a mold space of same dimension. The mold space was prepared by investing wax blocks in gypsum using conventional denture flasking techniques. Mold separation, packing & clamping followed standard practice. All specimens were processed according to manufacturer's instructions. After deflasking, the specimens were trimmed and hand polished in sequence using 320, 400,

600 grit silicon carbide paper. All specimens were stored in distilled water at room temperature for 7 days before testing.

Specimens were given type 'v' notch with help of Model 899 Impact Specimen Notcher for plastics. The thickness was recorded of each specimen with TINIUS Olsen Notch Thickness Gauge.

Notched Izod impact tests was performed in TINIUS Olsen Model Impact 503 acc. to ISO 180 for plastics. The test was used to study the energy absorbed by the acrylic resin until it fractures. A test pendulum weighing 4.530N, was swung at a radius of 334.898 mm. A load of 2.7624 J was selected to load the specimens. Specimen is held as a vertical cantilevered beam, dimension of specimen was entered into the program for computation, pendulum which was latched was released, swung down to fracture the centre of the rectangular bar that is supported at one end & struck at other end. Impact occurs on the notched side of the specimen. The energy lost by the pendulum during the fracture of the specimen was determined by comparison of length of it's swing after the impact with that of it's free swing when no impact occurs.[65]Therefore, strength was recorded of each specimens where weight of pendulum resulted in a value that is converted into kJ (as per ISO 1567).

WATER SORPTION & SOLUBILITY

Specimens were prepared as per manufacturer's instructions by compression-molding method having diameter of 50 ± 1mm & thickness of 5 ± 0.05mm with top & bottom surfaces flat as per ISO specification 1567.[34]After processing , the specimens were removed, trimmed and hand polished in sequence using 320, 400, 600 grit silicon carbide paper. All specimen were stored in distilled water at room temperature for 7 days before testing.

Each specimen was weighed before placing in the dessicator in ANAMED Digital weighing machine, recorded the readings. Later they were placed inside the dessicator. The dessicator was kept in the incubator at 37° C for 24 hours. Each specimen was weighed to a precision of 0.0002 gm. After all the specimens have been weighed, the dessicant $CaCl_2$was replaced in the dessicatorwith freshly dried gel. The above procedure was repeated till a constant mass, 'M1' or 'conditioned mass' was obtained; i.e. till the loss in the mass of each specimen disc is not more than 0.0002 gm between successive weighing.The diameter & thickness of the specimens was taken before immersion in water. The diameter was measured with vernier caliper, thickness with thickness gauge (25 x 1/100 mm).

The specimen disc was immersed in water at 37^0C for 7 days. Then, removed the disc from water, wiped until free from visible moisture, waved in the air for 15 second & weighed 1 minute after removal from water with a precision of 0.0002 gm recorded this mass as 'M2'.

After this, the discs were reconditioned to constant mass in the dessicator as before. The mass was recorded of the 'reconditioned disc' as 'M3'.

Volume 'V' of the specimen was calculated from the diameter & the mean of 5 thickness measurements, are taken at the centre& four at equally spaced locations around the circumference.

Water sorption & solubility were calculated using the equations.[34]

$W_{sp} = M2 - M1 / V$ $W_{sp} \rightarrow$ water sorption

$W_{sl} = M1 - M3 / V$ $W_{sl} \rightarrow$ water solubility

Where, M1 is 'conditioned mass'

M2 is 'mass of the disc after immersion in water'

M3 is the volume of the disc expressed in cubic millimeters.

W_{sp} foreach disc expressed in $\mu gm / mm^3$

W_{sl} for each disc per unit volume, leached out during immersion, is expressed in µgm / mm^3.

CYTOTOXICITY

Cell culture for toxicity was used. As per manufacturer's instructions, specimens were prepared in dimensions 8.5 ± 0.2mm diameter, 2.0 ± 0.2mm thickness in accordance to ISO 1567[10]. After processing , the specimens were removed, trimmed and hand polished in sequence using 320, 400, 600 grit silicon carbide paper. All specimens were stored in distilled water at room temperature for 7 days before testing. Preleaching in water was done to reduce the subsequent leaching of methyl methacrylate (TEGDMA-tetraethyleneglycoldimethacrylate).

Test method used here was Test on Extracts based on ISO 10993-5, 2009. Source of cell line was ATCC. Strain of L-929 which is an established & well characterized mammalian cell line demonstrating reproducible results was prepared. The cultures were maintained at 37 ° C in an atmosphere of 5% CO_2 and 95% air in Minimal Essential Medium (MEM) supplemented with 10% Foetal Bovine Serum (FBS).

Extract was prepared by incubating 1.25 cm^2 each test materials in previously prepared 1 ml culture medium with serum at 37 ± 1 ° C for 24-

26 hrs. 100% extracts were diluted with medium to get concentration of 50% & 25%. Different dilutions of extracts of test sample, negative control and positive control in triplicate were placed on subconfluent monolayer of L-929 cells.High density Poly Ethylene (USP) was negative control. Dilute phenol was used as positive control.After incubation of cells with extracts of test sample and controls at 37 ± 1^0C for 24 ± 1 hour, cell culture (cell monolayers) was examined microscopically for cellular response under Inverted Phase Contrast Microscope under 20X magnification.

Microscopically the cell cytoxicity scale bar distance 100µm is taken where the size of cell can be determined.

