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Original article

Pressure transmission area and maximum pressure transmission of different thermoplastic resin denture base materials under impact load

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ABSTRACT

Purposes: The purposes of the present study were to examine the pressure transmission area and maximum pressure transmission of thermoplastic resin denture base materials under an impact load, and to evaluate the modulus of elasticity and nanohardness of thermoplastic resin denture base.
Methods: Three injection-molded thermoplastic resin denture base materials [polycarbonate (Basis PC), ethylene propylene (Duraflex), and polyamide (Valplast)] and one conventional heat-polymerized acrylic resin (PMMA, SR Triplex Hot) denture base, all with a mandibular first molar acrylic resin denture tooth set in were evaluated (n = 6). Pressure transmission area and maximum pressure transmission of the specimens under an impact load were observed by using pressure-sensitive sheets. The modulus of elasticity and nanohardness of each denture base (n = 10) were measured on $15 \times 15 \times 15 \times 3\,mm^3$ specimen by using an ultramicroindentation system. The pressure transmission area, modulus of elasticity, and nanohardness data were statistically analyzed with 1-way ANOVA, followed by Tamhane or Tukey HSD post hoc test ($\alpha = .05$). The maximum pressure transmission data were statistically analyzed with Kruskal–Wallis H test, followed by Mann–Whitney U test ($\alpha = .05$).
Results: Polymethyl methacrylate showed significantly larger pressure transmission area and higher maximum pressure transmission than the other groups ($P < .001$). Significant differences were found in modulus of elasticity and nanohardness among the four types of denture bases ($P < .001$).
Conclusions: Pressure transmission area and maximum pressure transmission varied among the thermoplastic resin denture base materials. Differences in the modulus of elasticity and nanohardness of each type of denture base were demonstrated.

1. Introduction

The removable prosthesis is indicated to restore oral and masticatory function which leads to the improvement in the quality of life in edentulous patient [1]. The rate of being fully edentulous in several countries has declined but the reduction number expected from the anticipation will be offset by the increasing in adult population over than 55 years [2]. One of the significant aging problems found in most edentulous patients is residual ridge resorption, which contributes to the reduction in the height of alveolar bone and the size of the denture bearing area [3].

Residual ridge resorption is an irreversible, chronic, and progressive process that is observed in all edentulous patients [3]. The amount of bone resorption is subjected to interindividual and intraindividual variability. Prosthetic, metabolic, anatomic, and function are the possible factors responsible to the bone resorption [3,4]. Studies indicated that bone resorption increased when the high pressure was applied [5,6]. A 3.4 and 4.9 KPa continuous mechanical pressures exerted on molar region of hard palate via removable denture base was reported causing bone resorption in Wistar strain rats [5]. Moreover, it was also demonstrated that continuous compressive pressure ≥ 6.86 KPa or an intermittent compressive pressure ≥ 19.6 KPa caused the significant bone resorption in the same animal model [6]. Reducing the amount of force transferred to the residual ridges is considered as one of the goals in dental prosthesis fabrication. Appropriate denture tooth materials and cuspal angulation were demonstrated

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in reducing pressure and avoiding stress concentration to the residual ridges [7,8].

Polymethyl methacrylate (PMMA) is commonly used as denture base in removable prosthesis. It has higher flexural strength, modulus of elasticity, and impact strength compared to thermoplastic resin denture base [9]. However, allergic reaction, tissue irritation and hypersensitivity in some patients are still the remaining problems resulted from the residual monomer [10]. The development of polyamide, a thermoplastic resin denture base material in the 1950s, paved the way for non-metal clasp dentures (NMCDs) [11]. Despite its favorable esthetic outcome and higher flexibility than PMMA, polyamide provides inadequate bonding to auto polymerizing resin [12], poor flexural strength after water sorption [13], and high deformation under loading test [14]. Another injection-molded thermoplastic resin such as polycarbonate is also used for the NMCDs. It has been demonstrated that polyamide and polycarbonate have low flexural strength and modulus of elasticity, but they demonstrated great toughness and strong resistance to fracture in comparison to PMMA [15,16]. Duraflex, a trademark of ethylene propylene copolymer manufactured by The Myerson Company Limited, is also a thermoplastic resin denture base material, which is advocated for the NMCDs. Ethylene propylene copolymer has a good aging resistance, while high ethylene propylene content generates poor mechanical and elastic properties [17].

Previous studies have recorded the amount of pressure transmission and distribution under PMMA denture bases [7,8,18]. A pressure-sensitive sheet has been used as a pressure-detecting device for measuring occlusal pressure, occlusal force, and occlusal contact areas [7,8,19]. When pressure is applied on the film, different shades of red color develop which correlate to the amount of pressure. However, the pressure transmission and distribution under thermoplastic resin denture base has not yet been examined, which may be correlated to the residual ridge resorption.

