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Research Article

Micro-Hardness and Fracture Toughness of Thermosens Thermoplastic Material Versus the Conventional Heat-Cured Acrylic Resin After One Year of Water Storage

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Abstract

Objectives: The aim of this study was to evaluate the aged micro-hardness and fracture toughness of thermoplastic resin (ThermoSens) versus the conventional denture base resin (Major base 20).

Materials and Methods: For the hardness test, 20 square-shaped specimens (12 mm x 12 mm x 3 mm thickness) were prepared from both denture base materials using a stainless die. The hardness was measured for each specimen using a micro-hardness tester. For the fracture toughness testing, 20 rectangular specimens were prepared from both denture base materials using stainless steel plate. The specimen dimensions were 65 mm length, 10 mm width and 2.5 mm thickness. Each specimen has a central V-shaped notch of 2.5 mm depth. The fracture toughness was measured by a three-point bending test using a universal Lloyd testing machine.

Results: The conventional denture base resin (Major base 20) showed significantly higher hardness than that of thermoplastic denture base material (ThermoSens). On the other hand, thermoplastic denture base material (ThermoSens) showed significantly higher fracture toughness than that of the conventional denture base resin (Major base 20).

Conclusion: After one year of water storage, thermoplastic denture base material (ThermoSens) has higher fracture toughness and lower micro-hardness than that of the conventional denture base resin (Major base 20).

Keywords: Thermoplastic Denture Base; Heat-Cured Material; Micro-Hardness; Fracture Toughness

Introduction

Edentulous patients were treated with complete dentures 700 BC. There are several denture base materials were used for treatment of edentulous patients. Such as ivory, wood, gold, bone, and ceramics. In addition, vulcanized rubbers were used as complete denture base materials. Poly vinyl chloride, vinyl acetate, polycarbonates, modified phenol formaldehyde resin (bakelite), cellulose plastics and polyamides were used as denture base materials for treatment of edentulous patients [1].

Methacrylate polymers have increased popularity in dentistry as a denture base materials due to (1) easy in processing using simple techniques and equipment, (2) good aesthetic quality, (3) high chemical resistance in the mouth, and (4) low cost. There are several processing techniques available for denture base construction. For example, heat-activation was used in the fabrication of denture bases and heat injection technique was used. The thermal energy used for polymerization of these materials could be provided by a water bath or microwave oven. Poly methyl methacrylate denture base material was supplied in the form of powder and liquid [2]. Finally, the latest form of denture base materials was the Vertex™ ThermoSens thermoplastic material, which utilizes the thermal energy for curing [3].

Flexible resin materials were produced for the construction of provisional prostheses such as immediate removable dentures. These materials characterized by good esthetic quality, translucency, flexibility, and natural appearance. The advantage of flexibility for these materials could prevent prosthesis fracture [3]. Thermoplastic resins have several advantages over the conventional resins. They have high translucency, high creep resistance, high flexural and impact strength, fatigue endurance, and high wear resistance. In addition, they have good solvent resistance, no residual monomer, no porosity, has higher dimensional stability, low water sorption, biocompatibility, odorless and less staining. They are easier in finishing and polishing [4].

The term thermoplastic refers to polymers which softened by heating and solidify by cooling. Thermoplastic polymers are made of linear polymer and/or branched polymer chains. Thermoplastic polymers softened by heating above the glass transition temperature at which there is a molecular motion starts to force the polymer chains apart from each other. Therefore, the resin can be shaped and molded while it is soft, after cooling, it hardens in this form. Reheating of these polymers, they soften again and could be reshaped. The setting reaction of these materials is reversible because of the relatively weak bonds between the molecular chains [5].

Vertex ThermoSens is a thermoplastic material, rigid denture base material, free of monomer, virtually unbreakable and innovative. ThermoSens was used as complete or partial denture bases, bridge constructions and temporary crown. It composed of microcrystalline polyamide material with pigments. Therefore, it is acceptable for patients allergic to free monomers. Molding of Vertex ThermoSens based on the injection technique using automatic or manual injection machine. These thermoplastic denture base materials are flexible; therefor it is suitable for removable partial dentures due to it produces acceptable and stronger appliances. The flexibility of the thermoplastic dentures prevent transferring stresses to the adjacent teeth and the their surrounding tissues preventing trauma from the partial dentures. The esthetic appearance of the thermoplastic denture bases similar to the surrounding oral tissues. This eliminates the use of metal clasps that were used in the metallic partial dentures [6,7]. Vertex ThermoSens has lower flexural modulus and higher flexural strength when compared to the conventional denture base material after one year of water storage [7].

The null hypothesis of this study was that Vertex ThermoSens thermoplastic material is superior to the conventional denture base material in micro hardness and fracture toughness. There is a lack of information about the hardness and fracture toughness of ThermoSens denture base materials in the literatures. So, the aim of this research work was investigation of the hardness and fracture toughness of ThermoSens denture base material in comparison to the conventional heat-cured acrylic resin.