The following morphologic criteria for toxicity[4]:

(1) Cellular rounding

(2) Nuclear pyknosis

(3) Loss of cellular attachment to the dish

(4) Cytolysis

Each sample was scored independently by two calibrated evaluators and each scoring was accomplished blindly. Each culture dish was divided into four concentric regions from the sample disk center to the culture dish wall.[4]

Cellular responses were scored as 0 (without toxicity), 1, 2, 3, 4 (maximal damage to the cell monolayer) assigned to each culture, dependant on the distance aberrant cells were from the sample disk. Selected cell cultures were harvested into suspension, and viability staining with neutral red was done to verify that abnormal morphological characteristics correlated with dye exclusion and cell death.[4]

The remaining cell cultures were fixed for 45minutes with 2% gluteraldehyde in 0.1 mol/L phosphate buffer, pH 7.4, and stained 2 hours with 0.125% methylene blue, and the sample disks were examined for cellular adherence.[4]

So therefore, the test materials were in contact with fibroblast cells (L-929 cells) for 24-26 hours to determine extent or grade of cytoxicity of residual monomer leached out from the denture base resins. Mean values for cell number/cm^2 of culture area were obtained by counting five times per sample. Cytotoxicity was evaluated by determining the relative ratios of cell numbers to control values (incubated without adding any leachable substances).[10]

Fig.1. Heat cure denture base resins used in this study

Fig.2. Specimens used in this study

A. Specimen used for testing flexural strength

B. Specimen used for testing hardness

C. Specimen used for impact strength

D. Specimen used for water sorption, solubility

E. Specimen used for cytotoxicity placed in sterile containers

Fig.3. Flexural strength test specimen assembled in INSTRON Universal Testing Machine

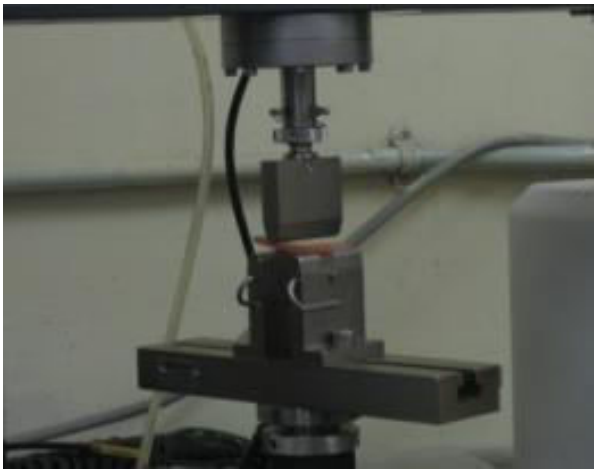


Fig.4. Shore D Durometer used to test hardness

Fig.5. TINIUS Olsen Izod Impact Tester- Model Impact 503

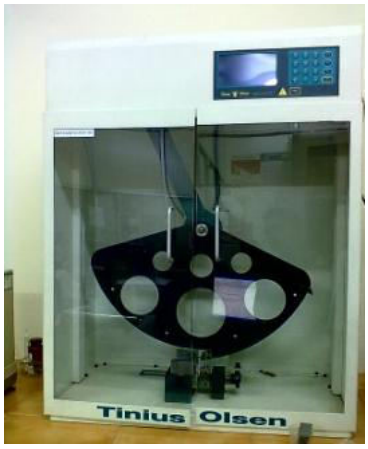


Fig.6. Impact strength test specimen assembled in Izod Impact Testing machine Model Impact 503

Fig.7. Electronic Balance used to weigh water sorption, water solubility specimens

Results and Observations

RESULT AND OBSERVATION

The basic data of flexural strength, hardness, impact strength, water sorption, water solubility are shown in Table II to VI.

The mean value of parameters studied for the four denture base resins are diagrammatically presented in Fig.8 to 12

The statistical analysis of the parameters studied are presented in Table VII to XI.

Mean value of flexural strength varied from 93.82MPa for DPI to 140.95MPa for SU.Statistical analysis by One-way ANOVA showed that these were statistically significant between the denture base resins for flexural strength with a two-tailed probability of value, < 0.05 was considered significant.Sunflex showed highest flexural strength than other denture base resins. Duncan Multiple Range Test showed that there was no statistical significant difference between SR and TR, DPI and SR.

Mean value of hardness varied from 76.33 for DPI to 85.33 for SR-Triplex HOT.Statistical analysis by One-Way ANOVA showed that these were statistically significant between the denture base resins for hardness with two-tailed probability of value,< 0.001 was considered significant.SR-

Triplex HOT showed highest hardness than other denture base resins. Duncan Multiple Range Test showed that there was no statistical significant difference between TR and SU.

Mean value of impact strength varied from 7.99 kJ/m^2 for SR to 31.71 kJ/m^2 for SU.Statistical analysis by One-Way ANOVA showed that these were statistically significant between the denture base resins for impact strength with two-tailed probability of value, < 0.001 was considered significant.SU showed the highest impact strength than other denture base resins. Duncan Multiple Range Test showed that there was no statistical significant difference between SR and TR and DPI.

Mean value of water sorption varied from 0.000401gm/mm^3 for SU to 0.000624gm/mm^3 for TR. Statistical analysis by One-Way ANOVA showed that these were statistically significant between the denture base resins for water sorption with two-tailed probability of value, < 0.001 was considered significant .Duncan Multiple Range Test showed that there was no statistical significant difference between SR and TR and DPI.

Mean value of water solubility varied from 0.14gm/mm^3 for TR to 0.35gm/mm^3 for SR. Statistical analysis for One-Way ANOVA showed that these were statistically significant between the denture base resins for water

solubilitywith two-tailed probability of value, < 0.001 was considered significant .Duncan Multiple Range Test showed that was no statistical significant difference between SU and DPI.

The test materials SR, SU, TR, DPI showed none reactivity to fibroblast cells after 24hour contact with numerical grade not more than 2 in Fig.13 to 16.

