Pressure absorbability between polymethyl-methacrylate and thermoplastic nylon denture base materials

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Abstract

The purpose of this present study was to evaluate the pressure absorbability between polymethyl-methacrylate (PMMA) and thermoplastic nylon denture base materials. Mandibular first molar acrylic denture tooth (Bioeco) embedded on 15x15x3 mm3 thermoplastic nylon (TCS and Biotone) and PMMA (Huge) denture base materials were evaluated (n=6). A 100N force was applied on the specimen using universal testing machine and the pressure absorbed by the specimen was observed using pressure transducer. Both data were statistically analysed using 1-way ANOVA followed by Tukey HSD post-hoc test (P<.05). The results showed that the pressure absorbability of PMMA, TCS and Biotone were significantly different (P<.001). PMMA has the lowest pressure absorbability compared to thermoplastic nylon denture base materials.

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Introduction

Polymethyl-methacrylate denture base material is a thermoset polymer which contains cross-linking agent and irreversible upon heating and widely used in fabrication of a denture.[1,2,3] The cross-linking agent could increase the modulus of elasticity of a material.[4] The advantages of PMMA are color stable, low of water absorption, easy to be manipulated and repaired, esthetic, and economical price.[5,6,7] While the disadvantages are irreversible material and cannot be reshaped and recycled, less flexible, and can cause allergic for some patients that intolerant with resin.[5,6,7] To overcome the disadvantages of PMMA, thermoplastic nylon denture base material was introduced as an alternative which have some advantages over PMMA.[7]

Thermoplastic nylon is a polymer derivate which produced by condensation reactions of diamine and dibasic acid.[8] It has almost no porosity, strong structural characteristics, and heat resistance.[6,9,10,11,12] The main advantage of this material is the resistance to repetitive pressure which attributed to its flexural strength, impact strength, and modulus of elasticity.[6,7] Other advantages of thermoplastic nylon are not easily broken, light, not shrink or become brittle, does not cause allergies, better in aesthetic, and high elasticity.[13,14,15] However, it is more difficult to be polished, increase surface roughness after use in a short time, high water absorption, color change, difficult and expensive in manufacturing process.[16,17]

One of the properties to be considered in the denture base material pressure absorbability is modulus of elasticity.[18,19] Modulus of elasticity is a measure of relative rigidity on a material to its elastic limit which describe the material ability to receive pressure without breaking.[19,20] PMMA has the highest modulus of elasticity around 3000 MPa, while polyester was 2000 MPa, and thermoplastic nylon was only 1000 MPa.[21]

One of the functions of a denture base is to absorb masticatory pressure and distribute pressure to the alveolar ridge.[22] Matsuo et al., suggested that a pressure of 27 to 68 g/cm^2 caused fibroblasts to increase the intracellular calcium which, in turn, initiated the alveolar bone remodeling.[23] Berg et al. reported that, to keep blood circulation normal, continuous mechanical pressure higher than 1.3 kPa should not be transferred to the denture supporting tissues.[24]

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Excessive pressure that given to the alveolar ridge can cause alveolar bone resorption.[22] Alveolar bone resorption can be caused by several factors such as metabolic, functional, and denture.[25] Metabolic factors include sex, age, and hormonal.[25] While functional factors are frequency, direction, and force applied to the ridge.[25] Furthermore, denture teeth and denture base will absorb mastication force and then transmit it to the alveolar ridge.[26,27] Previous study stated that the pressure absorption of a denture teeth and denture base can be influenced by its modulus of elasticity.[28] This is thought as the contributing aspect on alveolar bone resorption on denture wearers, although there is lack of study that correlates between the pressure absorbability from a denture base material to alveolar bone resorption.[28]

The purpose of this study was to evaluate pressure absorbability between PMMA and thermoplastic nylon denture base materials. The null hypothesis was that there would be no difference on pressure absorbability between PMMA and thermoplastic nylon denture base materials.

