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ORIGINAL RESEARCH

A Comparative Evaluation of Flexural Strength of Commercially Available Acrylic and Modified Polymethylmethacrylate: An *in vitro* Study

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ABSTRACT

Aim: The purpose of this study was to evaluate and compare the flexural strength of commercially available acrylic (trevalone) and modified polymethylmethacrylate (PMMA).

Materials and methods: Four groups were tested; Group 1—control group regular MMA, group 2—2% methacrylic acid, 88% MMA, group 3—16% methacrylic acid, 84% MMA group 4—20% methacrylic acid, 80% MMA 15 resin specimens of each group were polymerized. After processing, the specimens were subjected for flexural strength testing using three point bending test in a Universal Testing Machine. All data was statistically analyzed with one-way ANOVA, differences within the groups were analyzed by Scheffe's analysis.

Results: As the ratio of incorporated methacrylic acid to PMMA increased, the flexural strength decreased. Analysis of data revealed a significant decrease in flexural strength of specimens ($p < 0.000$) after incorporation of 12%, 16%, 20% methacrylic acid to heat polymerized acrylic resin, when compared with the control group. Lowest flexural strength was observed with specimens containing 20% methacrylic acid and highest flexural strength was observed with specimens containing conventional monomer without methacrylic acid.

Conclusion: It was observed that as the concentration of methacrylic acid in heat polymerized acrylic resin increases, the flexural strength decreases. Lowest flexural strength was observed with specimens containing 20% methacrylic acid and highest flexural strength was observed with specimens containing conventional monomer without methacrylic acid.

Clinical significance: The major advantages of addition of methacrylic acid to polymethylmethacrylate could be for the elderly people with restricted manual dexterity or cognitive disturbances, especially for patients who do not follow an adequate denture cleansing protocol and diabetic patients who are more susceptible for denture stomatitis.

Keywords: Polymethylmethacrylate, Methacrylic acid, Flexural strength.

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INTRODUCTION

Synthetic acrylic resin have a long, clinically proven history of use for dentures since they exhibit adequate physical, mechanical and esthetic properties. But, they are susceptible to microbial adhesion, leading to denture stomatitis.[1] Denture stomatitis is frequent among denture wearers and varies widely, reported prevalence range from 10 to 75%.[2]

Surface characteristics resulting from chemistry are significant in the initial adherence of the *Candida albicans* to the denture.[3,4]

Physical and mechanical properties of polymers are crucial in achieving clinical success and longevity of complete dentures fabricated. Important physical properties include the following: Compressive and tensile strengths, hardness, thermal characteristics, polymerization shrinkage; solubility and dimensional accuracy.[5]

The flexural failure of denture base materials is considered the primary mode of clinical failure. Smith has suggested that repeated flexing from chewing ultimately fatigues many dentures in the mouth.[6] However, there is sparse literature regarding the flexural strength after incorporating methacrylic acid in PMMA denture base resins.

Physical strength of these PMMA resins modified with methacrylic acid must be investigated in order to be accepted for daily clinical use.[3]

Hence, the purpose of this study is to evaluate and compare the flexural strength of commercially available acrylic (Trevalon) and mPMMA.

MATERIALS AND METHODS

A total number of 60 specimens were fabricated. The specimens were divided into four experimental groups, consisting 15 specimens in each group. The groups were as follows:

Group 1: Control group pure methylmethacrylate (MMA)
Group 2: 12% methacrylic acid: 88% MMA
Group 3: 16% methacrylic acid: 84% MMA
Group 4: 20% methacrylic acid: 80% MMA

The specimens were fabricated according to ADA specification no. 12 (measuring 65 × 10 × 2.5 mm), using chemicals as indicated in Table 1. Resins were mixed according to the manufacturer recommended polymer and monomer ratio (3:1 by volume). Polymerization of the specimens was carried out using a standard processing cycle. The specimens were rinsed and stored in sterile distilled water for 24 hours before use.

Table 1: Materials used, trade name and manufacturer

Material	*Trade name*	*Material type*
Denture base resin	Trevalon	Heat cure denture base polymer and monomer
Methacrylic acid	Rolex laboratory reagent	Liquid

Mechanical Testing

Utilizing a 3-point flexural test, the samples were mounted in a calibrated Instron Universal Testing Machine (Instron Corp., Canton, MA (Fig. 1). The peak load (fracture load) was recorded in chart recorder.