TABLE II

Basic data for flexural strength(MPa)

MATERIALS	Test number				
	1	2	3	4	5
SR	94.67	128.20	119.97	73.16	104.00
SU	204.45	127.71	123.98	107.65	140.95
TR	125.87	118.25	145.18	108.89	124.55
DPI	47.18	110.30	103.17	114.63	93.82

TABLE III

Basic data for Shore-D Hardness

MATERIALS	Test number					
	1	2	3	4	5	6
SR	86	85	85	85	86	85
SU	84	84	82	81	76	76
TR	85	84	82	84	81	79
DPI	77	77	76	77	76	75

TABLE IV

Basic data for Impact strength (kJ/m^2)

MATERIALS	Test number				
	1	2	3	4	5
SR	9.1246	8.38585	8.48745	5.95894	7.98846
SU	31.3825	40.0247	28.4254	27.0271	31.7149
TR	12.5289	9.72124	9.50968	9.79755	10.1393425
DPI	10.460	8.09586	9.38017	8.66588	8.65048

TABLE V

Basic data for water sorption (gm/mm^3)

MATERIALS	Test number				
	1	2	3	4	5
SR	0.000640	0.000577	0.0005981	0.0005896	0.00060145
SU	0.000325	0.000417	0.000436	0.000426	0.0004012
TR	0.000554	0.000582	0.0005682	0.0007919	0.00062435
DPI	0.000610	0.000672	0.0005272	0.0006224	0.00060965

TABLE VI

Basic data for water solubility (gm/mm^3)

MATERIALS	TEST NO:				
	1	2	3	4	5
SR	0.349586	0.379089	0.343193	0.338308	0.352544
SU	0.206115	0.2781006	0.3004093	0.2593441	0.2609924
TR	0.197518	0.140902	0.000772	0.228969	0.1420409
DPI	0.238770	0.248619	0.224697	0.243137	0.238806

Fig. 8. Mean flexural strength (MPa) of different denture base resins

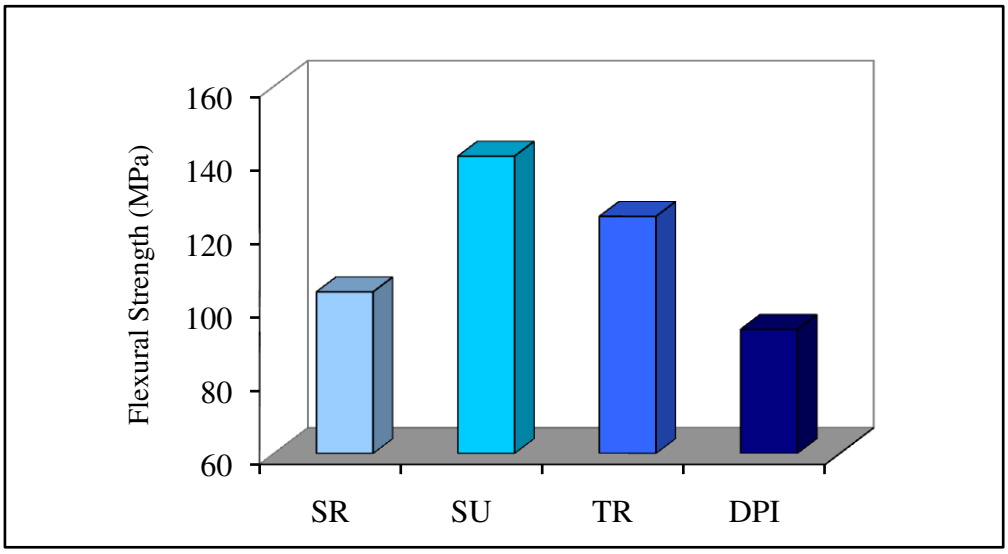


Table VII

Analysis of variance (One Way ANOVA) of flexural strength (MPa) comparing 4 different denture base resins

Group	Mean	± SD	F value	P value
SR	104.00[ab]	19.38		
SU	140.95[c]	33.48		
			4.771	< 0.05
TR	124.55[bc]	11.94		
DPI	93.82[a]	24.36		

a, b, c – Means with same superscript do not differ each other (Duncan's Multiple Range Test)

Fig.9. Mean hardness (kg/mm^2) of different denture base resins

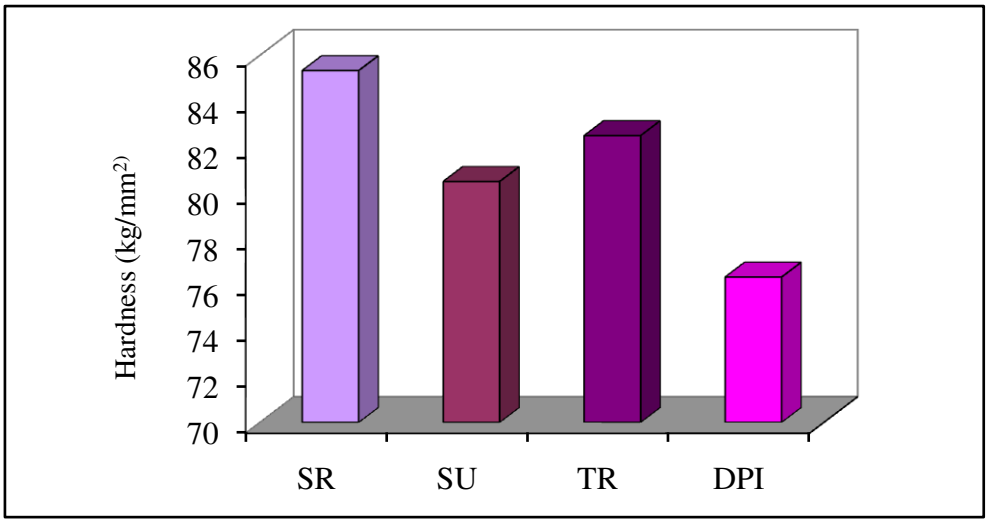


Table VIII

Analysis of variance (One Way ANOVA) of hardness comparing 4 different denture base resins

