Pressure Transmission of Thermoplastic Nylon Denture Base Using Denture Teeth with Different Cuspal Angulations

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Abstract

The purpose of this study was to evaluate the pressure transmission of thermoplastic nylon denture base using denture teeth with different cuspal angulations.

Three different cuspal angulations [non-anatomic (00), semi-anatomic (200) and anatomic (330)] of mandibular first molar acrylic denture teeth (BioEco) embedded on 15x15x3 mm3 thermoplastic nylon (TCS) as denture base were evaluated (n=10). A 100N force was applied on the specimen using universal testing machine and the pressure transmitted under the specimen was observed using pressure transducer. Data were statistically analyzed using One-way ANOVA, followed by Tukey's HSD post hoc test (P<.05).

Non-anatomic denture teeth showed significantly lower pressure transmission than anatomic and semi-anatomic denture teeth (P<.001).

Pressure transmission value under thermoplastic nylon denture base varied among different denture teeth cuspal angulations.

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Introduction

Denture can improve the ability of mastication, speaking, support the facial muscles, improve appearance, and have to be designed properly to maintain oral tissue structure.[1,2] Excessive pressure should not be transferred to the supporting tissue of dentures to maintain normal blood circulation.[2] Matsou et al suggested that a pressure of 27 to 68 g/cm^2 would cause fibroblasts to increase intercellular calcium resulting in the alveolar bone remodelling.[3] If the pressure changes the blood circulation to the alveolar ridge or causes mucoperiosteum inflammation, it can contribute to pathological bone resorption.[4]

Along with the dental materials development, thermoplastic resins are increasingly popular as denture base material.[5] Thermoplastic resins are favourable in esthetic, flexible, biocompatible and hypoallergenic properties.[6] Nylon is a type of thermoplastic resin polyamide group, derived from diamine & dibasic acid monomers.[7,8] Thermoplastic nylon is a monomer-free base material which act as an alternative for patients who are allergy to polymethyl methacrylate (PMMA).[9,10] It has lower modulus of elasticity and hardness compared to PMMA.[11,12] Nasution et al evaluated the correlation of modulus of elasticity and nanohardness to pressure transmission from thermoplastic and PMMA denture base. They reported that denture base with higher modulus of elasticity and nanohardness would transmit and distribute greater pressure.[13]

In addition, denture teeth selection need to be considered especially posterior denture teeth in order to get proper pressure distribution under denture base.[14] The posterior denture teeth selection is determined based on the ideal occlusion for the patient.[15,16] Based on cuspal angulations, the posterior denture teeth are divided into anatomic (33^0), semi-anatomic (20^0), and non-anatomic (0^0).[17] Posterior denture teeth would affect the magnitude of force that was transmitted and distributed through the denture base to the alveolar ridge.[18,19,20] Previous studies evaluated the effect of occlusal scheme on the pressure distribution of denture. They reported

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that denture teeth with less than 33^0 cuspal angulations would distribute the pressure more vertically than 33^0 denture teeth.[3,21,22] Denture teeth with flatter cuspal angulations or less than 33^0 would result in increased occlusal contact area.[23,24] Thus, it was expected to reduce the magnitude of the force transmitted to the alveolar ridge.[25]

Review articles on clinical application of removable partial denture using thermoplastic nylon suggested that according to prosthetic principles, thermoplastic nylon is not suitable as a definitive denture base except for patient with a metal allergy.[26] Therefore, further studies and clinical guidelines are recommended.[27]

The purpose of the present study was to evaluate the pressure transmission of thermoplastic nylon denture base using denture teeth with different cuspal angulations. The null hypotheses was that there would be no difference of pressure transmission of thermoplastic nylon denture base using denture teeth with different cuspal angulations.

