A Comparative Study of the Mechanical Properties of the Light-cure and Conventional Denture Base Resins

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Abstract

Purpose: To compare the flexural, tensile and compressive strengths of three denture base materials, namely, Lucitone 550, Bio Carbo Resin, and Eclipse.

Materials and Methods: A total of 180 specimens were prepared, with 60 specimens of each material tested. The dimensions of the specimens for each test were made according to the ADA specification. They were stored in distilled water bath at 37°C for 48 hours before testing. Each specimen was fixed on the table of the Instron universal testing machine. A force was applied at a cross-head speed of 5 mm/min until fracture occurred. Data were analyzed using a one-way analysis of variance (ANOVA) and Tukey's test ($p=0.05$) for the flexural, tensile, and compressive strengths among all groups.

Results: The flexural and compressive strength values showed significant differences between the three denture base materials. However, there was no significant difference in tensile strength between Lucitone 550 and Bio CarboResin.

Conclusion: Eclipse showed significantly higher mechanical properties than polycarbonate reinforced and conventional heat cured acrylic resins, which suggests the use of Eclipse denture base materials as an alternative to traditional denture base resins.

Key Words: Flexural strength, Tensile strength, Compressive strength, Denture base materials, Acrylic resins, Light polymerization

Introduction

Acrylic resins are the most widely used materials for the fabrication of denture bases. This is due to their acceptable aesthetics, ease of handling, good thermal conductivity, low permeability to oral fluids and color stability [1]. Inherent drawbacks of these materials are fracture as a result of fatigue when subjected to intra-oral forces and failure to withstand extra-oral impact forces [2]. Fracture may occur because of insufficient transverse, impact, flexural, and fatigue strengths. Recent advancements in the field of *Dental Materials* and the development of newer and more novel forms of denture base materials have enabled acrylic denture base resins to overcome some of these drawbacks. For example, polycarbonate and nylon based materials have been developed to overcome the mucosal irritation and polymerization shrinkage that is associated with the conventional Polymethyl methacrylate (PMMA) resins [3-5].

Over the years, many attempts have been made to improve the impact properties of PMMA in three general directions [6]: the search for, or the development of, an alternative material to PMMA; the chemical modification of PMMA by the addition of various polymers [7,8] such as a rubber graft copolymer, polyamides, epoxy resin, polystyrene, vinyl acrylic, polycarbonate [9] and nylon [10,11] and the reinforcement of PMMA with other materials, such as carbon fibers, glass fibers and ultra-high modulus polyethylene [12]. Heat, light and microwave polymerization methods have been employed for processing PMMA [13,14].

The addition of copolymers not only modifies mechanical properties of the conventional PMMA but also serves to improve toughness, increase impact resistance and prevent crack propagation. Most manufacturers of PMMA denture resins usually grade their products as "high impact" and claim these materials have new and enhanced strengthening properties, yet there is little or no research to support any strength differences between various versions of these products [15]. Polycarbonate denture base resins are injection molded thermoplastic resins. These materials have a significantly lower flexural strength at the proportional limit, a lower modulus elasticity, and a higher impact strength compared to conventional PMMA [16].

Light Activated Urethane Dimethacrylate (UDMA) denture base polymers were developed to surpass contact allergies, laboratory vapors, and the traditional lengthy lost wax technique of investing, flasking and boil-out used with the conventional PMMA materials [15]. This material was promoted on the basis that it does not contain methyl methacrylate monomer and instead contains a urethane dimethacrylate matrix with an acrylic copolymer, micro-tins, silica filler, and photo-initiator system. Triad was the first system of light activated UDMA denture base polymer, which was advocated because of its biocompatibility, ease of fabrication and manipulation, low bacterial adherence, and ability to bond to other denture base resins. It is not comprised of individual components that need to be measured or mixed [17]. However, the use of UDMA was limited by the low impact resistance and brittleness of the material [18]. This limitation led to the development of a new methyl methacrylate-free denture base material by

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Dentsply (Trubyte, York, PA) that was marketed under the name Eclipse. In this system, the base plate resin is used to fabricate the record base, which after light polymerization, is highly polishable and ultimately becomes the definitive denture base. Eclipse's uniquely formulated resin was found to have superior physical and mechanical properties than other urethane materials [19-21].