Group	Mean	± SD	F value	P value
SR	85.33^c	0.52		
SU	80.50^b	3.67		
			17.588	< 0.001
TR	82.50^b	2.26		
DPI	76.33^a	0.82		

a, b, c – Means with same superscript do not differ each other (Duncan's Multiple Range Test)

Fig.10. Mean impact strength (kJ/mm^2) of different denture base resins

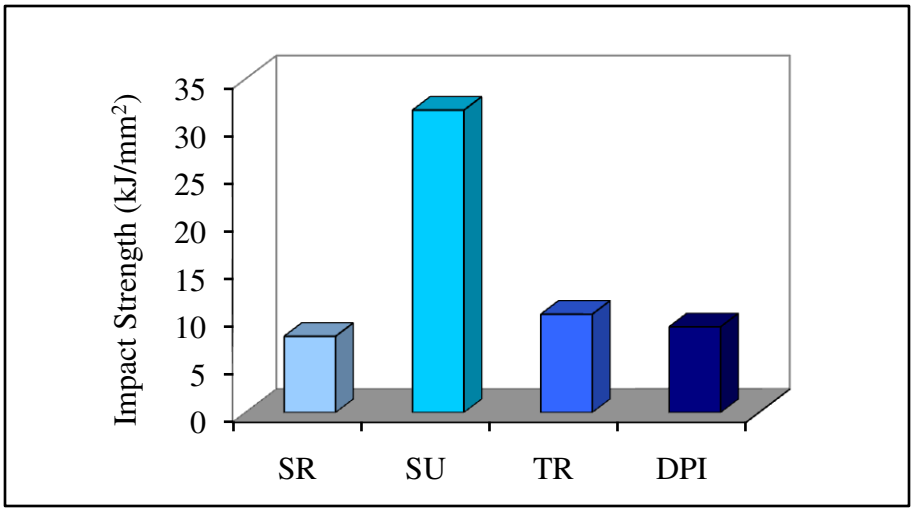


Table IX

Analysis of variance (One Way ANOVA) of impact strength (kJ/m^2) comparing 4 different denture base resins

Group	Mean	± SD	F value	P value
SR	7.99[a]	1.08		
SU	31.71[b]	4.52	131.631	< 0.001
TR	10.31[a]	1.12		
DPI	8.98[a]	0.83		

a, b – Means with same superscript do not differ each other (Duncan's Multiple Range Test)

Fig.11. Mean water sorption (gm/mm^3) of different denture base resins

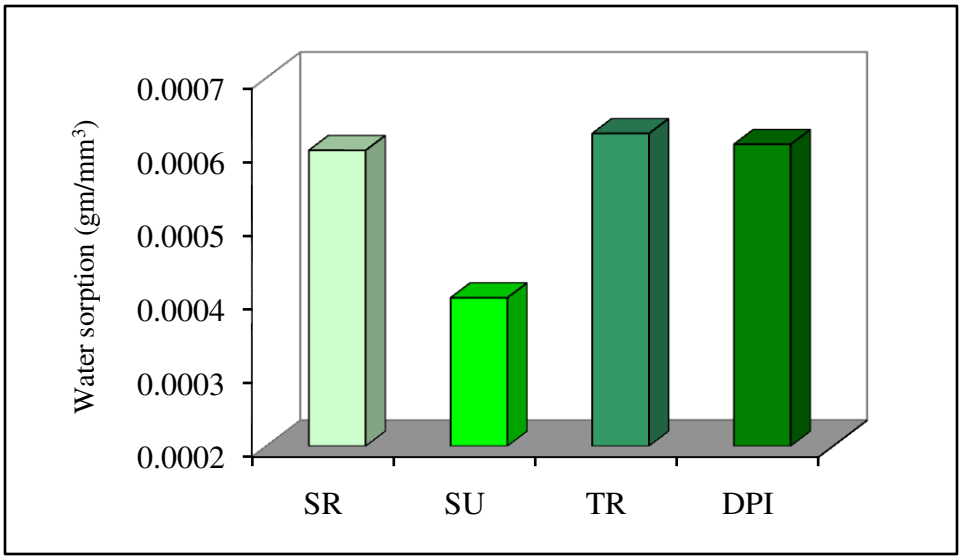


Table X

Analysis of variance (One Way ANOVA) of water sorption (gm/mm^3) comparing 4 different denture base resins

Group	Mean	± SD	F value	P value
SR	0.000602[b]	0.000021		
SU	0.000401[a]	0.000039		
			22.792	< 0.001
TR	0.000624[b]	0.000087		
DPI	0.000610[b]	0.000047		

a, b – Means with same superscript do not differ each other (Duncan's Multiple Range Test)

Fig.12. Mean water solubility (gm/mm^3) of different denture base resins

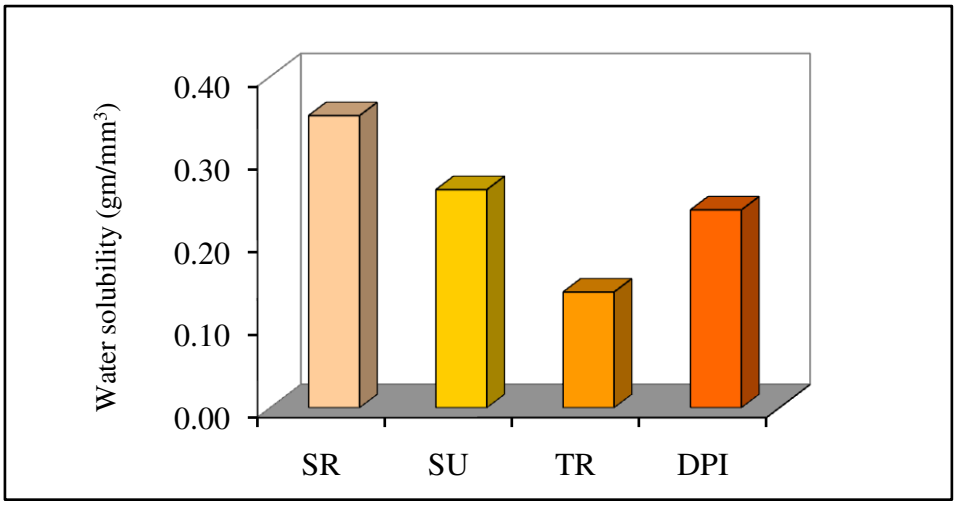


Table XI

Analysis of variance (One Way ANOVA) of water solubility (gm/mm^3) comparing 4 different denture base resins