The peak load is converted to flexural strength by the formula:

$S = 3PL/2bd^2$
S = Flexural strength (N/mm^2)
P = Load at fracture
L = Distance between jig supports
b = Specimen width
d = Specimen thickness

Fig.1: Flexural strength testing using Universal Testing Machine

Statistical Analysis

The mean, median and mode were calculated for each experimental group. Distribution curves were analyzed for normality and one-way analysis of variance (ANOVA) and Scheffe post hoc test were used to compare means between groups.

RESULTS

A representation of the difference in mean flexural strength is shown in Table 2. The 12% mPMMA group showed the highest mean flexural strength required. A comparison of mean flexural strength revealed significant difference between the control and the 12% methacrylic group. One-way ANOVA analysis demonstrated a highly significant difference ($p < 0.0001$) between the control and the test groups (Table 3).

Table 2: Descriptive statistics

Groups	*A*	*B*	*C*	*D*
Mean	103.8000	90.1000	85.7000	81.4000
Std.deviation	1.15416	1.18040	1.26582	1.32492

Group A: Control group; Group B: 12% methacrylic acid; Group C: 16% methacrylic acid; Group D: 20% methacrylic acid

Table 3: One-way ANOVA—Group

	Df	*F*	*Sig.*
Between groups	3	578.392	0.000
Within groups	54		
Total	57		

The graph (Fig. 2) depicts mean flexural strength values of all the four groups. The highest flexural strength value is seen with group A and the lowest flexural strength value is seen with group D. The flexural strength value significantly decreases as the concentration of methacrylic acid increase.

As the ratio of methacrylic acid MMA increased, the flexural strength decreased. The 20% mPMMA group showed a decrease in flexural strength that was statistically significant compared to the 12% mPMMA group ($p < 0.0001$). All values were well above the minimum value 65 MPa set forth by the ADA specification no.12.

DISCUSSION

Acrylic resins is the most widely used denture base material because of its superior esthetics, favorable working characteristics, processing ease, accurate fit, stability in the oral environment and use with inexpensive equipment. But

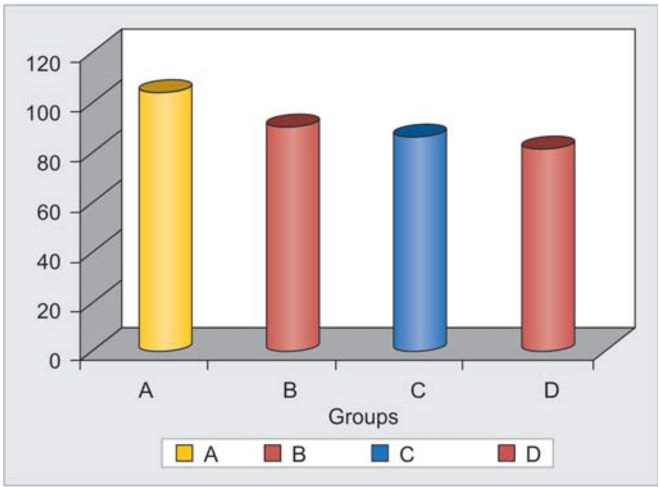

Fig. 2: The mean flexural strength values of all groups

one of the disadvantages of acrylic resin is that, the tissue surface of denture base is susceptible to adherence of *Candida albicans* and, hence, serves as an effective reservoir of microorganisms.[7]

Chemical disinfectants as chlorine dioxide, sodium hypochlorite, 4% chlorhexidine and glutaraldehyde are a recommended method to sanitise the prosthesis. However, chemical disinfection may present disadvantages like denture staining and brownish discoloration of the teeth and even the acrylic denture base.[8]

Studies have shown that antifungal drug resistance hinders the successful clinical treatment of candidiasis in denture wearers. Therefore, it is prudent to evaluate alternative materials which may hinder Candida adherence.[9]

Fungal cells are enclosed by cell walls, forms first barrier in direct contact with the biomaterial surfaces. Cell wall provide mechanical and chemical protection. The basic constituents of fungal cell walls are β-l, 3-glucans, β-1, 6-glucans, chitin and mannoproteins. β-glucans account for 50 to 60% of the cell wall by weight; mannoproteins, 40%. These cell wall constituents form a layered structure with mannoproteins mainly on the outside and the glucan layers on the inside.

