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Effect of Copolymerizing Antimicrobial Monomers on Mechanical Properties of PMMA Heat Cure Denture Base Resin

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To investigate the mechanical properties such as flexural strength (FS), and impact strength (IS) of conventional PMMA heat cure resin modified by copolymerizing it with different concentrations of DHMAI and DDMAI antimicrobial monomers. Two different quaternary ammonium-based copolymerizing antimicrobial monomers such as DHMAI (1, 2, or 5 μg/mL) and DDMAI (5, 10, or 20 μg/mL) were incorporated into PMMA resin, and its mechanical properties were evaluated. To determine the flexural strength (FS) specimens were subjected to a three-point bending test in a universal testing machine (UTM) and impact strength (IS) was assessed using an Izod-type impact testing machine. Data analysis was carried out using one-way ANOVA and Tukey's post-hoc test at a significance level of 95%. Addition of DHMAI (5 μg/mL), and DDMAI (20 μg/mL) to PMMA material significantly increased FS. However, no significant differences were observed for DHMAI (1, 2 μg/mL) and DDMAI (5, 10 μg/mL) concentrations compared to the control group. Whereas, copolymerization of DHMAI at 5 μg/mL and DDMAI at 20 μg/mL has increased the IS significantly ($p<0.001$). Copolymerization of antifungal monomers with PMMA resin improved FS. These antifungal monomers can be incorporated into PMMA denture base resin without significantly affecting the mechanical characteristics.

Introduction

In dentistry, Polymethyl methacrylate (PMMA) heat cure denture base material is extensively used for fabricating complete dentures and removable partial dentures [1]. Despite its widespread use, attempts are being made to impart antimicrobial activity to the material to inhibit microbial colonization on denture base surfaces. *Candida albicans*, *Streptococcus mutans*, and *Staphylococcus aureus,* in particular, can colonize to form biofilms on the denture prosthesis leading to denture stomatitis (DS) [2]. High prevalence of DS in complete denture wearers may lead to serious health complications, especially in elderly and immunocompromised patients [3].

To address this in concern, various antifungal additives have been incorporated into PMMA denture base materials [4]. Such modifications showed antifungal activity for only a limited period of time as some of the antifungal additives leached out or adversely affected the mechanical properties of the denture base materials [5,6]. Recently, novel monomers with antimicrobial characteristics are being copolymerized with PMMA resin for imparting antifungal activity. As these monomers are copolymerized with PMMA resin, they do not leach out and hence show long-term antifungal efficacy [7,8].

Compounds based on quaternary ammonium salt (QAM) exhibit broad-spectrum antimicrobial activity and are widely investigated for dental applications [9]. In this regard quaternary ammonium dimethyl-hexadecyl-methacryloxyethyl-ammonium iodide (DHMAI) and 2-dimethyl-2-dodecyl-1-methacryloxyethyl ammonium iodine (DDMAI) have beensynthesized through a Menschutkin reaction [10] and were added to dental restorative resins previously [11,12]. Such modifications imparted antimicrobial activity and improved mechanical properties of restorative resins. However, the effect of the incorporation of such monomers into denture base resins has not been investigated.

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It was observed that quaternary ammonium salts (QAM) with increasing alkyl chain lengths, from 5 to 16, exhibit superior antimicrobial activity. DHMAI contains a C16 alkyl chain and DDMAI has a chain length of C12. Their antimicrobial activity is attributed to the positive charge which enables them to react with the negatively charged cell membrane of microbes leading to cell death [10].

The increasing population of elderly around the globe and the need for complete denture prostheses, demands better denture base materials to reduce the incidence of denture stomatitis. Further, any modifications to impart antimicrobial activity should not affect the mechanical characteristics of denture base materials. In general, acrylic denture fractures during service due to low impact and flexural strengths [13]. In this regard, the present study aims to investigate the effect of incorporating antimicrobial monomers on the mechanical characteristics such as flexural strength (FS), and impact strength (IS) of conventional heat cure denture base materials. The null hypothesis tested is that copolymerization of PMMA resins with antimicrobial monomers will not significantly affect its flexural strength (FS), and impact strength (IS).

Materials and Methods

Specimen preparation

DHMAI (1, 2, or 5 μg/mL) or DDMAI (5, 10, or 20 μg/mL) were added to the monomer of conventional heat-activated PMMA denture base resin and then mixed with PMMA powder at a powder liquid ratio of 2.5:1. Specimens of heat cure PMMA with or without these monomers were prepared using the compression molding technique [14]. Prepared samples were stored in distilled water at 37ºC for 48hrs before the measurement of flexural strength and impact strength.