Group	Mean	± SD	F value	P value
SR	0.35^c	0.01		
SU	0.26^b	0.03		
			24.799	< 0.001
TR	0.14^a	0.08		
DPI	0.24^b	0.01		

a, b, c – Means with same superscript do not differ each other (Duncan's Multiple Range Test)

Fig.13 shows L-929 cells after contact with 100% extracts of SR

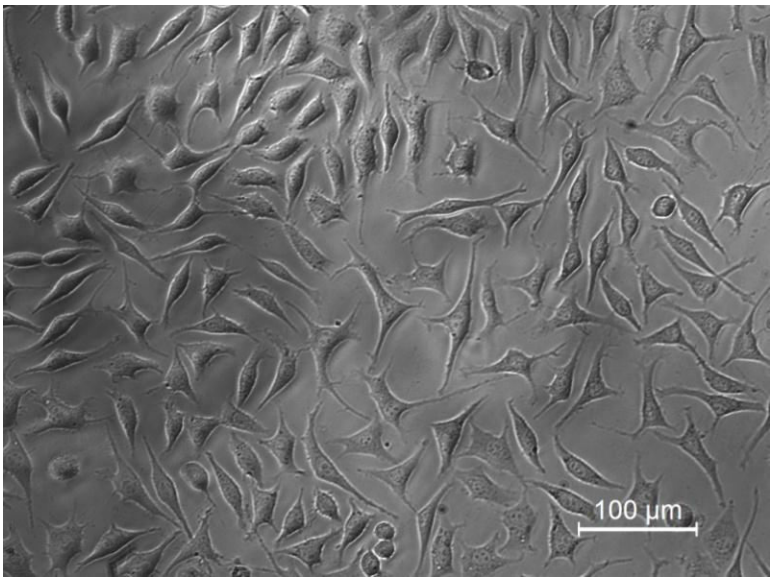


Fig.14 shows L-929 cells after contact with 100% extracts of SU

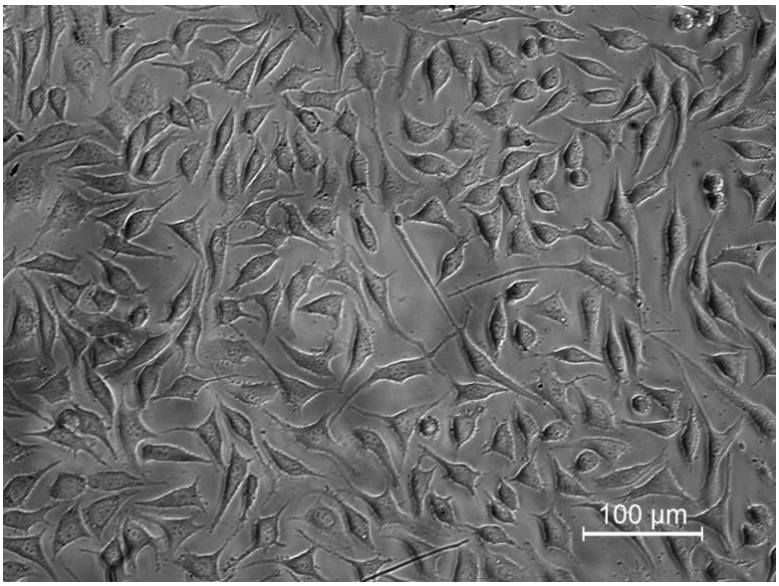


Fig.15 shows L-929 cells after contact with 100% extracts of TR

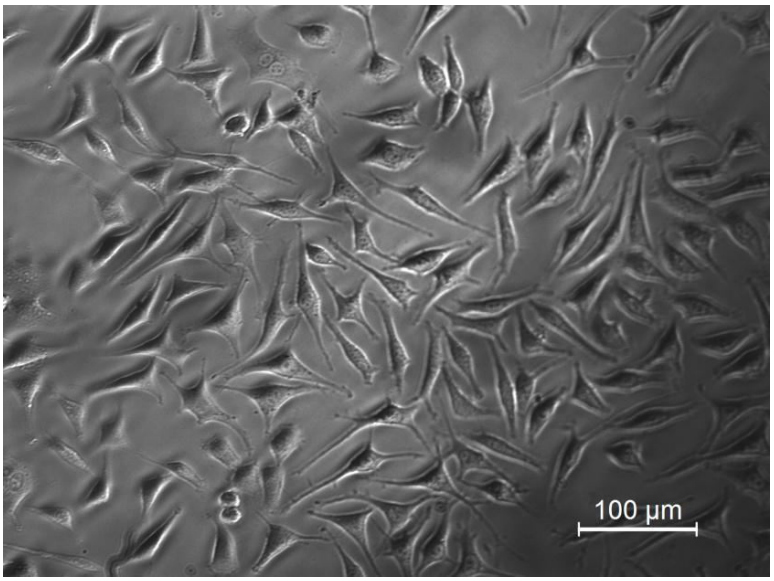
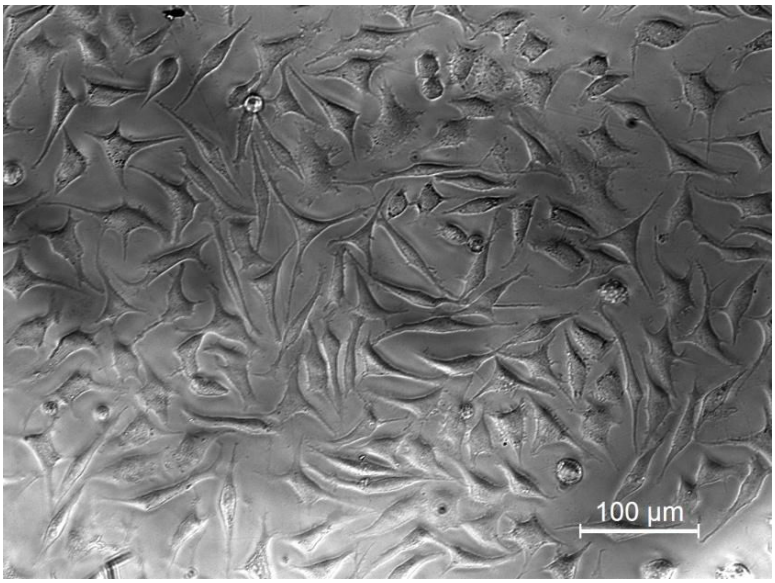


