Revista Odontológica Mexicana

Facultad de Odontología

Vol. 17, No. 3 ● July-September 2013
pp 144-149

ORIGINAL RESEARCH

Transverse deflection of polymer-based alternative materials for the manufacturing of a denture base

Deflexión transversa de materiales alternativos a base de polímeros para fabricación de base de dentadura

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ABSTRACT

Nowadays, alternative techniques are being developed for short-time manufacturing of full prostheses, entailing different materials for the denture base. The purpose of the present study was to compare transverse deflection among polymer-based materials currently proposed as an alternative to materials commonly used to conventionally manufacture a full prosthesis. For the denture base the following materials were tested: thermo-cured (setting) acrylic resin, self-cured acrylic resin, 60 and 80 gauge acetate sheets coated with self-cured acrylic resin, liquid (fluid) acrylic resin as well as light-cured resin. Ten 65 x 10 x 2.5 mm samples of each material were manufactured. The samples were placed in water at 37°C for 50 hours. Transverse deflection was measured and results were analyzed with the help of one-way analysis of variance (ANOVA). Results exhibited statistically significant differences among groups. Acetate sheets coated with self-cured acrylic could represent an alternative for the rapid manufacturing of temporary denture basis.

RESUMEN

En la actualidad se están desarrollando técnicas alternativas para la fabricación en tiempos cortos de prótesis totales en relación con la utilización de diferentes materiales para la base de dentadura. El propósito de este estudio fue comparar la deflexión transversa entre materiales a base de polímeros, propuestos como una alternativa a los materiales comúnmente utilizados para realizar una prótesis total en forma convencional. Se probaron resina acrílica termocurable, resina acrílica autocurable, láminas de acetato calibre 60 y 80 recubiertas con resina acrílica autocurable, resina acrílica fluida y resina fotopolimerizable para base de dentadura. Se fabricaron diez muestras de 65 x 10 x 2.5 mm de cada material. Las muestras se colocaron en agua a 37°C por 50 horas, se midió la deflexión transversa y se analizaron los resultados por análisis de varianza (ANOVA) de una vía. Los resultados mostraron que hubo diferencia estadísticamente significativa entre los grupos. Las láminas de acetato recubiertas con acrílico autocurable pueden ser una alternativa para la rápida fabricación de bases de dentadura de uso temporal.

Key words: Transverse deflection, polymers, denture base.
Palabras clave: Deflexión transversa, polímeros, base de dentadura.

INTRODUCTION

Nowadays, many alternative materials are proposed to achieve fast and simple manufacturing of denture bases when compared to more widely known conventional procedures. Nevertheless, up to this point, in scientific literature there is little information on the transverse deflection of these new materials.

In the field of dentistry, the most frequent application for polymers is the manufacturing of full or partial removable prostheses bases.[1]

Doctors Dappen and Schuebel, in Germany, began using acrylic resins in 1936-1940. In 1937,[2] acrylic polymers were first introduced as denture base material. Acrylic resin, called acrylic, is a synthetic resin, artificial chemical body, derived from the acrylic acid analogous to the resin, or methyl polymethyl-methacrylate. It can take in liquid or powder shape. The liquid is the monomer form of methacrylate and the powder or polymer is the polymerized form.[3]

The resistance exhibited by acrylic resins for manufacturing of denture bases varies according to

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the composition of the resin, the technical procedure as well as the operating environment of the prosthesis. In general terms, tensional properties of the resin are assessed through a transverse resistance test as described by specification number 12 of the American Dental Association.[4] Transverse deflection refers to the deformation a flexure force causes in an object.[5] The sample is subjected to a specific degree of transverse deviation load. The requirements of ADA's number 12 specification stipulate certain maximum deflections at the center of the samples when subjected to different loads. In practice the test assesses a combination of properties, such as tension and compression as well as elasticity module.[4] Many researchers have examined the flexure resistance of polymers used for denture bases: Hargreaves, 1983; Reitz, Sanders and Levin, 1985; Montes-G and Draugh, 1986; Bunch, 1987; Shlosberg, 1989; Hayakawa, 1990; Iwahori, 1992. Arima et al (1995) reported flexure resistance of six self-curing polymers. They showed lower flexure resistance than that observed in heat-curing polymers.[6]

Ruyter and Svendsen, in 1980, reported on flexure resistance of self-curing acrylic resins. In that same year, Stafford studied a variety of heat-curing resins for use in high impact denture bases.[7] The present mechanical test will enable us to predict clinical behavior of full prostheses bases.

