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Research Article

Properties Affecting the Fracture Resistance of All Acrylic Resin in All-on-4® Technique - An *In Vitro* Study

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Abstract

Introduction: All-on-4® concept has seen much success mainly due to its immediate loading quality. A temporary fixed hybrid usually made of all acrylic resin is given for 6 months which is later replaced by a definitive prosthesis. This temporary prosthesis is supported by only four implants and strength of the complete unit depends on the strength of denture base which plays a major role in final outcome. This study is designed to evaluate different commercially available all acrylic resin denture materials with better flexural strength, impact strength and water sorption properties.

Materials and method: Investigation of the impact strength, flexural strength and water sorption of three denture base materials, namely, Trevalon HI, Brecrystal and Ivocap plus. A total of 90 samples were prepared from these materials. Universal testing machine and Izod impact tester was used for flexural strength and impact strength and for evaluating water sorption, the specimens were stored in a desiccator at 37ºC for 23 hours and the samples are weighed using a balance.

Result: Brecrystal showed slightly higher flexural and impact strength mean values than Ivocap plus, but there was no significant difference statistically. Trevalon HI showed the least mean flexural, impact strength values than the other two materials. Brecrystal showed the least water sorption mean values comparatively. Trevalon HI showed the highest mean water sorption values followed by Ivocap plus and Brecrystal.

Conclusion: Each denture base material varied in different properties. Brecrystal showed slightly higher flexural and impact strength and Trevalon HI showed the highest mean water sorption values.

Clinical Significance: Since the final outcome of implant prosthesis in All-on-4® technique is partly depended on temporary fixed hybrid prosthesis, the material used for its fabrication should be chosen wisely considering various properties as these are of utmost importance in predicting their clinical performance up on immediate loading.

Keywords: Acrylic Resin; All-on-4®; Denture Fracture; Immediate Loading; Temporary Fixed Hybrid

Introduction

Edentulous state represents a compromise in the integrity of masticatory system, frequently accompanied by adverse function and cosmetic problems. It is also considered as a social psychological catastrophe by majority of people and its replacement by artificial substitutes, such as implants and dentures is vital to the continuance of normal life [1]. Implants have now become the best way to replace missing teeth. Implant dentistry has shown remarkable advancement in past few years and is being predominantly being practiced due to its longevity and high clinical success rates [2].

Among the techniques in implant dentistry, All-on-4® concept, developed by Paulo Malo, has seen much usage and success. It is one such treatment procedure which enlightens us for its use in the completely edentulous patients and which also leaves behind the routine treatment alternative of conventional implants with ability of immediate loading and with successful outcome in the short term, long term and the retrospective studies that have been done in the past. In this technique straight and angled multi-unit abutments are used to provide edentulous patients with an immediately loaded full arch restoration with only four implants [3]. A temporary fixed hybrid usually made of all acrylic resin is given for 6 months which is later replaced by a definitive prosthesis. Since this temporary prosthesis is supported by only four implants, strength of the complete unit depends on the strength of the denture base and the material used in fabricating it which plays a major role in final outcome.

With the introduction of all acrylic resin a revolutionary change took place in prosthodontics and has continued to dominate the basis for a majority of prosthesis till date. Its distinctive properties allow a range of clinical applications which are not possible with other types of materials. It is often the material of choice for fabrication of temporary fixed hybrid prosthesis because of its dimensional stability, ease of processing, excellent esthetics and accuracy of fit [4,5].

Despite these excellent properties, there is a need for improvement in the fracture resistance of acrylic denture base materials. The fracture of the temporary fixed hybrid prosthesis is a very common problem causing inconvenience to the patient. These fractures occur intraorally due to repeated masticatory forces that lead to fatigue phenomena and extraorally due to high impact forces such as dropping the prosthesis [6]. The temporary fixed hybrid prosthesis is subjected to various stresses during function which include compressive, tensile and shear stresses. The fracture of the prosthesis is not only contributed by these forces but also by the water sorption property of the resins. The absorbed water cause dimensional instability, thereby subjecting the material to internal stresses that may result in crack formation and eventually fractures the denture [7].

The strength of the acrylic resin denture materials may fluctuate considerably depending on the composition of the resin and method of fabrication [8]. Various newer denture base resins with different modifications are available in the market and manufacturers claim that their product is superior over the other materials available in the market. But do these modifications and processing methods really improve the mechanical properties of the resins is yet to be concluded.