There is limited available data on the mechanical properties of the Eclipse denture base in comparison to other denture base materials. Hence, the objective of this *in vitro* study was to compare the flexural, tensile, and compressive strengths of heat-cured denture base acrylic resin to polycarbonate and Eclipse denture base materials.

Materials and Methods

This *in vitro* experiment was performed to compare the mechanical properties of three denture base materials. The materials used in this study were heat cured PMMA denture resin (Lucitone 550, Dentsply International Inc., York), PMMA reinforced with polycarbonate polymer (Bio Carbo Resin, High Dental Co. Ltd, Osaka, Japan) and light activated UDMA (Eclipse, DENTSPLY Intl, York, PA) as shown in *Table 1*.

A total of 180 specimens were prepared and divided into three groups of 60 specimens each according to the material tested. Specimens for testing flexural, tensile, and compressive strengths of denture base acrylic resin (20 in each group) were fabricated in stainless steel dies. The dimensions of the specimens for each test were made according to the ADA specification for each performed test. The dies were invested in a Hanau type denture flask (Hanau Engineering Company Inc., Buffalo, NY) using type III dental stone (Sherapremium, Shera Werkstoff-Technologie, Lemforde, Germany). Once the dental stone was set, the two halves of the flasks were separated, and the dies were lifted out of the mold. Sodium alginate separating media (Al- Cote, Dentsply Trubyte, York, PA) was then applied to the mold.

Group 1: Specimens were fabricated from PMMA resin (Lucitone 550). The resin was mixed according to the manufacturer's instructions and packed into the mold space when the resin mix was in a doughy stage. With slow pressure, the denture flasks were then clamped in a bench press to ensure even flow of the material within the mold. Curing of the flasks was then completed in a water bath. After the curing cycle, the flasks were bench cooled for a few minutes prior to being immersed in cold water (curing and quenching was conducted in accordance to the manufacturer's instructions).

Group 2: Specimens were made using polycarbonate (Bio Carbo Resin) denture base materials. The material was mixed according to manufacturer's instructions and was packed into the mold space during the doughy stage.

Group 3: Eclipse was used to prepare specimens according to the manufacturer's instructions in the following manner: first, the separator and temperature indicator were applied to the mold space and placed in the conditioning oven until the indicator changed color. Then, the base plate material was adapted inside the mold using finger pressure. A glass slab was then pressed on top of the material to allow a uniform thickness of the specimens after removal of excess. An air barrier coating was applied on the resin surface to prevent inhibition of oxygen-induced polymerization. Next, the mold and denture base material were placed inside the Eclipse processing unit (light curing process) where they were subjected to a light source with a wavelength of 400-500 nm and 90 MW at a curing temperature of 165-170°F for 10 minutes.

All prepared specimens were then stored in a distilled water bath at 37°C for 48 hours before testing. A universal testing machine (Instron testing machine 8500; Norwood, MA, USA) was used for measuring the flexural, tensile, and compressive strengths.

Flexural strength test (three point bending test)

Twenty specimens were prepared from each material with the following dimensions: 65 mm in length, 10 mm in width and 2.5 mm thick. Each specimen was fixed on the table of the Instron testing machine. The force was applied at a cross head speed of 0.5 mm/min until fracture occurred, and was automatically recorded by the internal chart recorder of the Instron testing machine. The flexural strength was calculated according to the following equation [22], where p is the load at the fracture point on the load deflection curve, expressed in Newtons, L is the distance between the supports (50 mm), b is the width of the specimen (10 mm), and d is the thickness of the specimen tested (2.5 mm)

$$\frac{S = 3PL(\mathrm{MPa})}{2bd^2}$$

Table 1. Chemical composition and processing method of the denture base materials used in the study.

Acrylic resin	Processing method	Chemical composition	Manufacturer
Lucitone 550	Heat-polymerized Hot water bath-9 hours at 74°C	Powder: methylmethacrylate (methyl-n-butyl) co-polymer, benzoyl peroxide and mineral pigments. Liquid: methylmethacrylate, ethylene glycol dimethyacrylate (EGDMA) as a cross-linking agent and hydroquinone.	Dentsply International Inc., Chicago, IL, USA
Bio Carbo Resin	Heat-polymerized Hot water bath-9 hours at 74°C	Powder: PMMA, polycarbonate pellets Liquid: MMA and EDGMA	High Dental Japan Co. Ltd, Japan
EclipseTM Denture base system	Visible light curing	Acrylated urethane oligomer (TBDMA), urethane dimethacrylate (HDIDMA), octadecyl acrylate, hexanidiol dimethacrylate, photo initiators and accessories, pigments, and red fibers.	Dentsply International Inc., Chicago, IL, USA

PMMA: Poly Methyl Methacrylate; MMA: Methyl Methacrylate; EDGMA: Ethylene Glycol Dimethacrylate; UDMA: Urethane Dimethyl Methacrylate.