Materials and methods

Preparation of the specimens

Two thermoplastic nylon denture base materials [BioTone (Biotone, Denken-Highdental Co. Ltd., Kyoto, Japan) and TCS (Unbreakable by TCS, TCS Dental Inc., Signal Hill, CA, USA)] and PMMA denture base material (Denture base polymers, Huge Dental Material Co. Ltd., Pudong, Shanghai, China) sized 15x15x3 mm3 (n=6) were prepared as the denture base specimens by using a putty-type silicone impression material (Flexceed vinyl polysiloxane impression material, GC India Dental Pvt. Ltd., Pashamylaram Patancheru, India) as a mold. Melted wax was poured into the mold and a mandibular first molar acrylic denture tooth (One layer Bioeco High gloss, PDS A-1, New Stetic, Antioquia, Colombia, S.A.) was attached to the melted wax guided by a surveyor (Dentsply Ney Dental Surveyor, Dentsply Sirona, Ney Dental Inc., York, PA, USA) to ensure the occlusal surface of the denture tooth parallel to the specimen base. Injection molding technique was used to fabricate thermoplastic nylon denture base specimen. Each of the specimen was invested into the flasks, boiled out and placed into the injection molding machine. The cartridge was heated up according to the manufacturer's instruction as shown in Table 1. Conventional compression molding technique was applied to prepare PMMA specimens. The schematic drawing of the specimen is shown in Figure 1. The basal specimen surface was polished using automatic polishing machine (Metaserv 3000, Buehler Ltd, Lake Bluff, IL, USA) with SiC abrasive paper grit number 500, 800, 1000, 1200 under constant water irrigation. Then, the specimens were stored in 37^{0}C deionized water for 24 hours before testing.

Material	Type	Processing method	Manufacturer
BioTone	Polyamide	Injection technique; 300^{0}C for 15 min	Denken-Highdental Co., Ltd., Kyoto, Japan
TCS	Polyamide	Injection technique; 288^{0}C for 11 min	TCS Dental Inc., Signal Hill, CA, USA
PMMA	Polymethyl methacrylate	Compression technique; 100^{0}C for 40 min	Huge Dental Material Co., Ltd., Pudong, Shanghai, China

Table 1. Denture base materials used in the present study.

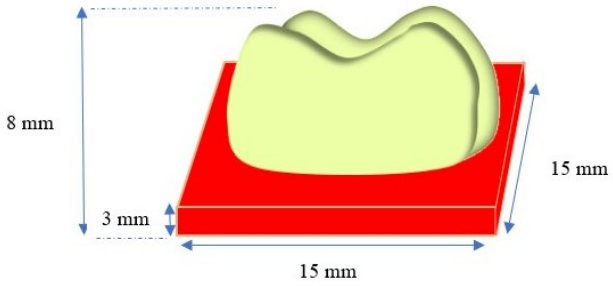

Figure 1. Schematic drawing of the specimen.

Pressure absorbability measurements

Universal testing machine (Shimadzu Universal Testing Machine EHF-EB100KN-20L, Shimadzu Co., Kyoto, Japan) and pressure transducer were used to measure the pressure absorbability of the specimens. The pressure transducer was connected and placed on the universal testing machine's table. The mandibular denture tooth specimen was placed on the pressure transducer, whereas the antagonist denture tooth specimen was attached to the indenter of the universal testing machine. A 100N force was applied to the specimen with cross-head speed of 0.05 mm/min Figure 2.

The pressure absorption percentage can be obtained by reading the pressure transmission value from the pressure transducer (aN) and the given force (100N).

Pressure absorbability = $\frac{(100\ \mathrm{N} - a\mathrm{N})}{100\mathrm{N}}\ x\ 100\%$

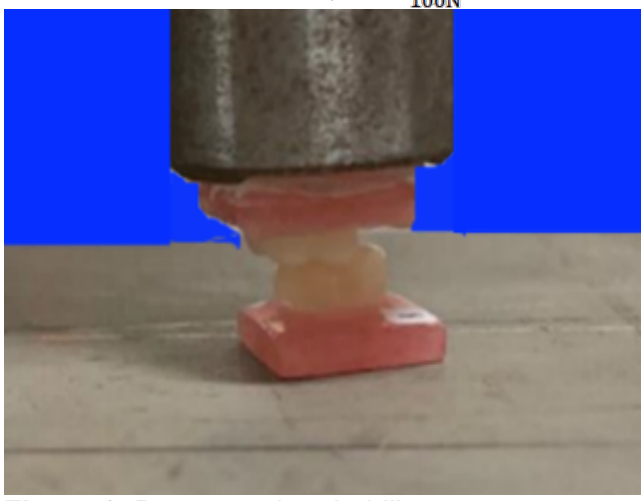

Figure 2. Pressure absorbability apparatus.