Materials and methods

Three different cuspal angulations of mandibular first molar acrylic resin denture teeth (BioEco; New Stetic S.A, Antioqia, Colombia); non-anatomic (0^0), semi-anatomic (20^0) and anatomic (33^0) embedded on 15x15x3 mm^3 thermoplastic nylon denture base (TCS Unbreakable; TCS Dental Inc., Signal Hill, California, United States) (n=10) were evaluated. The non-anatomic denture teeth (0^0) were prepared manually by flattening the semi-anatomic acrylic resin denture teeth using abrasive paper grit number 800, 1000, and 1200 until the flat occusal surface was achieved. To standarized the occlusal surface, there was only one operator and with the same forward and backward movement. The final servico-occlusal height of the non-anatomic denture teeth was 4 mm. After the denture teeth were flattened, there were still some grooves on the occusal surface.

The acrylic resin denture teeth are listed in Table 1. The specimens were prepared by using a putty-type silicone impression materials (GC Flexceed; GC India Dental Pvt Ltd., Pashamylaram Patancheru, India) as a mold. Melted wax was poured into the mold, the denture tooth was attached to the wax by using a surveyor (Dentsply Ney Dental Surveyor; Ney Dental Inc., York, United States) to ensure that the occlusal surface of the denture tooth was parallel to the base of the specimen. Wax specimen molding is shown in Figure 1.

Type	Brand Name	Code	Manufacturer
Non-anatomic denture teeth	BioEco (modified)	PF	New Stetic S.A, Antioqia, Colombia
Semi-anatomic denture teeth	BioEco	PF	New Stetic S.A, Antioqia, Colombia
Anatomic denture teeth	BioEco	34M	New Stetic S.A, Antioqia, Colombia

Table 1. Denture teeth used in the present study

Figure 1. Wax specimen molding.

Injection molding flask was used to fabricate the specimens. The specimens were invested into the flask, boiled out, and placed into the injection molding machine. The cartridge containing thermoplastic nylon materials was heated up according to the instructed temperature (288^0C for 11 minutes). Then the material within the cartridge was injected into the flask and allowed to bench cool. The same

method was used for maxillary denture teeth as the antagonist specimen. All specimens were then removed from the denture flask and the specimen's surface were polished by using a rotary grinder (Metaserv 3000; Buehler Ltd., Illinois, United States) under constant water irrigation at 100 rpm. Abrasive paper grit number 500, 800, 1000, 1200 were used to polish the specimens. The specimens were immersed for 24 hours with distilled water at 37^0C in the incubator before testing. The schematic drawing of the specimen is shown in Figure 2.

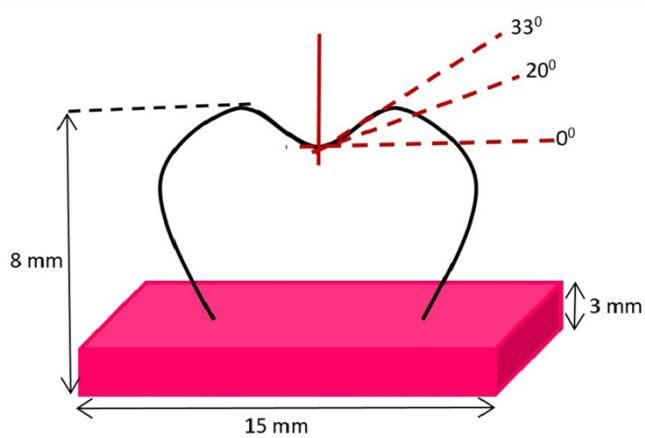

Figure 2. Schematic drawing of the specimen.