Tensile strength test

Twenty dumbbell shaped specimens were prepared with a length of 80 mm, width of 10 mm in the center section, and a thickness of 4 mm as shown in *Figure 3*. Vertical alignment of the specimen was an important factor for avoiding side loading or bending movements on the specimens. Mounting the specimen in the upper grip assembly was performed first to allow it to hang freely and maintain alignment during testing.

The tensile strength was calculated according to the following equation:

$$\sigma = \frac{\text{Load}}{\text{Area}} = \frac{P}{a}$$

Compressive strength test

A split brass mold with an inner diameter of 20 mm and height of 40 mm was used for preparing the cylindrical specimens for testing the compressive strength for each material. Compressive testing determines the behavior of materials under crushing loads. The specimens were compressed and the deformation at various loads was recorded.

Statistical Analysis

All statistical analysis were performed with GraphPad® Instat 3.05 software (GraphPad Software Inc., San Diego, CA, USA) using one-way analysis of variance (ANOVA) and t-test. Tukey-Kramer Multiple Comparisons Test was used to analyze the groups. Differences were always considered significant at p-values less than 0.05.

Results

The results of the studies are shown in *Table* 2 and *Figures* 1-3.

Flexural strength

The highest mean value of flexural strength (MPa) was exhibited by Eclipse (122.6 ± 13.7), followed by polycarbonate (105 ± 14.6), while the heat cured denture base material had the lowest value in this category (88.9 ± 15.1). There was statistically significant variation ($P<0.01$) in the flexural strength between the three groups studied (*Table* 2, *Figure* 1).

Tensile strength

The tensile strength of the tested specimens showed that there was no significant difference between conventional heat cured acrylic resin and polycarbonate denture base resin (*Table 2*,

Table 2. *Compressive, tensile and flexural strength (MPa) values of three denture base materials studied.*

Denture base	Flexural strength (MPa)	Tensile strength (MPa)	Compressive strength (MPa)
Lucitone 550 (n=20)	88.9 ± 15.1	71.9 ± 10.4	122.2 ± 12.5
Bio Carbo Resin (n=20)	105 ± 14.6	75.7 ± 10.5	143.25 ± 12.9
Eclipse (n=20)	122.6 ± 13.7	89.9 ± 10.1	157.7 ± 12.4