Fig.16 shows L-929 cells after contact with 100% extracts of DPI



Discussion

DISCUSSION

Complete or removable dental prosthesis is a prosthesis that replaces the entire dentition & associated structures of maxilla & mandible. Such a prosthesis has artificial teeth attached to a denture base.

Denture base is part of the denture which rests on soft tissues which derives support through contact with the oral tissues/implants. Denture base acrylic/resins have been used since mid-1940's in restorative/ prosthodontic/surgical purposes.[58]

Heat activated resin are used in fabrication where thermal energy is required for polymerization of such materials. Thermal energy is provided by using a water bath or microwave oven. These resins are more prevalent among heat/chemical/light-activated resins.

The properties required for an ideal denture base material are:

(1) Adequate volumetric & linear (polymerization) shrinkage

(2) Absence of porosity, adequate resilience

(3) Dimensional stability with water absorption & solubility rate adequate

(4) Adequate diametral tensile strength to biting, chewing

(5) Adequate flexural strength (resistant to fractures due to thin/ thickened areas, midline fractures)

(6) Improved strength [e.g:- fibres like Kevlar(aramide), nylon, polyamide, polycarbonate, ultra-high modulus polyethylene, Fiberkor, Vectris, Glass woven & raided fibers][17]

(7) High impact strength to impact forces

(8) Adequate hardness during excessive wear under mastication.[58]

(9) Low creep, lighter in weight

(10) High modulus of elasticity with high proportional limit

(11) Abrasive resistance

(12) Impermeability to oral fluids or chemically stable (polymerize to completion without leaching any residual monomers)[62]

(13) Repair (relining/rebasing) without any distortion

(14) Easy to manipulate

(15) Color stability, sufficient translucency, transparency- hue, chroma, value, pigmented or tinted

(16) Most importantly BIOCOMPATIBLE

(17) Comfortable

Apart from these requirements an ideal denture base should be plaque resistant, stain resistant, have adequate retention, resistance from dislodging during masticatory function/ even speech.

A good, satisfactory, comfortable denture base should cover & protect denture bearing tissues other than forming "a base' for denture construction. It should also provide good peripheral seal & most importantly desireable esthetics.

The primary monomer usedin this study is 2-hydroxy ethylmethacrylate (HEMA) cross-linked with TetraethyleneglycolDimathacrylate (TEGDMA) giving a three dimensional swollen hydrogel.[58]

In this present study, a comparitive analysis of mechanical, physical property, biocompatibility of 3 compression molded heat polymerized denture base resin (SR Triplex-HOT, Trevalon-HI, DPI-Heat Cure) & flexible/injection molded heat polymerized denture base resin (Sunflex) was undertaken.

SR Triplex-HOT ensures accuracy of fit and stability of shape and shade for conventional and implant supported dentures, complies with ISO EN 1567. Indicated in Complete, partial, combination, Hybrid dentures, Relining, Implant supported overdentures. It's also stain resistant.

Trevalon-HI is a high impact denture base resin. It offers excellent strength, fracture resistance, dimensional and colour stability. It is available in 2 shades: veined and transveined.

DPI-Heat cure is a conventional compression molded heat cure resin which after polymerization shows residual monomer content acting as a plasticizer, altering it's mechanical as well biocompatible properties.

Sunflex is a pressure-injected, nylon-based thermoplastic flexible denture base resin. It is biocompatible, does not deteriorate chemically when it comes into contact with the fluids, bacteria, physical environment of the mouth. It's stain resistant, monomer free & hypoallergenic with perfect degree of flexibility. It does not warp or become brittle providing maximum retention & stability and using tissue-colored clasps. It is available in five shades – Crystal, light pink, pink, medium meharry, dark meharry. It is usually indicated in unilateral, bilateral partial denture , combination sunflex with cast partial framework denture.

(a) Specimen preparation & the test for analyzing the mechanical properties of denture bases were carried out according to ISO specification 1567 for denture base polymers.

(b) Flexural strength(F_s)

In the evaluation of denture base resins, the ultimate flexure strength of a material reflects it's potential to resist catastrophic failure under a flexure load. High flexural strength is crucial to denture wearing success, as alveolar resorption is gradual, irregular process that leaves tissue- borne prosthesis unevenly supported. Plasticization of water on the polymer matrix can reduce flexure property of material.[49]

When PMMA reinforced with carbon graphite fiber, glass fibers (silanized/ unsilanized), aramide fibers (KEVLAR), ultra-high modulus polyethylene; polyamide, nylon, polycarbonate can improve flexural properties.[24]Cross-linking agents such as TEGDMA added to monomer to modify flexural properties.[49] Water storage time has no effect on transverse strength.[57]TheF_s acts on the lower half below the neutral axis of the test specimen.