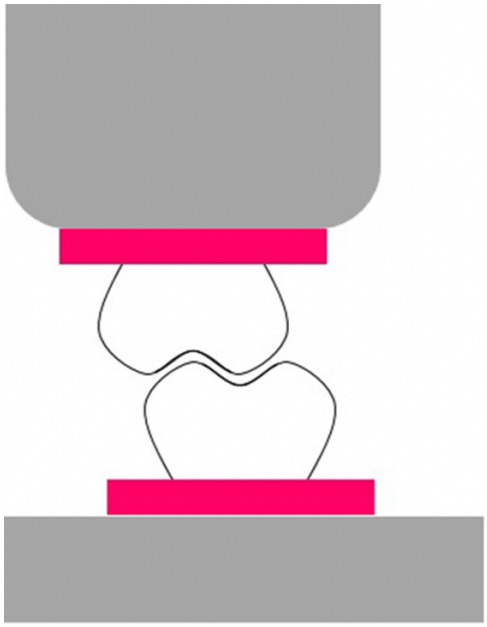

Figure 3. Schematic of pressure transmission apparatus.

Universal testing machine (EHF-EB100KN-20L; Shimadzu Co., Kyoto, Japan) and pressure transducer were used to measure the pressure transmission under the specimens. The pressure transducer was connected to the universal testing machine's table. The maxillary denture tooth specimen was placed at the indenter of the universal testing machine and the mandibular denture tooth specimen was placed at the pressure transducer following a Class I Angle occlusal relationship. A 100N vertical force with cross-head speed 0.5 mm/min was applied at the specimens and the pressure detected under the denture base was recorded. The schematic of specimen apparatus is shown in Figure 3.

Statistical software (SPSS Statistics V20; IBM Corp., New York, United States) was used for statistical analysis. Data were statistically analyzed using One-way ANOVA, followed by Tukey's HSD post hoc test (*P*<.05).

Results

Significant differences in pressure transmission under thermoplastic nylon denture base using denture teeth with different cuspal angulations was founded using One-way ANOVA test (Table 2). Tukey's HSD post hoc test was performed to determine comparison between groups. Non-anatomic denture teeth showed the lowest pressure transmission (*P*<.001). However, no statistically significant difference was found between semi-anatomic and anatomic denture teeth group (*P*=.498). Means of pressure transmission and Tukey's HSD analysis are shown in Figure 4.

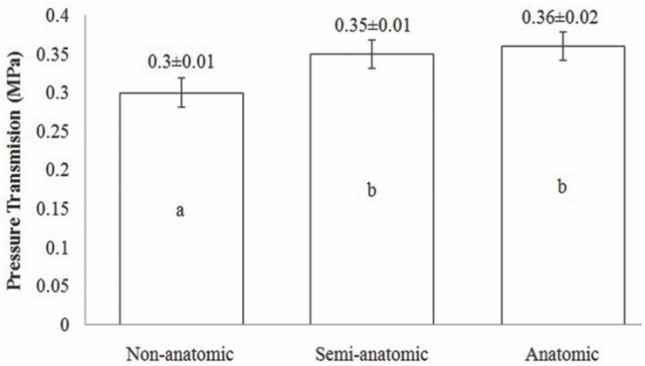

Figure 4. Means and standard deviations of pressure transmission from all cuspal angulations denture teeth groups (vertical bars show standard deviation; bars with the same letter are not significantly different between groups at P<.001).

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1150.726	2	575.363	42.451	<.001
Within Groups	365.945	27	13.554		
Total	1516.672	29			

Table 2. One-way ANOVA results.

Discussion

Pressure transmission difference occurred due to several factors such as denture base materials and denture tooth selection. The present study evaluated pressure transmission under thermoplastic nylon denture base using denture teeth with different cuspal angulations. Statistical analysis showed significant differences in pressure transmission under denture base using denture teeth with different cuspal angulations; therefore, the null hypotheses was rejected.