Data Analysis

Pressure absorbability data were analysed using statistic software (SPSS Statistics Version 20; IBM Corp., NY, USA) with 1-way ANOVA and followed by Tukey HSD post hoc test (*P*<.05).

Results

Polymethyl-methacrylate showed lower pressure absorbability than thermoplastic nylon denture base materials. Polymethyl-methacrylate pressure absorbability was (9.82±3.70), then followed by TCS was (22.45± 2.29) and the highest pressure absorbability was Biotone (30.87± 2.21) Figure 3 and Table 2 (*P*<.001).

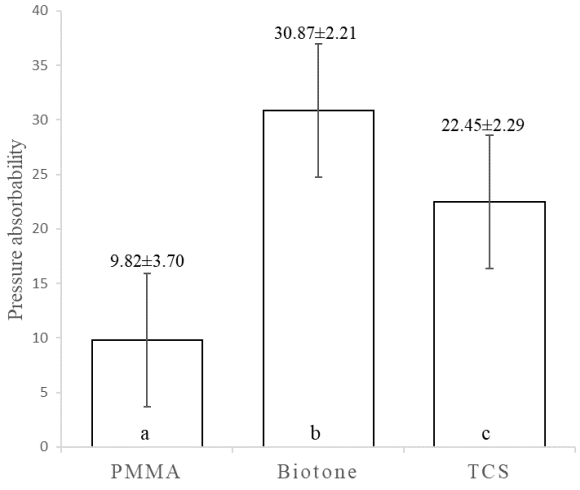

Figure 3. Mean and standard deviations of pressure absorbability (bars with different alphabets means significantly different at (*P*<.001).

Source	Sum of squares	Df	Mean square	F	*P*
Pressure absorbability					
Between groups	2020.351	2	1010.175	126.839	<.001
Within groups	191.142	24	7.964		
Total	2211.493	26			

Table 2. 1-way ANOVA for pressure absorbability.

Discussion

The present study evaluated two thermoplastic nylon denture base materials and one PMMA on its pressure absorbability property. Statistical analysis showed significant differences in pressure absorbability, therefore, the null hypotheses was rejected.

Polymethyl-methacrylate denture base material showed lower pressure absorption which was only half compared to thermoplastic nylon TCS and one third compared to thermoplastic nylon Biotone. These differences occurred due to modulus of elasticity of the denture base materials.[13] Those denture base materials have different polymer chain bond.[5] Thermoplastic nylon is a polymer with a single chain form and easily to undergo crystallization than polymers that form cross-linking chain.[5] The crystallization stages could affect its material properties such as modulus of elasticity, hardness, stiffness, and etc.[5] Thermoplastic nylon has more flexibility and absorbability properties, which caused by its low modulus of elasticity, while PMMA was more rigid due to addition of dimethacrylate as cross-linking.[13] The higher modulus of elasticity, the higher pressure will be transmitted under the denture base, so that the denture base will be more difficult to absorb pressure.[16]

The pressure absorbability value of thermoplastic nylon TCS was two third compared to thermoplastic nylon Biotone. This was attributed to thermoplastic nylon TCS and Biotone composition. Thermoplastic nylon TCS is a thermoplastic nylon 12 group that developed from the type of nylon with 99.9% of its composition containing poly laurolactam $[CO(OH_2)_{11}NH]n$ which has good resistance of thermal, fatigue, and abrasion.[6,13] Thermoplastic nylon is a crystalline polymer, where the material with high degree of crystalline will produce an atomic arrangement that is regular, strong and stiff. Thermoplastic nylon 12 (poly laurolactam) has been reported to have outstanding impact

resistant and the lowest absorbance of all the thermoplastic nylon groups.[7] Thermoplastic nylon Biotone is a microcrystalline group which is a new generation group of thermoplastic nylon that was created to cover up the deficiencies of other thermoplastic nylon groups.[13]

