the Journal of Contemporary Dental Practice
at www.thejcdp.com
Volume 6 Number 4 November 15, 2005
Fall Issue

Physical Properties of Four Acrylic Denture Base Resisns

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Abstract

Resistance to impact fracture and high flexural strength are desirable properties of denture base acrylics. The purpose of this laboratory study was to determine the Izod impact strength, the flexural strength, the flexural modulus, and the yield distance for four premium denture resins. Bar specimens 86 x 11 x 3 mm of Lucitone 199, Fricke Hi-I, ProBase Hot, and Sledgehammer Maxipack were fabricated following the manufacturer's instructions for heat processing. The bars were surface finished using silicon carbide paper to 600 grit. Ten specimens from three lots of each material were made (n=30). Flexural strength, flexural modulus, and 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 (n=60). Analysis of variance (ANOVA) and post-hoc Tukey's test were used for statistical comparison of each property. There were significant differences in the physical properties among the denture acrylics tested. Lucitone 199 demonstrated the highest impact strength, flexural strength, and yield distance ($p<0.05$). Lucitone 199 with an Izod impact strength of 5.5 ± 1.2 N·m, a flexural strength of 99.5 ± 4.5 MPa, and yield distance of 9.9 ± 0.76 mm exhibited statistically greater results than Fricki Hi-I, ProBase Hot, and Sledgehammer Maxipack. Fricki Hi-I with a yield distance of 7.3 ± 1.1 mm was statically greater than ProBase Hot and Sledgehammer Maxipack. Fricki Hi-I, ProBase Hot, and Sledgehammer Maxipack were statistically similar for the Izod impact strength and flexural strength tests performed. ProBase Hot and Sledgehammer Maxipack yielded statistically similar results for all tests performed. Flexural modulus had an inverse relationship to the impact strength, flexural strength, and yield distance.

Keywords: Denture base physical properties, acrylic resin flexural strength, yield distance, flexural modulus, impact fracture strength

Citation: Meng TR, Latta MA. Physical Properties of Four Acrylic Denture Base Resins. J Contemp Dent Pract 2005 November;(6)4:093-100.

Introduction

The ideal denture base material should possess several key physical attributes. Some of these properties include biocompatibility, good esthetics, high bond strength with available denture teeth, radiopacity, ease of repair, and should possess adequate physical and mechanical properties.[1] The denture base must be strong enough to allow the prosthesis to withstand functional and parafunctional masticatory forces. In addition, because these prostheses are removable, shock induced fracture resistance, possibly due to patient abuse, is desirable.

Many different materials have been used for denture bases. Historically materials such as bone, wood, ivory, and vulcanized rubber were utilized; now poly methyl methacrylate (PMMA) is used.[2-6] New materials such as polystyrene and light-activated urethane dimethacrylate have been developed, but PMMA remains the preferred material for removable complete and partial prostheses.[7] The popularity of PMMA materials is based on its low cost, relative ease of use, and reliance on simple processing equipment. There are, however, significant differences in the chemistry among denture materials based on PMMA chemistry. Some materials rely on high levels of crosslink resin and heat activated initiators to maximize the physical properties of the processed materials, i.e., Sledgehammer Maxipak and ProBase Hot. Other formulations like Lucitone 199 and Fricke Hi-Impact employ a PMMA polymer modified by adding a rubber compound to improve shock resistance and improve strength properties.

Causes of denture fractures are more often related to design errors rather than problems with the resin itself. Denture failures can occur in excessively thin areas or weakened flanges around frenal notches.[8] Midline fractures of denture base resins are especially troublesome, leading some to recommend selectively increasing the bulk of material in regions subject to deformation and fractures. These locations include the palatal incisal junction, the posterior palatal midline, and the mandibular incisal area adjacent to the lingual and labial frenal attachments.[9] Increasing bulk, however, can lead to other problems. A denture base that is too thick can cause gagging or dislodgement of the denture when the patient opens wide or yawns. Excessive thickness in a maxillary denture can interfere with the coronoid process during movement of the mandible. Bulk in the area lingual of the maxillary anterior teeth can cause speech problems such as a slushy “S” sound by flattening the median grove of the tongue. While minimizing the thickness of the denture base can lead to better patient acceptance, it also increases the potential for fracture making the use of a stronger acrylic resin very important.

These factors have led manufacturers to develop higher strength denture base materials.[10, 11] Considering the recent recommendations of the McGill Consensus Statement[12] suggesting implant supported overdentures be the standard of care for mandibular edentulous patients and the concomitant increase in the use of overdentures, the use of strong resins is imperative.[13] A variety of physical properties can be used to assess the strength of denture materials. The most common tests are impact strength; the ability of a material to resist a sudden high level force or ‘shock;’ flexural strength, the force needed to deform the material to fracture or irreversible yield; and flexural modulus, a measure of the stiffness of a material. In addition the distance a material specimen can be deformed (yield distance) before failure also is an indication of the toughness of a material.

Because of the risk of fracture should a patient drop their denture, high impact strength is a desirable property. Given the function of a denture base in a removable prosthesis, high flexural strength, flexural modulus, and a large yield point distance would help resist torsional forces in function leading to a longer clinical service life for the prosthesis.

The purpose of this study was to determine the impact fracture strength, flexural strength, flexural modulus, and the yield distance of high impact and conventional denture base resins.