Purpose of the Study

Impact strength, Flexural strength and Water sorption properties of denture base resins are of great importance in predicting their clinical performance up on immediate loading. This study investigated the impact strength, flexural strength and water sorption of three denture base materials, namely, Trevalon HI, Brecrystal and Ivocap plus. This study is designed to evaluate the different commercially available polymethacrylate materials with better flexural strength, impact strength and water sorption properties.

Materials and Methods

A total of 90 samples (10 samples of each material for flexural strength, impact strength and water sorption) were prepared from three different materials. For flexural strength and impact strength the samples are tested using universal testing machine and Izod impact tester. For evaluating water sorption, the specimens are stored in a desiccator at 37ºC for 23 hours and the samples are weighed using a balance. Then the dried specimens are immersed in water at a temperature of 37º C for 7 days and dried with a clean towel and weighed again. Following denture base resins were used:

- Heat cure denture base resins (Figure 1) TREVALON HI (Dentsply international, Germany).
- Thermoplastic injection molded resins (Figure 2) BRECRYSTAL (Bredent, Germany).
- Injection molded resin (Figure 3) IVOCAP PLUS (Ivoclar, Liechtenstein).

Fabrication of die: A master die was fabricated with stainless steel sheets. The stainless steel sheets were cut into the following dimensions according to ASTM D 256 and ISO specifications.

Figure 1: Heat cure material: Trevalon HI.

Figure 2: Thermopress injection molding material-brecrystal.

Figure 3: Ivocap Plus injection molding material.

Fabrication of resin samples

All the samples were prepared according to the manufacturer's instructions.

Dies for	Dimensions	Standards
Transverse strength	65 × 10 × 3 mm	According to ASTM D 256 or ISO standards 1567:1999
Impact strength	63.5 × 12.7× 3 mm	ASTMD 790
Water sorption	50 ± 1 mm in diameter 0.5 ± 0.05 mm thick	ISO specification 1567:1999

Table

Evaluation of flexural strength (Transverse strength): Transverse strength is defined as force per unit area at the point of fracture of test specimen subjected to flexural loading.

According to the American Society for Testing and Materials (ASTM) standard D790, the samples were tested for transverse strength with a 3- point bending test using Instron universal testing machine (model no. Autograph AG 15, Shimadzu, Japan). The load was applied centrally on the bar specimen at a crosshead speed of 2 mm/min and a span length of 50 mm. The specimens were deflected until fracture occurs (Figure 4).

Figure 4: Sample testing for flexural strength.

The transverse strength was calculated using the following formula:

$$\sigma = 3pl/ 2bd^2$$

Where, σ - transverse strength, p - is the applied load, l - is the span length, b - is the width of the sample, d - is the sample thickness.

Evaluation of impact strength

Impact strength is energy required to fracture a material under an impact force. For impact testing the samples were tested using an Izod impact tester (model no: 6456/000, CEAST, Italy). The specimens were clamped at one end and a swinging pendulum of 0.5 J was used to break the samples. The absorbed energy of the sample was noted (Figure 5).

Figure 5: Sample testing for impact strength.

The impact strength was calculated using the formula:

Impact strength = $E/b \times d^2$

Where, E - absorbed energy, b - sample width, d - sample thickness.

Evaluation of water sorption

All samples are placed in a desiccator containing silica gel and kept in an incubator at 37 ± 1ºC for 23 hours. The specimens were transferred to second desiccator at 23 ± 2ºC for 1 hour. Each sample was weighed and the previously described cycle was repeated until the loss in mass of each sample is not more than 0.0002 g between successive weighing. The weight (m1) of the dried sample was determined using an electronic balance. Then the dried samples are immersed in distilled water at a temperature of 37 ± 1ºC for 7 days, then dried with a towel and weighed again (m2) (Figure 6). The Water sorption can be calculated using the formula: Water sorption = (m2) – (m1)/V

Where, m1 is conditioned mass, m2 is mass after immersion, V is volume of the sample.

Results

The obtained values for water sorption, transverse and impact strength were subjected to statistical analysis. Mean values were compared by one-way ANOVA and multiple range tests by Tukey - HSD procedure.

The results were tabulated and statistically analyzed. Mean and standard deviations were estimated from the sample for each material. Mean values were compared by one-way ANOVA and multiple range tests by Tukey - HSD procedure was employed to identify the significant groups at 5% level. The results showed significant difference in flexural strength, impact strength and water sorption values between injection molded resins and compression molded resins. Brecrystal showed slightly higher flexural and impact strength mean values than Ivocap plus, but there was no significant difference statistically. Trevalon HI showed the least mean flexural, impact strength values than the other two materials. Brecrystal showed the least water sorption mean values comparatively. Trevalon HI showed the highest mean water sorption values followed by Ivocap plus and Brecrystal.