Flexural strength (FS)

Acrylic specimens of 65 × 10 x 2.5 mm dimensions were prepared according to ISO 20795-1: 2013. Flexural strength was measured using a three-point bending test using a universal testing machine with a 50 kg load cell. The specimens were stressed at a loading rate of 5mm/min until fracture. Flexural strength, in MPa, was calculated using the formula:

$$\text{Flexural strength} = 3PL/2bd^2$$

P is the maximum load, L is the span length (50 mm), b and d are the width and thickness of the specimen, respectively [15].

Impact strength (IS)

Specimens of 64 x 12 x 3.2 mm were prepared and mounted vertically onto an Izod-type impact testing machine [16]. Samples were hit by a swinging pendulum at a velocity of 3.4 m/s and the energy required to fracture the specimens, in joules, was used to calculate the impact strength using the following formula,

$$\text{Impact strength} = EC(Kg.mm)/h.Ba$$

EC is the energy absorbed by the test specimen and Ba is the thickness at the notch tip, and "h" is the specimen width [17].

Statistical analysis

Data were analysed using a one-way analysis of variance (ANOVA) at a confidence interval of 95%, and significant differences were compared using the Tukey's post-hoc test.

Results

The flexural strength of PMMA denture base resins with and without the addition of antimicrobial monomers is presented in figure 1. PMMA denture base resin without any copolymerized antimicrobial monomers showed flexural strength of 97.40 ± 16.56 MPa. The addition of DHMAI at 5μg/mL concentration increased the flexural strength significantly to 122.86 ± 19.09 MPa (p=0.019). Similarly, the addition of DDMAI of 20 μg/mL also increased flexural strength significantly to 107.12 ± 20.77 MPa ($p<0.001$). No significant difference in flexural strength was observed with other concentrations of the monomers used in the present study.

The impact strength of PMMA denture base resin with or without antimicrobial monomers is presented in figure 2. Impact strength of control PMMA denture base resin was found to be 0.399 ± 0.077 MPa.

Discussion

Conventional PMMA based denture base materials do not exhibit antimicrobial activity, which may lead to colonization of *Candida albicans* on its surface resulting in denture stomatitis. Although their mechanical characteristics are satisfactory for most clinical situations, fracture of the dentures due to flexural failure or impact failure is common [18]. The present study investigated the effect of incorporating antimicrobial monomers on the mechanical characteristics of conventional heat cure denture base materials.

The results of the present study indicate that an increase in flexural

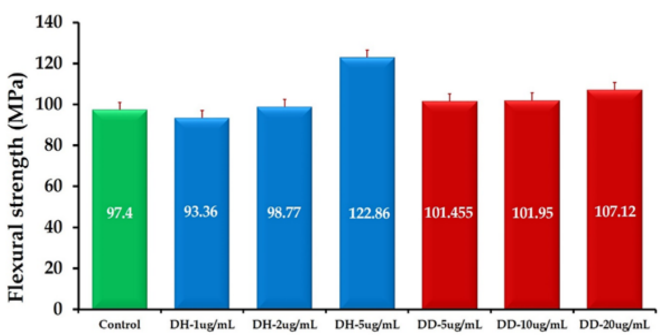

Figure 1: Flexural strength of PMMA denture base material incorporated with antimicrobial monomers

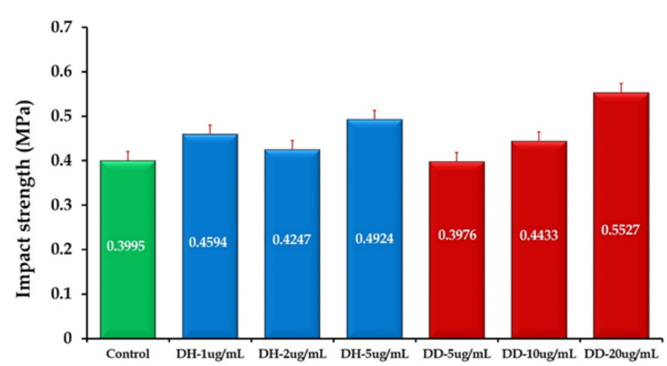

Figure 2: Impact Strength of PMMA denture base material incorporated with antimicrobial monomers

strength of conventional denture base materials with the addition of antimicrobial monomers. This could be due to the copolymerization of added antimicrobial monomers and PMMA polymer chains leading to the formation of a cross-linked network [19]. The copolymerization of added monomers also minimizes its leaching out from the polymeric matrix, thus enabling long-lasting antimicrobial activity [10].

Conclusion

The results of the present study indicate that copolymerization of PMMA heat- activated denture base resins with 5μg/mL of DHMAI and 20 μg/mL of DDMAI monomer can be considered to impart antifungal activity without significantly reducing the mechanical characteristics of dentures. Further studies are needed to investigate the effect of these monomers on the biocompatibility, antimicrobial activity, and physical properties of PMMA denture base materials.

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