Materials and Methods

Micro-hardness testing

This study utilized the following materials, thermoplastic Vertex™ ThermoSens (Vertex Dental B.V. 3705 HJ Zeist, Netherlands) and the conventional denture base material as Major base 20 (Major Prodotti Dentari S.p.A; Italy). 20 square-shaped specimens, 10 from each denture base material were prepared using a stainless die (12 mm x12 mm x 3 mm thickness). Impressions were done for the metallic specimens by using a heavy body polyvinyl siloxane rubber base material (Silastic E; Dow Corning, Midland, Mich, USA). The metallic specimens were carefully removed after setting of the impression material. Baseplate wax (Tru Wax, Dentsply International Inc., York, Pa.) was melted and poured into the impression molds and compressed by using a glass slab to produce a flat and smooth wax specimen. The wax specimens were carefully removed from the impression molds and randomly divided into 2 groups (10 specimens each). The first group was processed from Major base 20 and the second group was processed from Vertex ThermoSens denture base materials. [7-9].

For the conventional heat-cured denture acrylic resin, the Major base resin material was molded into their flasks and cured following the manufacturer's recommendations. Processing of the material was done by placing the flasks in boiling water at 100°C for 30 minutes for complete curing. The flasks with the specimens were slowly cooled to the room temperature. The acrylic specimens were removed carefully from their flasks and then finished and polished under water at room temperature. The specimens were stored in water at 37°C for 12 months [7].

For the thermoplastic Vertex™ ThermoSens, the wax specimens were prepared, flasked and washed as the above Major base resin heat-cured material. This group was processed according to the manufacturer recommendations. This system used special metallic flask, which has posterior wax sprue suitable for injection of the Vertex™ ThermoSens inside the gypsum mold. This material could be injected within the mold through automatic or manual injection machine. The dimension of the main sprue was about 9.5 mm and side sprues were about 4.5mm. The Vertex™ ThermoSens resin was heated to 270-280 °C within 18 minutes and automatically injected at a pressure of 8.5 bars into the flask molds. After complete curing, the flasks were slowly cooled to the room temperature. The specimens were removed from the flasks, finished, polished and stored at 37 °C for 12 months [5,7,8].

The Vickers micro-hardness numbers were obtained using a calibrated Vickers micro-hardness Tester (Micro hardness tester, FM-7, Japan). The Vicker's hardness involves the use of diamond pyramid indenters. The diamond indenter has equal diagonals, which used to produce indentation on the specimens' surface. Ten micro-hardness readings were determined with the application of a 100-gf load for 15 second. The device has a built-in microcomputer, which automatically calculate the Vickers hardness value of each indent in kg/mm^2.

Fracture toughness test

A total of 20 rectangular specimens were prepared from both denture base materials, 10 specimens each using stainless steel plate. Each specimen has dimensions of 65 mm length, 10mm width and 2.5 mm thickness following the American Dental Association Specification No.12 for denture base materials. Impression was taken for the metallic specimen using heavy body polyvinyl siloxane impression material (Silastic E; Dow Corning, Midland, Mich, USA). The metallic specimen was carefully removed after setting of the impression. Melted Baseplate wax (Tru Wax, Dentsply International Inc., York, Pa.) was poured inside the impression mold and compressed by glass slab to produce smooth and flat wax specimen. The wax specimens were removed carefully from the impression molds and divided into 2 groups (10 specimens each) randomly. The first group was processed from Major base 20 and the second group was processed from Vertex ThermoSens materials as mentioned before. The flasks were left for cooling slowly and the specimens were deflasked, finished and polished [5,7,8].

To produce a single edge notched beam, a standardized pre-crack in the middle of each specimen was machined following the ISO 20795 (0.5-mm-wide notch, 3.0 mm in length) using a motorized diamond sawing blade. The notch tip was carefully sharpened using a razor blade together with a diamond paste of 1 μm grain size. The specimens were stored in water at 37 ^{0}C for 12 months. Stress intensity factor (KIc) was measured using a three-point bending test through a universal testing machine (Lloyd Model TT-B, Instron Corp., Canton, MA, US). Bar-shaped notched specimen was fixed in the device grip where the notch on the tensile side (opposite the applied load). The load applied exactly above the notch of the specimen until fracture occurred. The fracture load was recorded in Newton and the stress intensity factor was calculated in MPa $m^{0.5}$ according the following equations [10,11].

$K_{IC} = 3PL/BW^{3/2}. Y$

Where P is the peak load (N), L is the span length (m), B is the specimen width (m), W is the specimen thickness, and Y is calibration function for given geometry which is calculated as below

$Y = 1.93 \times (a/w)^{1/2} - 3.07 \times (a/w)^{3/2} + 14.53 \times (a/w)^{5/2} - 25.11 \times (a/w)^{7/2} + 25.80 \times (a/w)^{9/2}$

Where (a) is the notch depth.