Heat-cured acrylic resins are generally formed by polymethyl-methacrylate (PMMA), benzoyl peroxide constitutes its polymerization initiator. Chemistry of self-cured resins is identical to that of heat-cured resins, except that curing process is initiated by a tertiary amine (dimethyl-p-toluidine or sulfonic acid).[4,8] This curing method is not as effective as heat-curing, and results in a material with lower molecular weight, which entails a negative effect on the material's resistance properties and originates in the resin a certain amount of non-cured residual monomer.[4,8]

Alternatives to the conventionally used heat-cured and self-cured acrylic resins could be a combination of polyvinyl-acetate-polyethylene with a coating of self-cured acrylic resin. This is the system proposed by Dr. Enrique C. Aguilar in his technique «full prosthesis in one appointment» which uses fluid acrylic resin and light-cured resin for denture bases. The acetate plate is made up of thermoplastic polymers and a polyvinyl-acetate-polyethylene polymer. Other products might contain polyurethane, latex rubber and plastisol vynil.[1,3] Vinyl-ethylene acetate co-polymers are supplied in heat-softened sheet form.[9-11]

Liquid type acrylic resins have a similar composition to heat-cured resins. Nevertheless, they are used with a significantly lower liquid-powder ratio which varies from 2:1 to 2, 6:1 when compared to the conventional ratio of 3:1.[3] Particle size of powder polymer is smaller.[10-11] Work time is lesser than required time when using heat-cured material. Nevertheless, when considering mechanical properties in comparison to resins, these materials exhibit lesser flexure resistance, they are softer, easily abraded and more severely deformed when subjected to a constant load.[10]

Light-cured resins used for denture base first appeared in the market in 1983.[12] This material was made of a urethane dimethacrylate matrix with an acrylic co-polymer, silica micro-fine filling material and a camphoroquinone photo-initiator.[12,13]

A 400-500 nm blue light chamber is used to polymerize the material.[12] This system precludes the need to use a muffle, waxing or boiling tanks. It has the advantage of requiring short working time and exhibits physical properties similar to those of thermo-cured acrylic.[4] This resin has been used due to the fact that it does not contain methyl-methacrylate of the free monomer.[15,16]

The purpose of the present study was to compare transverse deflection found in thermo-cured acrylic resins, self-cured acrylic resins, number 60 and 80 acetate sheets coated with self-cured acrylic resin, fluid acrylic resins and light-cured resins. All the aforementioned are materials offered and used for the manufacturing of denture bases.

MATERIALS AND METHODS

Samples used to determine transverse deflection were conducted as described by the American Dental Association's specification number 12,[17] following technical indications suggested by manufacturers.

Thermo-cured acrylic resin samples were made up as control (Nic Tone®, MDC Dental, Jalisco, Mexico, lot 26589), self-cured acrylic resin (Cross Linked, Nic Tone®, MDC Dental, Jalisco, Mexico, lot 207863). For the technique «full prosthesis in one appointment» samples were made of number 60 and 80 acetate sheets (Base plate sheets, Ultradent Products Inc., USA, Cat 25-0030) coated with self-cured acrylic resin (Cross linked, Nic Tone®, MDC Dental, Jalisco, Mexico, lot 207863). Targeted thickness was 2.5 mm with 65 x 10 mm dimensions. Fluid acrylic resin (Fluid cross linked, Nic Tone®, MDC Dental, Jalisco, Mexico, lot 27074008), 65 x 10 x 2.6 mm light-cured resin for denture base (Triad®, Dentsply International, York, Pa.) were used. Samples surfaces were polished with fine sandpaper (numbers 280, 320, 360, 500, Fandeli, Mexico). Dimensions were corroborated using a digital vernier (Fowler & NSK Max-Cal) with 0.05 tolerance.

All samples were placed in a container with water, within a controlled-temperature oven (Felisa oven, Mexico, D. F.) at 37°C for 50 hours previous to the test. The samples were mounted on a device (Universal testing machine, Cell AFI, Mecmesin, U. K.). The device was suitable gauged and able to provide a uniform load index. It was equally equipped with a device to measure deflection (Hommel depthmeter, Germany), within a 0.01 mm approximation at the center of the sample. The load was applied in a straight line. Both support devices on which samples were placed were parallel and exhibited a 3.2 mm highly polished cylindrical surface. The distance between both support centers was 50 ± 0.025 mm.