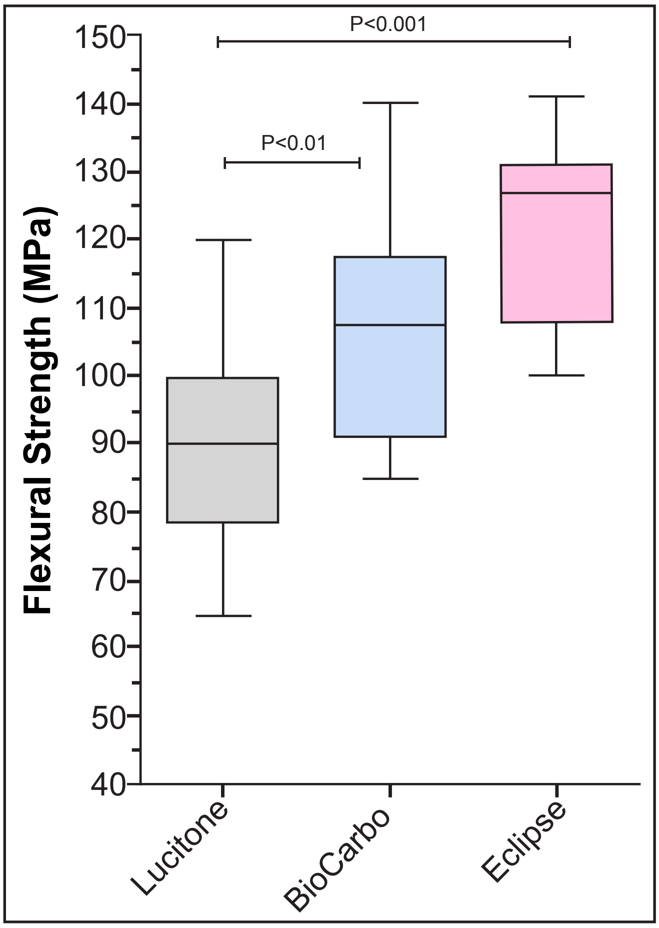

Figure 1. *The flexural strength of the three denture base resins studied*

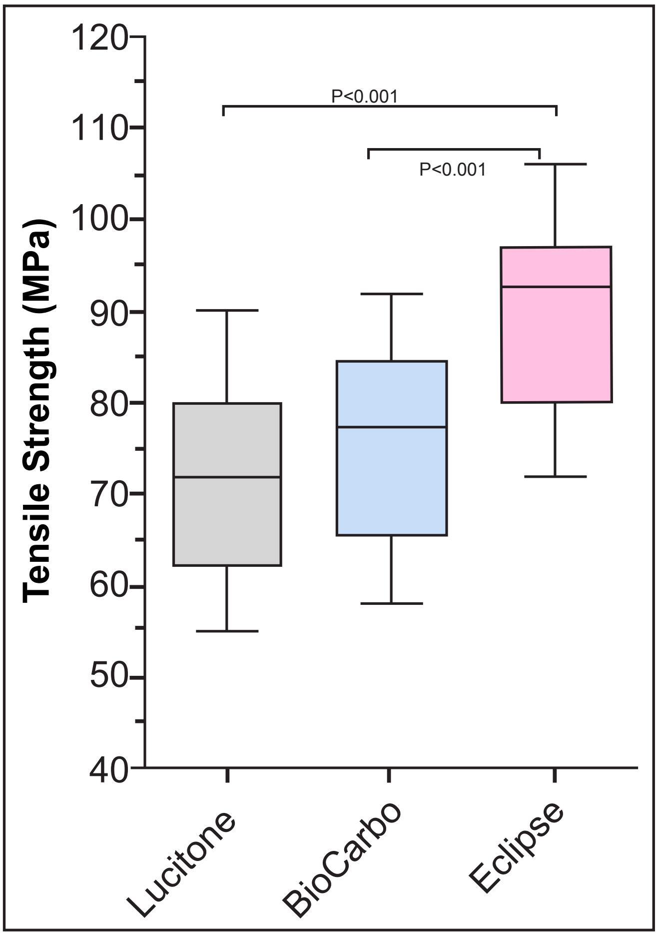

Figure 2. *The Tensile strength of the three denture base resins studied.*

Figure 2). However, there was a significant difference between Eclipse and the other denture base materials (P<0.001).

Compressive strength

Eclipse demonstrated the highest mean compressive strength, followed by polycarbonate and the conventional heat cured acrylic resin (157.7 ± 12.4, 143.3 ± 12.9, 122.2 ± 12.5, respectively). The difference in the compressive strength was statistically significant (P<0.001) between the three denture base materials (*Table* 2, *Figure* 3).

Discussion

The study was conducted to assess and compare the mechanical properties of three denture base materials. The flexural, tensile and compressive strengths of a conventional PMMA based heat-cured acrylic, PMMA reinforced with polycarbonate and Eclipse (UDMA based) were analyzed. The results of this study indicated that the light cured denture base material (Eclipse) showed better mechanical properties than polycarbonate and conventional heat-cured acrylic resins. The flexural strength test is thought to be useful in comparing denture base materials because it reflects the complex stresses applied to the denture during mastication and it provides an indication of a materials' rigidity [6,23,24]. The high flexural, tensile and compressive strengths exhibited by Eclipse may be related to the high degree of polymerization and crystalline nature of the formulation as well as less voids within the materials [25].

Several authors have reported that the presence of voids in PMMA and copolymers reinforced PMMA denture base resins were associated with the polymerization shrinkage due to the excess monomer applied during impregnation procedures [26,27]. The Eclipse system uses the indirect build-up technique to fabricate dentures and utilizes three different resins to form the denture base: base plate resin, set-up resin, and contour resin. The resins handle like wax and are cured when the shaping is complete. The completed denture base is fabricated on the master mold to record jaw relations, which helps to assess and obtain a stable jaw relationship for the denture fitting.