Denture base material	N	Mean	SD	p-value
TREVALON HI	10	77.33	4.96	< 0.001
BRECRYSTAL	10	89.93	8.39	
IVOCAP PLUS	10	86.40	8.21	

Table 1: Mean and standard deviation values for flexural strength.

Denture base material	N	Mean	SD	p-value
TREVALON HI	10	35.57	4.12	< 0.001
BRECRYSTAL	10	87.57	8.55	
IVOCAP PLUS	10	78.93	9.04	

Table 2: Mean and standard deviation values for impact strength.

Denture base material	N	Mean	SD	p-value
TREVALON HI	10	29.86	1.97	< 0.001
BRECRYSTAL	10	20.29	1.54	
IVOCAP PLUS	10	25.82	1.99	

Table 3: Mean and standard deviation values for water sorption.

Discussion

During the post insertion phase of a temporary fixed hybrid prosthesis many complications may occur, among which its fracture is most common. The temporary prosthesis needs to be maintained more carefully by the patient than the final prosthesis to avoid its fracture. To overcome this problem many modifications in the material and processing methods were introduced to improve its strength. Modification of the acrylic resin designed to improve specific properties such as plasticization, copolymerization, cross linking and reinforcement. One such attempt led to the production of high impact resins that contain copolymers of low molecular weight. With advances in polymer science, new techniques such as microwave activation, light activation and injection molding techniques have been introduced, to develop polymers that exhibit improved fracture resistance. In order to investigate the effectiveness of modifiers or fillers in denture base resins or to compare the performance of different products, various mechanical tests can be performed. The commonly used methods to predict the fracture resistance is transverse strength, impact strength and water sorption.

The sample preparation followed here was similar to the one adopted by John., *et al*. [9]. Here the metal strips were directly invested in to dental stone to form stone molds for fabrication of test samples. The criteria for preference of investing the metal strips over the dental stone were to avoid errors in dimensions, distortion and expansion of mold space, ease of preparation and for minimal finishing required after deflasking [6]. Before testing, all the samples used for impact and transverse strength were immersed in a water bath at 37ºC for one week to simulate the oral conditions [10]. Dixon., *et al.* showed that a week immersion in water was necessary to saturate the samples and 30 day water storage was necessary to maximize the plasticizer effect of water [11]. Water sorption was performed using incubator and was determined according to increase in mass per unit volume. The incubator was used to maintain the temperature which stimulates the oral condition. The weight of the samples before and after immersion in distilled water was measured.

The increase in impact and transverse strength values for Brecrystal and Ivocap plus may be due to the presence of polycarbonate nylon and butadiene styrene grafted rubber in the methyl methacrylate. These rubber inclusions serve as a matrix and prevent crack propagation. This modification increases the impact strength, which is accompanied by some increase in flexural strength [10]. Tulin., *et al.* found that the water molecules diffuse through polymer during the immersion in water or saliva and reach the interface of polymer matrix and acts as plasticizer and decreases the mechanical properties such as hardness, transverse strength and fatigue limit [9]. The decrease in water sorption values for Brecrystal when compared to Ivocap plus and Trevalon HI were due to homogenenecity of the material, less void formation and less residual monomer content [12,13]. Miettein and Vallittu found that water sorption and solubility of polymers depend on the homogenecity of the material. The more homogenous a material, the less water it absorbs and the less soluble it is [14].

Conclusion

Brecrystal showed slightly higher flexural and impact strength mean values than Ivocap plus, but there was no significant difference statistically. Trevalon HI showed the least mean flexural, impact strength values than the other two materials. Trevalon HI showed the highest mean water sorption values followed by Ivocap plus and Brecrystal.

Clinical Significance

All-on-4® concept facilitates immediate loading using a temporary fixed hybrid prosthesis usually made of all acrylic resin. This prosthesis is given for 6 months and is later replaced by a definitive prosthesis. The prosthesis is supported by only 4 implants and hence needs to be strong to withstand masticatory forces for 6 months. Final outcome of implant prosthesis is partly depended on the clinical performance and strength of temporary fixed hybrid prosthesis and the material used for its fabrication. Various denture base resins with different modifications are available in the market which have to be chosen wisely considering various properties such as Impact strength, Flexural strength and Water sorption, to avoid fracture of the temporary prosthesis. These properties of denture base resins are of utmost importance in predicting their clinical performance up on immediate loading.

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