Various dental materials have been introduced in the market, especially thermoplastic nylon, but there is lack of study in terms of the mechanical properties. In the previous study, the TCS thermoplastic nylon have modulus of elasticity of 733.58±6.42 MPa. It indicated that TCS has low modulus of elasticity.[11] Modulus of elasticity could affect pressure transmission under denture base.[4,13,18,29] Denture material with a lower modulus of elasticity can flex and absorb the impact force, thus reduce stress on the underlying structure.[13,28] Therefore, thermoplastic nylon denture base was expected to reduce the magnitude of the force transmitted to the alveolar ridge.[13]

The difference of pressure transmission values in the present study indicated that the angulations of the cusps influenced pressure transmission value under denture base. It was caused by differences in the width of the occlusal contact area between the cuspal angulations.[14,24] Reduction in cuspal angulations caused a decrease in pressure transmission because the width of the occlusal contact area was increased.[23,24] Greater pressure transmission would affect the shape of the alveolar ridge and can cause resorption.[14]

Denture base fabrication in the present study was controlled to be the same in each specimen. The denture teeth were selected from the same manufacturer and only non-anatomic denture teeth that were manually modified. The result showed that semi-anatomic denture teeth showed no significant difference in pressure transmission compared to anatomic denture teeth. It meant that the reduction of the cuspal angulations from 33^0 to 20^0 did not cause a significant increase in the occlusal contact area, thus it led to a statistically insignificant decrease in pressure transmission. The result of the present study corresponded to the previous study.[3] Arksornnukit et al reported anatomic and semi-anatomic acrylic denture teeth had no significant difference in the maximum pressure transmission, but semi-anatomic acrylic denture teeth significantly showed smaller pressure distribution area compared to anatomic acrylic denture teeth. These results suggested that semi-anatomic denture teeth may be preferable to anatomic denture teeth.[3]

The results showed that non-anatomic denture teeth significantly the lowest pressure transmission compared to semi-anatomic and anatomic denture teeth. These meant the reduction of the cuspal angulations to 0^0 in non-anatomic denture teeth may result in a significant increase in the area of occlusal contact area.[24] It led to a decrease in pressure transmission under denture base.[23,24] Chowdhary et al suggested that using denture teeth with lower cuspal angulations might be a desirable option because it transfer less force and pressure to the supporting tissue.[25] Non-anatomic denture teeth, which provide less force and better pressure distribution, should be used in highly atrophied residual ridges.[21] Those denture teeth showed lower pressure to the buccal and lingual slopes of the residual ridge, thus it induced lower lateral forces than anatomic and semi-anatomic denture teeth.[22]

Berg et al. reported that to keep normal blood circulation, continuous mechanical pressure higher than 1.3 kPa should not be transferred to the supporting tissue of dentures.[2,4] The pressure transmission values in present study showed higher score than the above value which attributed to the size of the denture base specimen in the present study was only 225 mm^2, thus the area to absorb pressure was limited. In addition, complete denture base area in the maxilla is about 2296 mm^2, while in the mandible is about 1225 mm^2.[29] Therefore, to minimize the pressure to alveolar ridge, an extension of denture base within anatomical and

physiological limits is advised.[16]

The limitations of the present study were that pressure transmission was evaluated in vitro with vertical load and limited denture base surface area, and the test equipment used could only measure the pressure without seeing its distribution pattern. Therefore, in vivo study with actual occlusal force and surface area is recommended.

Conclusions

Within the limitations of the present study, the following conclusions were drawn. Non-anatomic denture teeth showed significantly lower pressure transmission than anatomic and semi-anatomic denture teeth. Anatomic denture teeth is still a common choice as posterior denture teeth. Semi-anatomic and non-anatomic denture teeth are alternative denture teeth in denture fabrication in certain cases.

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Declaration of Interest

The authors report no conflict of interest.