Therefore, we can speculate that mannoproteins are responsible for the initial interaction with the polymeric surfaces owing to their position.[4] Phosphorylation of mannosyl side chains contributes to its anionic surface charge in yeasts. It has been demonstrated that outer chain mannosylation is correlated with cell surface hydrophobicity.

Candidal adherence to denture base resin can be attributed to the substantial difference in the protein composition of the acquired enamel pellicle in comparison to denture pellicle. The acquired enamel pellicle contains antimicrobial peptides like histatins along with other constituents, such as IgA, amylase, salivary statherins and mucins. In contrast, the denture pellicle lacks salivary statherins and histatin. The absence of these important salivary defence molecules on the denture base has been attributed to the lack of anionic charge in polymethyl methacrylate (PMMA) polymers. Thus, this lack of surface charge may be responsible for the decreased protective function of the acquired pellicle on the denture.[9]

The addition of methacrylic acid made the new polymer (mPMMA) more hydrophilic and showed a significant correlation between the amount of methacrylic acid in the polymer and decrease in adhesion of *C. albicans*.[4] These positive findings made the new surface-modified denture resins attractive for future dental applications.

Although these methods have been effective in reducing the adhesion of *C. albicans* to the acrylic surfaces, there are concerns regarding the physical properties of these modified polymers. Fractures may occur in use because of its unsatisfactory transverse strength, impact strength or fatigue resistance.[10]

Zappini et al noted that flexural strength is important because it reflects the rigidity of material. For this reason, flexural bend test was selected as it was the most relevant to clinical conditions of the masticatory load to evaluate the strength of acrylic resins.[11]

The ability of *Candida albicans* to adhere to polymeric surface has been correlated with attractive hydrophobic and repulsive electrostatic forces.[4]

Studies show that negatively charged denture base materials can prevent adhesion of *C. albicans* and reduce the development of denture-induced stomatitis due to electrostatic interactions.[4]

Thus, there exists a repulsive electric force between the negative charge of the mPMMA from the carboxylate groups and the charges or hydrophobic nature of the cell wall of *C. albicans* due to the mannoproteins.

In the present study, prepolymerizing or mixing two different types of monomers, methacrylate and methacrylic acid produced a copolymer. Methacrylic acid is a small molecule with a free carboxyl group providing a negative charge at physiologic pH. Stearic interactions can be postulated as the free carboxyl group altering the spatial structure of the new polymer, thereby affecting its physical properties. By creating an ionic molecule, stearic hindrance probably causes repelling forces within the resin material. The influence of these internal forces becomes apparent, when a material is subjected to physical testing.

A statistically significant decrease of flexural strength in comparison to the control groups was observed as increasing the methacrylic acid content of the resin samples, which probably resulted from an increase in internal repulsive forces which is consistent with the findings of previous investigations.

However, it is important to realise that the flexural strength values obtained for the samples comply with the minimum value (65 MPa) set forth by the ADA specification no.12 and it may have no clinical relevance.[12]

The present study has its limitations because it was done under laboratory conditions. The specimens prepared in this study were not of denture base configuration.

Further modifications may be needed for the modified resins to improve its physical properties while still exhibiting its beneficial antifungal characteristics. A range of methods have been reported for improving the strength of resins through chemical modification of PMMA and through incorporation of fibers, such as carbon, glass, aramid and polyethylene.[7,13,14]

CONCLUSION

The mechanical tests suggest that incorporation of methacrylic acid decreases the flexural strength of heat polymerized acrylic resins. Nevertheless, the addition of methacrylic acid to polymethylmethacrylate may be effective against microorganisms and, therefore, its impact on mechanical properties may be less significant than the potential benefits.

CLINICAL SIGNIFICANCE

The major advantages of addition of methacrylic acid to polymethylmethacrylate could be for the elderly people with restricted manual dexterity or cognitive disturbances, especially for patients who do not follow an adequate denture cleansing protocol, and diabetic patients who are more susceptible for denture stomatitis.

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