In the study, $F_s$of Sunflex was 140.95 MPawas found to be highest. Mean $F_s$of Trevalon-HI (124.55MPa) & SR Triplex-HOT (104 MPa) showed comparable values. DPI-Heat cure showed least F_s93.82 MPa.

The high flexural strength of Sunflex can be attributed to presence of nylon-based fibres, low molecular weight. Trevalon-HI & SR Triplex-HOT were similar since PMMA were reinforced with thin Kevlar fibres& has TEGDMA as cross-linking agent. DPI-Heat cure showed reduced flexural strength (conventional heat-cure).

(c) Hardness

Hardness is important in determining the success of denture base resins. The residual monomer and water absorbed into resin is recognized as a plasticizer & affects hardness of the material. Increase in hardness results in increased wear resistance. Hardness has been widely used as an indirect method to investigate factors that influence degree of conversion of conventional heat-cure & self-cure resins.[37]

Immersion type cleanser is better than tooth-brushing to avoid abrasion & scratch for denture hygiene. Hardness increased with dry storage. Water immersion can cause absorption of water by polymers & soften the polymer. So, lower the powder:liquid ratio, more residual monomer will be

left in polymerized resin, will result in lowest hardness values.[37]Disinfection by immersion in sodium perborate won't adversely affect hardness.[53]

In this study, Shore-D hardness seen comparable in TR (82.50) & SU (80.50) while highest mean hardness & wear resistance seen in SR (85.33). DPI-Heat cure showed lowest Shore-D hardness values (76.33) due to lower powder:liquid ratio resulting in high residual monomer content.

(d) Impact Strength (I_s)

I_s a measure of the energy absorbed by the material before it fractures,[24] when struck by a sudden blow from an impact instrument with a weighed pendulum. Use of cross-linking agent added to improves I_s with decreased concentrations e.g.-TEGDMA. Processing technique like heat/chemical/ microwave/ long or short curing cycle affect I_s.[44] Woven E-glass fibers, glass fibers (silanized/unsilanized),[20] carbon fibers (less esthetic due to dark color), Kevlar (esthetically better)- Thick or Thin,[31] incorporation of rubber phase in the bead polymer increase I_s. Fiber can be used in 3 forms: continuous parallel, chopped, woven.Carbon has a dark color, Kevlar, Polyethylene are invisible in dentures.[17]

Notching of specimen is employed which is better than unnotched specimens for test; impact force in this study is applied to specimen from

notched side.[17]Silanization of glass fibers enhanced adhesion between fibers & polymer matrix, I_s also increased. Immersion in water for release of residual monomer during 24 hours can cause brittleness & accentuate difference between conventional & high impact denture base resins (that contain additional rubber phase).[38]

In this study, Sunflex (31.71kJ) shows significant difference with the highest impact strength. Others Trevalon-HI (10.31), DPI-Heat cure (8.98), SR-Triplex HOT (7.99) show comparable difference only (similarly resistant to impact forces).

(e) Water sorption (W_{sp})

Water molecule diffusion among the polymer chains[33] or water absorbed into the material acts as a plasticizer lowering the mechanical property like hardness &F_s. Plasticizer allows the release of stresses, increases expansion. Sorption rate higher in rougher materials i.e. water enters porous surface of acrylic resin submitted to abrasion increasing hydrophilic property. Lower W_{sp} of finished dentures is desirable for dimensional stability. Mechanically polished surface showed lower W_{sp} than chemically polished surface.[18]Cross-linking agents e.g.- TEGDMA are

added to monomer which influences greatly W_{sp}. Highly cross-linked decreases W_{sp} than non-crosslinked materials.

Szabo reports water uptake independent of storage time in water after 24 hours & also type of denture base.[33]Arima et al suggested chemical nature of polymer versus that of water molecule directly affect$W_{sp}$of resin. Dixon et al stated residual monomer affect W_{sp} expansion.[48]

Initial water content (M_2- mass after immersion in water) of dry-heat processed more than wet-heat processed dentures. $W_{sp}$to saturation of both dry-heat & wet-heat processed dentures are low because of high initial water content.[18] Takahashi et al found out that W_{sp} should be as low as possible that affects it's durability.[48]

In this study, Sunflex shows significant lowest W_{sp} value 0.000401gm/mm^3 thus revealing no effect on mechanical properties & won't discolor often on absorbing water. Trevalon-HI (0.000624), DPI (0.000610), SR Triplex HOT (0.000602) show similar W_{sp} values, higher than Sunflex altering the mechanical properties. Trevalon-HI, DPI, SR-Triplex absorbs more water (plasticizing effect) relatively increasing expansion of material effecting denture stability.

(f) Water solubility (W_{sl})

W_{sl} is directly proportional to release of residual monomer, plasticizing effect from polymers.[33]

Denture base acrylics have low W_{sl}, the little present is result of leaching out of traces of unreacted monomer & water soluble additives into oral fluids causing allergy.[48] Cross-linking agents e.g.- TEGDMA are added to monomer which influences greatly. [44]Takahashi stated that W_{sl} should be as low as possible since water molecules spread between macromolecules of material; forcing them apart.[48]

In this study, Trevalon-HI (0.14) shows low W_{sl}which relates to it's low residual monomer content fulfilling desirable quality for dimensional stability. Sunflex (0.26), DPI (0.24) show similar W_{sl} values that is moderate release of residual monomer. While SR-Triplex HOT (0.35) show highest W_{sl} value thus revealing high residual monomer content affecting hardness &F_s. High concentration of crosslinked agents is another factor for high W_{sl} value seen in SR-Triplex HOT.