Materials and Methods

Flexural Strength, Flexural Modulus, and Yield Distance

Bar specimens for testing were made of Lucitone 199 (Dentsply/Trubyte 570 W. College Ave, York, PA, USA), Fricke Hi-Impact (Fricke

Dental International, 208 West Ridge Rd., Villa Park, IL, USA), ProBase Hot (Ivoclar Vivadent, 175 Pineview Drive, Amherst, NY, USA), and Sledgehammer Maxipact (Keystone Dental, 616 Hollywood Ave., Cherry Hill, NJ, USA) denture base resins. The manufacturers' instructions for mixing and processing were followed. Ten specimens from three lots of each material were made creating a total of 30 specimens for flexural strength, flexural modulus, and yield distance. Following deflasking, each specimen was wet-ground using in sequence, 120, 320, 400, and 600, grit silicon carbide paper on a lapidary wheel. The finished specimens were approximately 86 mm x 11 mm x 3 mm and were stored at 23°C and 50% humidity for 24 hours prior to testing.

Flexural strength, flexural modulus, and yield distance were determined using an Instron testing machine with a three-point bending fixture with a span of 80 mm, 1,000-pound load cell, and a cross-head speed of 0.1 inches per minute. Results for flexural strength were calculated by the following equation.[10]

$$FS = \frac{3\,PL}{2\,BH^2}$$

P = dead load weight
L = span
B = width of test sample
H = depth

Flexural modulus was determined from the slope of the stress-strain line developed during the three-point bending test. Yield distance was also determined from the stress-strain curve and was the distance the bar deflected in the three-point apparatus prior to irreversible deformation or breakage.

The fractured bar specimens were saved and subjected to impact strength testing.

Impact Strength

Impact strength was determined using an Izod tester on un-notched specimens. Impact strength was measured directly from the test device. The fracture specimens from the three-point test were used in the Izod tester (n=60). These specimens measured approximately 43 mm in length.

One-way analysis of variance (ANOVA) and post-hoc Tukey's test were used for statistical comparison of each physical property.

Results

The impact strength, flexural strength, flexural modulus, and yield distance results are shown in Table 1.

ANOVA revealed significant differences for materials in each physical property category ($p<0.05$). The results of the post-hoc test are described in the Table as follows: Groups connected with a like symbol were statistically similar ($p>0.05$). Groups not connected were statistically different ($p<0.05$).

Discussion

Zappini et al.[14] noted most studies evaluating the strength of denture base resins rely mainly on impact data, and this may not be the best test to predict clinical function. Impact tests are influenced by loading conditions and specimen

Table 1.

	Izod Impact Strength (N·m)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Yield Distance mm
Lucitone 199	5.5 ± 1.2	99.5 ± 4.5	2628.2 ± 167.5*	9.9 ± 0.76
Fricki Hi-I	3.8 ± 0.61*	88.9 ± 7.3*	2740.6 ± 242.3*	7.3 ± 1.1
Probase Hot	3.4 ± 0.65*	87.4 ± 8.9*	2904.9 ± 281.4+	5.6 ± 0.86*
Sledgehammer Maxipack	3.1 ± 0.68*	84.9 ± 7.0*	2915.7 ± 230.9+	5.4 ± 0.64*

* Groups connected with a like symbol were statistically similar ($p>0.05$).

geometry, such as the dimensions of the sample and the presence and configuration of notches. The authors also suggested a more reasonable test would be a fatigue test. However, the time and number of samples required for fatigue testing and the fracture toughness test might be more practical.

We chose to include impact test results given the number of studies that have previously reported those data. Flexural strength, flexural modulus, and yield distance were tested to get an understanding of how denture base resins hold up under function. Of the four materials tested, Lucitone 199 exhibited statistically superior performance in Izod impact strength, flexural strength, and yield distance compared to the other three products ($p<0.05$). The flexural modulus of Lucitone 199 was the lowest ($p<0.05$). This would be consistent with a less brittle, more energy absorbing material, and this inverse ranking with respect to modulus is entirely consistent with the other parameters tested. Of the other three materials, generally Fricke Hi-Impact resin yielded higher values for impact strength, flexural strength, and yield distance than both ProBase Hot and Sledgehammer, although the differences were not consistently statistically significant.

There were significant differences in the acrylic resin denture base materials tested. Lucitone 199 denture base material generated higher impact strength, flexural strength, and yield distance compared to Fricke Hi-Impact, ProBase Hot, and Sledgehammer resins. The use of a rubber modified polymer in the Lucitone and Fricki Hi-Impact materials led to better performance in the physical property testing the materials that employed cross-linking agents and high initiator levels. These higher properties are indicative of the needed strength and durability of resins used for denture prostheses.

It must be noted these specimens were stored in 50% humidity and not immersed in water for 24 hours. We felt the conventional resins would release residual monomer during immersion for 24 hours. This would cause them to become more brittle and accentuate the difference between the conventional resins and the high impact denture base resins that contain additional rubber like materials.

Conclusion

Lucitone 199 exhibited the highest impact and flexural strengths and the highest yield distances.

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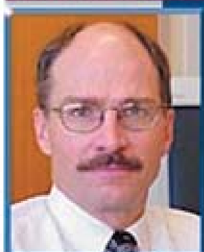

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Acknowledgements

The authors would like to express their special gratitude to Mr. Gary Wedel and Mr. Terry Haftings for their help in preparing the samples utilized in this study.