The load was applied on a straight line, at the sample middle point (center). Samples were submerged in water during the test. The initial load consisted of the free movement of the apparatus sections, directing enough load to provide a 14.71 N to the sample. At every 4.90 N, the load was increased to a uniform speed during the last 30 seconds of each minute. The table provided *(Table I)* was used to apply the load and make observations. Differences among deflections in the initial load and other specific loads were recorded as the sample's deflection. The numeric value of deflection was calculated to the nearest 0.1 mm.

Table I. Diagram recording load results as specified by ADA norm 12.

Time		Load		Reading
Min	Sec	Newtons	g	mm
0	00	14.71	1,500	
0	30	14.71	1,500	
1	00	19.61	2,000	
1	30	19.61	2,000	
2	00	24.52	2,500	
2	30	24.52	2,500	
3	00	29.42	3,000	
3	30	29.42	3,000	
4	00	34.32	3,500	
4	30	34.32	3,500	
5	00	39.22	4,000	
5	30	39.22	4,000	

Transverse deflection values were recorded according to specifications of the norm where the sample was loaded. It began at 14.71 N (1,500 g) and was recorded in mm as the sample's deflection. At later points, the load was applied, and deflection millimeters were recorded for every 500 g, until reaching a point of maximum deflection or fracture.

In order to obtain values, formulae B-A and C-A were applied, in where A = 1,500 g, B = 3,500 g and C = 5,000 g.

An average of the values to be compared was established, according to norm requirements. Obtained values to compare examined groups were statistically analyzed using one way analysis of variance (ANOVA) as well as Tukey p <tests.

RESULTS

Table II describes the comparison of values obtained from the samples with values required by the norm. Samples of light-cured resin for denture base could not be considered for the statistical analysis due to the fact that they fractured before reaching 3,500 and 5,000 g deflection values as specified by the norm. Samples made of heat-cured acrylic resin and acetate 80 coated with self-cured acrylic resin presented the lowest deflection values. Samples of acetate 60 coated with self-cured acrylic resin reached high deflection values, although they were within the established norm. Fluid acrylic resin samples exhibited high deflection values, accepted by the norm, only when subjected to a 3,500 g load. Nevertheless, when subjected to a 5,000 g load, they fractured and did not reach norm-established limits. Self-cured acrylic resin samples when subjected to 3,500 g load showed a high deflection value(not allowed by the norm); when they were subjected to a 5,000 g load, they fractured, thus were unable to reach the norm-allowed limit.

One-way ANOVA statistical analysis showed average values of analyzed groups *(Tables III and IV)*. A statistically significant difference (p = <0.001) was observed.

In 3,500g deflection B-A (3,500-1,500 g), the Tukey test exhibited differences among all groups, except for the acetate 60 coated with self-cured acrylic resin, fluid acrylic resin and thermo-cured acrylic resin when compared to acetate 80 coated with self cured acrylic resin.

Tukey test in 5,000 deflection C-A (5,000-1,500 g) exhibited differences among all groups.

Table II. Deflection ranks obtained in the study and norm specified deflection ranks.

Material	B-A	Norm		C-A	Norm	
	3,500 g	Min	Max	5,000 g	Min	Max
Heat cured A.	1.2*	…	2.5	2.7*	2.0	5.5
Self-cured A.	3.3*	…	2.5		2.0	5.5
Acetate 60+ self A.	2.3*	…	2.5	4.7*	2.0	5.5
Acetate 80 + self A.	1.1*	...	2.5	2.3*	2.0	5.5
Fluid A.	2.2*	…	2.5		2.0	5.5
Light-cured A.		…	2.5		2.0	5.5

* Average
Blank cells indicate lack of values recorded due to sample fracture when reaching 3,500 g and 5,000 g respectively.

Table III. Average and standard deviation of 3,500 deflection (N = B-A).

Material	Average	Standard deviation
Heat-cured A.	1.250	0.227
Self-cured A.	3.300	0.278
60 Acetate + self-A.	2.370	0.340
80 Acetate + self-A.	1.100	0.0667
Fluid A.	2.200	0.163
Light-cured A.	*	*

* Light-cured acrylic samples could not be included in the analysis since they fractured before reaching norm-specified values.