The denture base material which contain cross-linking agent will have outstanding mechanical properties as high modulus of elasticity, stiffness, and good abrasion resistance.[4] While thermoplastic nylon is a crystalline polymer, where the material with high degree of crystalline will produce an atomic arrangement that is regular, strong, and stiff.[8,11] Microcrystalline has more degree of crystalline than nylon 12.[8] Therefore, microcrystalline is more rigid than nylon 12.[8] Previous study showed that, modulus of elasticity in PMMA was (2508,62 ± 92,25 MPa). Modulus of elasticity in TCS was (733,58 ± 6,42 MPa). Modulus of elasticity in Biotone was (1358,55 ± 50,46 MPa).[20] Thus, it means the pressure absorption in PMMA will be lower due to high in modulus of elasticity.[16]

The result of the present study contradicted to the previous study on pressure transmission that the PMMA had the highest pressure absorbability compared to thermoplastic nylon and polyester.[21] This was due to the different specimen design on removable partial denture setting with metal rest at the anterior and posterior to the edentulous area which serve as the supporting point. Therefore, thermoplastic nylon with the lowest modulus of elasticity more flexible and resulted in more loads were applied to the mucosa under the denture base.[21]

Pressure absorbability can affect the process of alveolar bone resorption.[18] Matsuo et al., suggested that a pressure of 27 to 68 g/cm^2 caused fibroblasts to increase the intracellular calcium which, in turn, initiated the alveolar bone remodeling.[23] In the present study the maximum pressure that can be transferred to the alveolar bone was much higher than these pressure after the denture tooth and denture base material absorb the applied pressure. It was attributed to the specimen size which was only 225 mm^2, thus it had a limited area to absorb pressure. Therefore, maximum extension of denture base within anatomical and physiological limits is recommended to increase pressure absorption, the supporting area, and minimize the pressure that transmitted to the alveolar bone.[26]

Polymethyl-methacrylate is still the material of choice as denture base. However, in the patient with hypersensitivity or allergy to PMMA material, thermoplastic nylon is an alternative material. From the results of the present study, Biotone was better than TCS, but both were great in absorbing forces and would transmit lesser forces under the denture base. Clinician should be aware of the properties of the denture base material in choosing a proper denture base material for each patient. The present study was limited to in vitro evaluation which only performed vertical load and without evaluating the distribution pattern. Therefore, it is recommended to use actual occlusal force application and evaluating the distribution pattern in further in-vivo study.

Conclusions

After the testing of pressure absorbability between three type of denture base materials, the following conclusion can be drawn: Biotone was significantly higher in pressure absorbability compared to TCS and PMMA denture base (P<.001).