(g) Cytotoxicity

Various autopolymerized, heat polymerized resins have varying degrees of cytotoxicity.[9] Biologic properties of denture base resins are highly influenced by it's monomer- polymer conversion. Residual monomer

leached out into usually water as well as saliva. Toxic substances that eluate are formaldehyde, methyl methacrylate, methacrylic acid, benzoic acid, dibutyl phthalate, phenyl benzoate, phenyl salicylate, dicyclohexyl phthalate.

Residual monomer that is leached out from unpolymerized resin after curing is main factor that affect oral epithelial cells.[56]

(1) Local chemical irritation

(2) Hypersensitivity (allergy)

(3) Signs of mucosal inflammation, vesiculation & ulceration.

(4) Burning sensation (burning mouth syndrome)

(5) Systemic allergic conditions

Because denture prosthesis are in contact with oral mucosa, effects on cells within tissue maybe clinically relevant.[23] Differences in toxicity pattern at various elution times, especially after 24 hours of incubation; maybe related degree of polymerization & amount of fiber resulting in density of materials. This deflects the rate of component leaching.[9]

Baker et al found that most of methyl methacrylate was released in 1st hour& recommended soaking dentures 24 hours prior to insertion minimizes exposure to toxic substances.[3]

Methacrylic acid is identified as primary degradation by-product of different monomers, such as triethyleneglycol dimethacrylate (TEGDMA), hydroxyethyl methylacrylate (HEMA), MMA. Lesion in oral epithelium/ lung tissues when vapours inhaled caused by metabolism of MMA to MA, an irritant & corrosive metabolite.[56]Primary monomer is HEMA cross-linked with TEGDMA to give 3-D swollen hydrogel.[58]

Formaldehyde is cytotoxic in range of it's leaching concentrations & shows cytotoxic at lower concentration than MMA. Preleaching in water reduces subsequent leaching of both formaldehyde & MMA. Dentures should be immersed in hot water (50^0C) before insertion to decreasing cytotoxicity.[8]Effect on oral epithelium cells related to the specific formulation &not type of polymerization.[5]Light-polymerization resin inhibits synthesis of both RNA & DNA as compared to heat-processed resin.[7]Chemically activated resin increasing cytotoxic than eluates from heat-activated & microwave activated resins. Apart from skin, eye, mucous membrane irritation, caused by leachable components; gastrointestinal complaints can also be detected. Inflammation of lung cells.[12]

TEGDMA has 10-fold more toxic potential using MTT (colorimetric functional assay) test & fluorescence microscopy, comparing to HEMA

inhibiting gluconeogenesis in kidney cells. Whereas HEMA caused larger accumulation of apoptic cells seen by fluorescence microscopy & flow cytometry.[42]TEGDMA affected glutathione transferase P1 activity of human gingival fibroblasts & induced extensive reduction of intercellular glutathione (GSH); a major intracellular reducing agent, at cytotoxic concentrations. Therefore, it's clear that oxidative stress is involved in cytoxicity of TEGDMA & HEMA (less toxic monomer).[41]Chemical-biological interactions such as cell growth inhibition caused by elevated TEGDMA concentrations were due to apoptosis & necrosis. Apoptotic effects appear at concentrations exhibiting cytotoxicity; resin monomers cause genotoxicity at concentrations lower than those for apoptotic effects. [41]

Different parameters used to monitor the cytotoxic effects such as inhibition of cell growth, cytolysis, cytoplasmic markers & changes in metabolic activity. 3H-Thymidine Incorporation Test is a biological assay for cytotoxicity testing which measures no: of cells synthesizing DNA. But it's expensive & there's production of radioactive waste has been reported. Evaluating the cell growth in the media previously exposed to test material were accurate indication of toxicity.[4]

So in this study, in vitro cytotoxicity test; Test on Extract method based on ISO 10993-5, 2009 was performed. Samples were examined under Inverted Phase Contrast microscope (20X-magnification). Cellular responses were scored as 0,1,2,3,4 according to none, slight, mild, moderate & severe. The test materials SR, SU, TR, DPI showed none reactivity to fibroblast cells after 24hour contact. The achievement of numerical grade more than 2 is considered as cytotoxic effect. Since the materials SR, SU, TR, DPI achieved a reactivity grade not more than 2 the material is considered as not cytotoxic. Extracts of negative control gave none cytotoxic reactivity & positive control gave severe cytotoxic reactivity as expected.

Summary and Conclusion

SUMMARY AND CONCLUSION

The study was conducted to compare the physical properties, mechanical properties and biocompatibility of four different commercially available heat cure denture base resins.

The materials used in this study were:

1) SR-Triplex-HOT (fiber reinforced denture base resin)

2)Sunflex (flexible denture base resin)

3) Trevalon -HI (high impact denture base resin)

4) DPI- heat cure (conventional denture base resin)

The samples were tested for flexural strength, hardness, impact strength, water sorption and solubility, cytotoxicity.The specimen preparation and testing were done according to ISO 1567. The results were statistically analyzed by One-way ANOVA and Duncan's Multiple Range Test (DMR) was employed as post hoc comparisons along with ANOVA.

CONCLUSIONS

Within the limitation of the study, the following conclusions have been made.

Sunflex shows significantly higher flexural strength, impact strength and lowest water sorption compared to other denture base resins.

The hardness of SR-Triplex was found to be higher than other materials tested. Trevalon and Sunflex showed moderate hardness, the least hardness value was obtained for DPI.

The water solubility of Trevalon was significantly lower than the other than denture base resins.

The cytotoxicity test showed that the cellular response of four denture base resins was less than Grade 2 indicating that the materials were not cytotoxic.

The Sunflex denture base resin showing superior physical and mechanical properties, biocompatible to the oral tissues, can be selected as a suitable denture base material in daily clinical practice.

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