References

1. Wahjuni S, Mandanie SA. Fabrication of combined prosthesis with castable extracoronal attachments (laboratory procedure). Jour Voc HS 2017;1(2):75-81.
2. Berg T Jr, Chase WW, Ray K. Denture base pressure tests. J Prosthet Dent 1967;17(6):540-8.
3. Nakago-Matsou C, Matsou T, Nakago T. Intracellular calcium response to hydraulic pressure in human periodontal ligament fibroblasts. Am J Orthod Dentofac Orthop 1996;109(3):244-8.
4. 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.
5. Vojdani M, Giti R. Polyamide as a denture base material: a literature review. J Dent Shiraz Univ Med Sci 2015;16(1):1-9.
6. Lee HH, Lee JH, Yang TH, et al. Evaluation of the flexural mechanical properties of various thermoplastic denture base polymers. Dent Mater J 2018;37(6):950-6.
7. Kohli S, Bahtia, S. Polyamides in dentistry. IJSS 2013;1(1):20-5.
8. Nandal S, Ghalaut P, Shekhawat H, Gulati MS. New era in denture base resin: A review. DJAS 2013;1(3):136-43.
9. Sharma A, Shashidhara HS. A review: Flexible removable partial dentures. IOSR-JDMS 2014;13(12):58-62.
10. Soesetijo FA, Prijatmoko D, Hidajati L. Biocompatibility of thermoplastic nylon flexible removable partial denture – A review. Int J Curr Res Aca Rev 2016;4(10):75-83.
11. Fitri AA, Nasution H, Andryas I, Wahyuni S, Ritonga PWU, Chairunnisa R, et al. The difference and correlation of modulus of elastisity and surface hardness of PMMA and thermoplastic nylon denture base materials. J Int Dent Med Res 2020; 13(4): 1598-603.
12. Shah J, Bulbule N, Kulkarni S, Shah R, Kakade D. Comparative evaluation of sorption, solubility and micro-hardness of heat cure polymethyl methacrylate denture base resin & flexible denture base resin. J Clin Diagn Res 2014;8(8):ZF01–4.
13. Nasution H, Kamonkhantikul K, Arksornnukit M, Takahashi H. 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.
14. Winkler S. Essentials of complete denture prosthodontics. 2nd ed. United States: Ishiyaku Euro America Inc; 2000:217-52.
15. Krishna PD, Prasad BR, Bardia A, Anupama PD. Enhancing stability: A review of various occlusal schemes in complete denture prosthesis. NUJHS 2013;3(2):105-12.
16. Dawson PE. Evaluation, diagnosis, and treatment of occusal problems. 2nd ed. St. Luois: The C.V Mosby Company; 1989:253-4.
17. Devi KM, Nayar S. Posterior teeth selection. IOSR-JDMS 2018;17(8):54-6.
18. 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.
19. Zmudzki J, Chladek G, Kasperski J. Biomechanical factors related to occlusal load transfer in removable complete dentures. Biomech Model Mechanobiol 2015;14(4):679-91.
20. Rangarajan V, Padmanabhan TV. Textbook of prosthodontics. 2nd ed. India: Elsevier; 2017: 157-64.
21. Swoope CC Jr, Kydd WL. The effect of cusp form and occlusal surface area on denture base deformation. J Prosthet Dent 1966;16(1):34-43.
22. Lopuck S, Smith J, Caputo A. Photoelastic comparison of posterior denture occlusions. J Prosthet Dent 1978;40(1):18-22.
23. Anusavice KJ, Shen Chiayi, Rawls HR. Phillips' science of dental materials. 12th ed. Riverport Lane: Elsevier Saunders; 2013:48-50.
24. Breithaupt J. Physics. 3rd ed. United Kingdom: Nelson Thornes Ltd; 2001:229.
25. Chowdhary R, Lekha K, Patil NP. Two-dimensional finite element analysis of stresses developed in the supporting tissues under complete dentures using teeth with different cusp angulations. Gerodontology 2008;25(5):155-61.
26. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, 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(1):3–10.
27. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, 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(2):71–84.
28. Mosharraf R, Zisei F, Ahhasi M. Effect of denture tooth material on load transmission under denture bases. J Dent 2018; 5(5): 325-31.
29. Zarb GA, Bolender CL. Prosthodontic treatment for edentulous patients; complete dentures and implant-supported prostheses. 12th ed. Philadelphia: Mosby; 2004:10.