References

1. Khanna G, Aparna IN. Comparison of microhardness of three different types of acrylic artificial denture teeth: in vitro study. J Orofac Res 2013; 3(3):181-5.
2. Khindria SK, Mittal S, Sukhija U. Evolution of denture base materials. JIPS 2009; 2(2):64-8.
3. O'brien WJ. Dental material and their selection. 3rd ed. Michigan: Quintessence Books; 2002:142.
4. Albeladi HK, Al-Romaizan AN, Hussein MA. Role of cross-linking process on the performance of PMMA. Int J Biosen Bioelectron 2017; 3:279-84.
5. Anusavice KJ, Shen C, Rawls HR. Philips science of dental materials. 12th ed. India: Elsevier; 2012:99-100.
6. Kohli S, Bhatia S. Polyamide in dentistry. IJSS 2013; 1(1):20-5.
7. O'Connor HJ, Dowling DP. Comparison between the properties of polyamide 12 and glass bead filled polyamide 12 using the multi jet fusion printing process. Addit Manuf 2020; 31:1-8.
8. Sari W, Fardaniah S, Masulili C. Color changing in denture base polyamide 12 and polyamide microcrystalline after polishing in laboratory and dental clinic. J Phys 2017; 884:1-6.
9. Nandal S, Ghalaut P, Shekhawat H, et al. New era in denture base resins: A review. DJAS 2013; 1(3):136-43.
10. Fueki K, Ohkubo C, Yatabe M, et al. Clinical application of removable partial dentures using thermoplastic resin – Part I: Definition and indication of non-metal clasp dentures. J Prosthodont Res 2014; 58:3-10.
11. Vojdani M, Giti R. Polyamide as a denture base material: A literature review. J Dent 2015; 16(1):1-9.
12. Utami M, Febrida R, Djustiana N. The Comparison of Surface Hardness Between Thermoplastic Nylon Resin and Heat-Cured Acrylic Resin. Padjadjaran J Dent 2009; 21(3):200-3.
13. Fueki K, Ohkubo C, Yatabe M, et al. Clinical application of removable partial dentures using thermoplastic resin - Part II: material properties and clinical features of non-metal clasp dentures. J Prosthodont Res 2014; 58:71-84.

14. Ali AM, Raghdaa KJ. Evaluation and comparison of the effect of repeated microwave irradiation in some mechanical and physical properties of heat cure acrylic resin and valplast (nylon) denture base material. J Bagh Coll Dentistry 2011; 23(3):6-10.
15. Wieckiewicz M, Opitz V, Richter G, et al. Physical properties of polyamide-12 versus PMMA denture base material. BioMed Research Int 2014; 1-8.
16. Nasution H, Kamonkhantikul K, Arksornnukit M, et al. Pressure transmission area and maximum pressure transmission of different thermoplastic resin denture base materials under impact load. J Prosthodont Res 2018; 62(1):44-9.
17. Shah J, Bulbule N, Kulkarni S, et al. Comparative evaluation of sorption, solubility and microhardness of heat cure polymethylmethacrylate denture base resin & flexible denture base resin. JCDR 2014; 8(8):1-4.
18. Kawano F, Ohguri T, Ichikawa T, et al. Shock absorbability and hardness of commercially available denture teeth. Int J Prosthodont 2002; (15)3: 243-7.
19. Craig RG, Powers JM. Restorative dental materials. 13th ed. USA: CV Mosby Co; 2012:83-8.
20. Fitri AA, Nasution H, Andryas I, et al. The difference and correlation of modulus of elasticity and surface hardness of PMMA and thermoplastic nylon denture base materials. JIDMR 2020; 13(4):1598-603.
21. Wadachi J, Sato M, Igarashi Y. Evaluation of rigidity of dentures made of injection-molded materials. Dent Mater J 2013; 32(3):508-11.
22. Phunthikaphadr T, Takahashi H, Arksornnukit M. Pressure transmission and distribution under impact load using artificial denture teeth made of different materials. J Prosthet Dent 2009; 102(5):319-27.
23. Nakago-Matsuo C, Matsuo T, Nakago T. Intracellular calcium response to hydraulic pressure in human periodontal ligament fibroblast. Am J Orthod Dentofac Orthop 1996; 109:244-8.
24. Berg T.Jr, Chase WW, Ray K. Denture base pressure tests. J Prosthet Dent 1967; 17:540-8.
25. Atwood DA. Reduction of residual ridge: a major oral disease entity. J Prosthet Dent 1971; 26(3):266-79.
26. Arksornnukit M, Phunthikaphadr T, Takahashi H. Pressure transmission and distribution under denture bases using denture teeth with different materials and cuspal angulations. J Prosthet Dent 2011; 105(2):127-36.
27. Saavedra G, Valandro LF, Leite FP, et al. Bond strength of acrylic teeth to denture base resin after various surface conditioning methods before and after thermocycling. Int J Prosthodont 2007; 20(2):199-201.
28. Hamanaka I, Misa I, Lippo VJL, et al. Wear resistance of injection-molded thermoplastic denture base resins. Acta Biomater Odontol Scand 2016; 2:31-7.