Statistical analysis

The data analyzed using paired t-test statistical analysis at the level of significance $p \leq 0.05$.

Discussion and Conclusion

Flexible denture base materials supplied in the form of granules in cartridges of varying sizes. Thermoplastic materials are polyacetal or polyamide nylon. These are super polyamides, which belong to nylon family. Nylon is a resin produced from dicarboxylic acid, amino acid. diamine, and lactams. Injection-molding technique used for fabrication of flexible denture base prosthesis [12].

Some of the requirements of acceptable denture base materials are good strength, durability, biocompatibility, chemical stability, ease of fabrication, easily repair, satisfactory thermal properties, color stability and moderate cost. Flexible partial dentures can be a good option for the restoration of the missing teeth regarding to the patient aesthetics [13,14].

The results of this study concluded that the heat cure acrylic resin has higher micro hardness than that of ThermoSens thermoplastic denture base material. Another study showed higher micro hardness for heat-cured resin than flexible thermoplastic polyamide nylon. This thermoplastic polyamide nylon resin is more flexible than PMMA [14].

Surface hardness test is essential because it used to determine the resistance of material for scratching. The chemistry of thermoset elastomers differ mainly from thermoplastic elastomers in the type of cross-linking in their structure. The cross linking in the thermoset polymer is a covalent bond produced during polymerization reaction. Cross-linking is the critical structural factor, which impart the high elastic properties. The thermoplastic materials have higher flexural strength than that of the high impact acrylic resin [15]. Vertex thermosens denture base materials showed significantly higher impact strength and flexural strength greater than that of the conventional polymethyl-methacrylate denture base materials [16].

Poly-methyl methacrylate denture base polymer showed higher hardness values than that of flexible resin. These results may be due to the cross-linking agents, which exist in the material, which improve the hardness of the resins. Flexible resin demonstrated lower hardness values due to the presence of lower amounts of cross-linking agents. These results showed that polyamide resin is a more flexible material than the conventional heat-cured resin-base materials [17].

Denture base resin material must meet or exceed the standards presented in ANSI/ADA Specification No. 12 to provide acceptable physical properties. A chemical change occurs in the thermosetting polymers and become permanently hard when they were heated above the polymerization temperature. They are cross-linked in this state, insoluble and will not melt. In addition, they do not soften again on reheating to the same temperature. They decompose if heated to a higher enough temperature. Thermosetting polymers have higher abrasion resistance and dimensional stability when compared to the thermoplastic polymers, which have higher flexural strength and impact properties [2].

A three-point bending test could be used to determine the relationship between the applied load and resultant deflection in a resin specimen of specified dimensions [2]. A three-point bending test is important due to it can reflect the ability of denture base material could resist the functional masticatory forces in the oral cavity. The three-point flexural test is helpful in comparing denture base materials because it simulates the stress that is applied to the denture during function [18,19].

The knop hardness values of heat-cured acrylic resins may be as high as 20 KHN [20]. The results of this study showed significantly higher hardness values for the Major. Base 20 (heat-cured acrylic resin) denture base materials when compared to thermoplastic ThermoSENS material. One study concluded that thermoplastic resin was less surface hardness than that of the conventional heat-cured acrylic resin [21]. Other study concluded that there were no significant differences in the surface hardness of both conventional and flexible cured acrylic resin [22]. On the other hand, other study concluded that the Vertex ThermoSens denture base material showed higher tensile strength and surface roughness when compared with heat cure acrylic denture base material. This difference between these studies may be related to the difference in the materials and testing machine that were used [23,24].

Groups	Means	SD	t-value	p-value	SEM
Heat-cured material	70.0783	3.1344	19.7753	0.0001	1.27966
ThermoSENS material	29.6750	2.1326			0.8706

Table 1: Shows means, standard deviations and standard errors of micro hardness of heat-cured versus thermoSens denture base materials.

Two-tailed P-value is less than 0.0001.

95% confidence interval of this difference df = 5.

Groups	Means	SD	t-value	p-value	SEM
Heat-cured material	1.47167	0.39756	17.5936	0.0001	0.16230
ThermoSENS material	4.302	0.71306			0.29111

Table 2: Shows the means, standard deviations and standard errors of the fracture toughness of heat-cured versus thermoSens denture base materials.

Two-tailed P-value is less than 0.0001.

95% confidence interval of this difference. df = 5.

The results of this study showed higher fracture toughness for Vertex ThermoSens than that of Major. Base 20 denture base material on the opposite of the hardness property. The Vertex ThermoSens denture base material showed higher impact and flexural properties when compared to the conventional resin [8]. After storage in water for 12 months, Vertex ThermoSens material exhibited higher flexural strength than that of Major Base 20. Major. Base 20 resin base material had higher flexural modulus than that of Vertex ThermoSens after storage in water for 12 months [7].

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