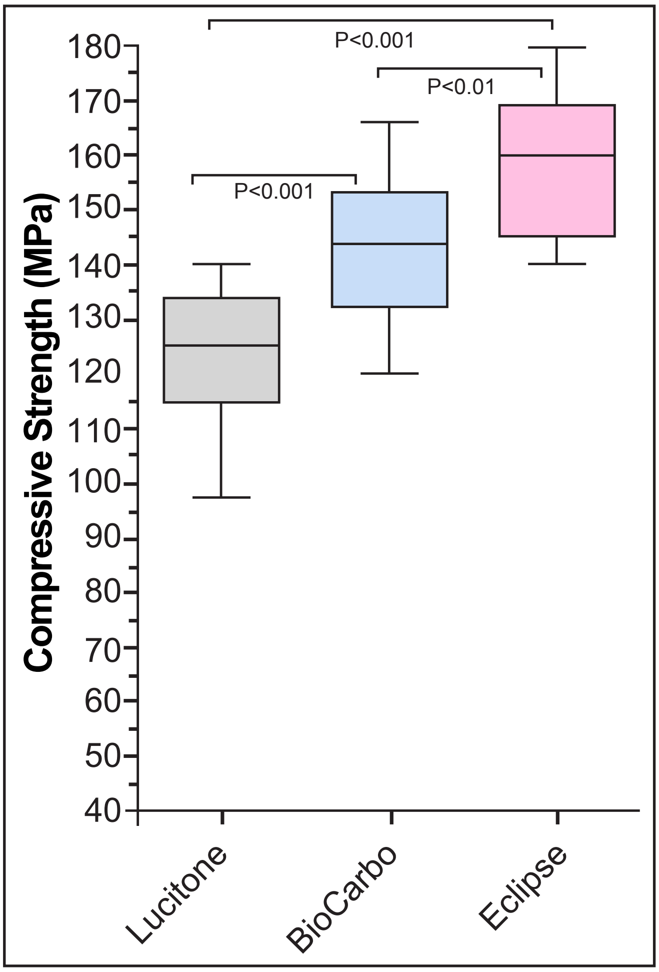

Figure 3. *The compressive strength of the three denture base resins studied.*

In our study the flexural strength of Eclipse was higher than the conventional acrylic resins. The manufacturer claimed that the improved strength was attributed to the initiator in the formulation as well as the complete mode of polymerization [28]. The completeness of polymerization is significant for two major reasons: firstly, degree of polymerization affects the material and geometric properties of the resultant prosthesis [29]. Secondly, unreacted monomer may produce undesirable effects in the human body [30]. It has been reported that polymerized UDMA denture bases are nontoxic and that the unpolymerized material appears to have low toxicity [17]. UDMA material is also less allergenic than other acrylate series. The higher flexural strength of the Eclipse agreed with earlier studies [19,31,32]. Several authors have supported the use of light-polymerized denture base resins, not only for its satisfactory strength and dimensional stability but also for their ease of manipulation and fabrication [17,33-37].

The results of this study showed that PMMA reinforced with polycarbonates showed better strength than conventional acrylic resin. *In vitro* studies are valuable and can be clinically applicable even though these tests may not always reflect intraoral conditions or be predictive of clinical performance [37]. The limitation of the present study includes testing only the denture base component of the materials and the absence of cyclic loading to simulate the masticatory forces. Further studies are needed to investigate impact resistance and the effects of other physical properties, as well as additional potential benefits of the Eclipse system.

Conclusions

Within the limitations of this study the following conclusions can be made: the Eclipse denture base has better mechanical properties (including flexural, tensile and compressive strength) than PMMA reinforced with polycarbonate or conventional heat cured acrylic resin. Denture base resin comprised of PMMA reinforced with polycarbonate has higher flexural and compressive strengths than conventional denture base material.

Acknowledgment

The authors would like to extend their appreciation to the Research Center, College of Applied Medical Sciences and Deanship of Scientific Research at King Saud University for funding this research project.

Conflicts of Interest

The authors declare to have no conflicts of interest.

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