The modulus of elasticity and nanohardness of denture base materials may be the factors that affect the pressure transmission and distribution. Denture base with a lower modulus of elasticity may flex and absorb the impact energy from the impact force [8]. Hardness can predict the wear resistance of a material and its ability to abrade the opposing structure [20]. Most of thermoplastic resin denture base showed low modulus of elasticity and nanohardness [9,15,21–23]. It was found that thermoplastic resin with low modulus of elasticity and nanohardness was easily worn under the wear scratch test when compared with PMMA [21].

Recent review articles on clinical application of removable partial denture using thermoplastic resin suggested that according to prosthetic principles, NMCDs is not suitable as a definitive denture except for patient with a metal allergy [24]. Furthermore, future studies and a clinical guideline are recommended [25].

The purposes of the present study were to examine the pressure transmission area and maximum pressure transmission of different thermoplastic resin denture base materials under an impact load, and to evaluate the modulus of elasticity and nanohardness of thermoplastic resin denture bases. The null hypotheses were that there would be no differences in pressure transmission area, maximum pressure transmission, modulus of elasticity and nanohardness among the thermoplastic resin denture base materials.

2. Materials and methods

Three injection-molded thermoplastic resin denture base materials [polycarbonate (Basis PC), ethylene propylene (Duraflex), polyamide (Valplast)], and a conventional heat-polymerized acrylic resin denture base material (PMMA, SR Triplex Hot) as a control group were evaluated in the present study. The chemical structures of the materials are shown in Fig. 1. Denture base specimens ($15 \times 15 \times 3\,mm^3$) were prepared for each material (n = 6) by using a putty-type silicone impression material (Silagum-Putty, DMG, Hamburg, Germany) as a mold. Melted wax was poured into the mold, a 30° cusp angle mandibular first molar acrylic denture tooth (FX Posterior M30, Yamahachi Dental Mfg., Co., Aichi, Japan) was attached to the wax by using a surveyor (Ney Surveyor Parallometer System, Dentsply Ceramco, PA, USA) to ensure that the occlusal surface of the denture tooth was parallel to the base of the specimen. A tunnel of 0.8-mm diameter was created between mesial and distal surfaces of denture tooth as a mechanical undercut. Injection molding flasks were used to fabricate thermoplastic resin specimens. Wax replica of specimen with attached denture tooth were invested into the flasks, boiled out, and placed into the injection molding machine. The cartridge containing thermoplastic material was heated up according to the instructed temperature and time as shown in Table 1. Then, the material within the cartridge was injected into the flask and allowed to bench cool. The conventional compression molding technique was employed to prepare PMMA specimens

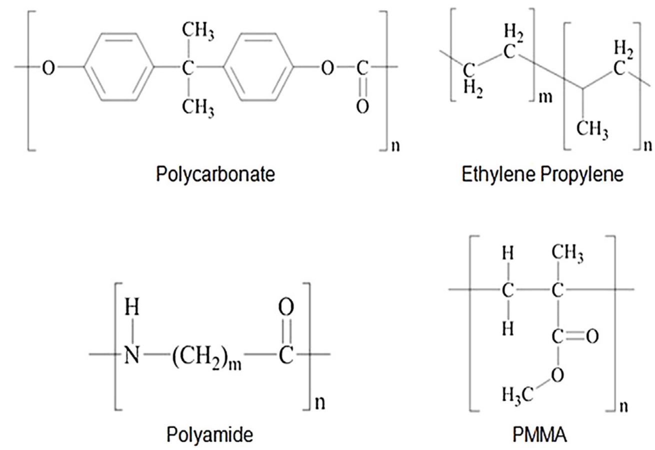

Fig. 1. Chemical formula of thermoplastic resin materials used in the study (n and m are the degree of polymerization).

After completion of the polymerization, the specimens were removed from the denture flasks, and any flash was removed with a carbide bur (CX251, Jota, Rüthi, Switzerland). The basal surfaces of the specimens were polished by using an automatic polishing machine (Nano 2000, Pace Technologies, AZ, USA) at 100 rpm and constant water irrigation with abrasive paper grit number 800, 1000, and 1200. Final polishing was performed with 0.05-μm-particle-sized alumina powder slurry (Alpha alumina powder, Leco Corp, MI, USA). The overall denture base area calculated from the base of the specimen was $225\,mm^2$ ($15 \times 15\,mm$). The specimens were stored in 37 °C deionized water for 24 h before testing. The schematic drawing of the specimen is shown in Fig. 2.

The impact drop test used in the present study was modified from the previous study [8]. Pressure transmission area and maximum pressure transmission were recorded by using two types of pressure-sensitive sheets (Prescale Film, LLLW and LLW, Fuji Photo Film Co., Ltd., Tokyo, Japan). The reliable measuring of pressure by LLLW is between 0.2–0.6 MPa and LLW is between 0.5–2.5 MPa. The LLLW sheets were used for the initial pressure measurement for each specimen. When the maximum pressure was found to be over the LLLW sheet measuring ranges, the LLW sheet was then used. This is due to the limitation of pressure-sensitive sheets sensor system.In the impact drop test procedures, a pressure-sensitive sheet was placed beneath the denture base