Table IV. Average and standard deviation at 5,000 g (N = C-A).

Material	Average	Standard deviation
Heat-cured A.	2.720	0.368
Self-cured A.	*	*
60 Acetate + self-A.	4.733	0.137
80 Acetate + self-A.	2.320	0.0789
Fluid A.	*	*
Light-cured A.	*	*

* Samples of self-cured, light-cured and fluid acrylic could not be included in the analysis since they fractures before reaching norm-specified values.

DISCUSSION

Acetate 80 coated with self-cured acrylic resin showed lesser transverse deflection. This could be attributed to the fact that acetate 80 conferred resistance to self-cured acrylic resins. Polyvinyl acrylics and reinforced plastics exhibited a flexion module 20% lower than conventional thermo-cured resins.[4], unlike the independent use of self-cured acrylic resin where obtained values were different from norm-established values, since this material showed greater flexural deformation. This could be related to the amount of residual monomer in self-cured acrylic resins (approximately ten times more than in thermo-cured acrylic resins. Anusavice (1996) reported the fact that polymers in a self-cured acrylic resin presented lower molecular weight (Anusavice, 1996; Craig, 1996). Large amounts of residual monomer in the polymer decrease mechanical properties.[6] To lower polymerization degree, lesser will be its resistance and rigidity.[4] Acetate 60 coated with self-curing acrylic resin exhibited values within the norm, which were higher than those shown by thermo-cured acrylic resin. That is to say, higher values of flexural deformation were attained.

Fluid acrylic resin only reached norm-acceptable values in 3,500 g deflection. At 5,000g deflection it failed to exhibit norm-established values. This could be due to the very small particle size,[10,11] coupled with the lesser 2:1 powder/liquid average used. When lower temperatures were used, the polymerization degree was limited and residual monomer amounts increased. They were deformed under a constant load and suffered lesser resistance to impact.[10]

Denture base light-cured resin did not reach norm-specified flexure values: when compared to the control group the material fractured prematurely. Andreopoulus and Dar-Odeh mentioned the fact that in the tests they conducted, this material achieved values specified in ADA's norm 12. Transverse resistance tests revealed that denture base light-cured resins exhibited greater rigidity than heat-cured, or self-cured materials. These latter exhibited lesser resistance to fracture.[12,14]

Mechanical properties have been compared among heat-cured and light-cured materials. In 1991 and 1995, lower values were reported for light-cured materials.[2,6,18] In 1993 similar values were established. Recently, in 2004, it was published that light-cured denture base material was inferior in physical properties and biocompatibility when compared to polymethacrylate resin. For this reason, light-cured resins for denture bases are not widely accepted as a material to use for permanent denture base.[18] These results justify many authors recommendations to only use this material to manufacture recording bases, as re-lining (re-basing) rigid material, for impression trays manufacture, or to repair fractured dentures[8] (Goto, 1986;[14] Andreopoulus and Polyzois, 1991;[12] Dixon; 1991).[15]

When related to our study, these results help us substantiate the fact that light-cured resin used for denture base is not recommended for final use in permanent denture.

The clinical scope of the present study resides in the importance of suitable handling of dental materials, due to their response within the oral cavity. In our present study we could infer the fact that, the greater the transverse deflection potential of a denture base material is, greater will be the possibility of the material separating from the base of the alveolar ridge during masticatory function, causing thus retention and stability loss of the prosthesis in the mouth. The aforementioned facts might contribute to greater bone loss in residual processes.[1]

Number 60 and 80 acetate sheets coated with self-curing acrylic exhibited low deflection levels which showed norm-accepted values. Therefore, this material demonstrated to be an alternative to rapid (one appointment) manufacture of denture bases, always establishing a before-handed knowledge that the material should only be used in a temporary fashion. Long-term clinical result will depend on the material used to manufacture the denture base.

CONCLUSIONS

Within the scope of this methodology we can conclude that heat-cured acrylic resin exhibited the lowest degree of deflection, and was placed within norm-established ranks.

Self-cured acrylic resin presented high deflection levels and exceeded norm-accepted limits.

Fluid acrylic resin reported at 3,500 g a deflection level close to the maximum norm-allowed limit. At 5,000 g it exhibited high deflection grade and exceeded norm-established limits.

Deflection of light-cured resin used for denture base could not be estimated, since the material fractured as a result of its greater rigidity, and therefore, could not fulfill norm-established parameters.

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