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MODULUS OF ELASTICITY OF DIFFERENT RESIN DENTURE BASE MATERIALS: A COMPARATIVE STUDY

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ABSTRACT

Objective: The objective of this in vitro study was to compare modulus of elasticity of CAD /CAM milled, 3D printed and flexible pressed resins. **Materials and Methods:** eighteen rectangular specimens with specific measurement (65mm X 10mm X 3 mm) were constructed from different resin denture base materials and divided into 3 groups (6 specimens for each group). Group I contained the CAD/CAM milled resin specimens, Group II contained 3D printed specimens and Group III contained polyamide flexible resin. The specimens were evaluated by the three-point bending test on universal testing machine (INSTRON) to calculated modulus of elasticity. Data was analyzed with ANOVA and Tukey's pair-wise post-hoc tests. **Results:** The modulus of elasticity values of all groups ranged from 845.5 MPa to 2962.3 MPa. There were significant differences among the tested resin denture base materials. CAD/CAM milled materials had the highest modulus of elasticity, while the polyamide pressed materials had the lowest. The 3D-printed acrylics materials had lower modulus of elasticity values than CAD/CAM milled materials. **Conclusion:** The CAD/CAM milled and 3D printed denture base resins showed higher modulus of elasticity when evaluated with polyamide pressed materials.

KEY WORDS: Modulus of elasticity, CAD/CAM, 3D-printed, denture base.

INTRODUCTION

Polymethyl methacrylate (PMMA) has been the most common material used for denture fabrication since its introduced in 1937[1]. It has various advantages such as an excellent esthetic characteristic, little water sorption, acceptable strength, low toxicity, easy repair, and a simple processing technique. However, it has some drawbacks such as polymerization shrinkage, weak flexural, low impact toughness, and low fatigue resistance. These often lead to denture failure during chewing or when drop out from the patient's hand [2, 3].

In recent years, polyamide polymer has attracted consideration as a denture base material. Polyamide resins was suggested as a denture base material in the 1950s[4]. These polyamides are created by the condensation reactions among a diamine and a dibasic acid [5]. Polyamide is a crystalline polymer, while PMMA is amorphous, this crystalline effect accounts for the lack in strength coupled with ductility [6].

Many of these disadvantages of conventional heat cured denture fabrication can be resolved by the replacement of computer aided designing, computer

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aided milling and 3D printing technology [7]. CAD/CAM technology has been used for production of crowns, inlays, fixed bridges, implant abutments, and other prostheses. It can either involve additive manufacturing (rapid prototyping) or subtractive manufacturing (computerized numerical control machining). Additive manufacturing or 3D printing uses images from digital file to create an object by printing the object layer by layer of chosen material. Subtractive manufacturing uses images from digital file to create an object by machining (cutting/milling) to physically remove material to achieve desired geometry [7].

There are several expected advantages of current CAD/CAM milled denture over other commercially available PMMA polymerization methods. Denture can be fabricated in only two clinical visits which profits both patients and clinicians and optimal occlusal scheme can be developed with only minimal adjustments and a denture can be easily duplicated as the CAD files are digitally stored also that denture fit is better as the denture base is milled from prepolymerized block of acrylic resin [8].

A denture base material with a higher modulus of elasticity can withstand permanent mastication-induced deformation. Fracture of the upper dentures invariably occurs through the midline of the denture, due to flexure. Therefore, the denture base should have sufficient flexural modulus to resist fracture [9].

There is limited available data available about the modulus of elasticity of different denture base resins. Hence, the objective of this in-vitro study was to compare of modulus of elasticity of CAD/CAM milled and 3D printed, and pressed denture base resins.

MATERIALS AND METHODS

Eighteen specimens were fabricated according to the international standards specifications (ISO 20795-1:2013)[10] for *three Point Bend Test*. The specimens were divided into three groups as following: Group I: contained six specimens for CAD-CAM prepolymerized acrylic denture base, Group II: contained six specimens for 3D printed denture base resin. Group III: contained six specimens for flexible denture base resin.

Rectangular specimen with specific measures (65mm length, 10mm width and 3mm thickness) was designed using ExoCad software producing standard tessellation language (STL) file.

For Group I six rectangular shaped specimens were fabricated as following: The STL file of the designed virtual specimen was exported to the CAM milling machine (Ceramill Motion 2; Amann Girrbach). Then, the Pre-polymerized CAD-CAM PMMA acrylic plates (Polident d.o.o. VolčjaDraga 42, Sl-5293 VolčjaDraga, Slovenia) were milled. For Group II six specimens had been fabricated using additive technique as following; the STL file of designed specimen was exported to the 3D printer (Phrozen Shuffle, phrozen, Hsincu city, Taiwan). The specimens were printed using PMMA (NextDent Base, Vertex Dental, Soesterberg, Netherlands), then the specimens were exposed to UV light of polymerization unit. For Group III six stainless steel dies with rectangular shaped (65mm length, 10mm width and 3mm thickness) was constructed and used for fabrication of six specimens of the flexible resin material (Bre.Flex second edition, Germany) using injection molding technique.

Testing the samples for modulus of elasticity:

The modulus of elasticity was obtained from Universal testing machine (INSTRON, USA.). The specimens were centered on supports of the universal testing machine (three-point loading). While positioning the specimens on the testing machine, care was taken that the central loading plunger was touching the center of the sample (Fig.1). The load was applied gradually perpendicular to the midpoint of specimen strips at the crosshead speed of 0.5 mm /min. The load was applied till maximum capacity of the three-point testing device was recorded.

Then load-deflection curves were recorded by the connected computer software (Bluehill v1.5; Instron Ltd). From load-deflection curves, the elastic modulus was calculated according to following formula[11]: $E = FL^3/4Ybd^3$ where E= Flexural modulus (MPa), F=maximum load (N), L=span length (65 mm), Y=recorded deflection when the load is applied at the middle of the beam, b=specimen width (10 mm), d=specimen thickness (3mm).

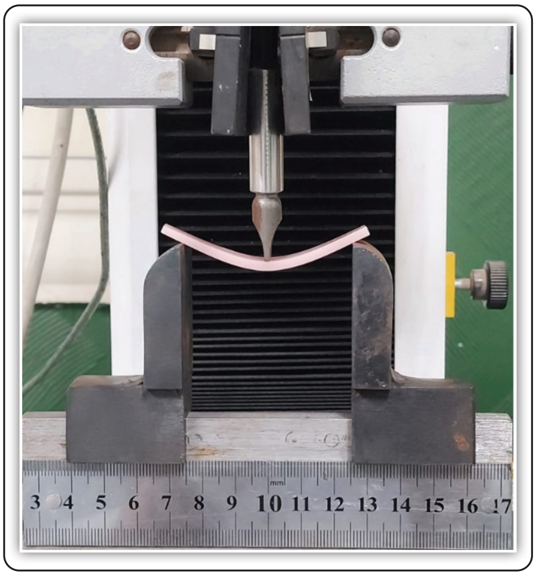

FIG (1) The specimen after testing on the universal testing machine

RESULTS

The informative statistical analysis which showing mean values and standard deviation (SD) of modulus of elasticity results measured in mega Pascal (MPa) for all tested groups are summarized in table 1 and graphically drawn in Fig.2

The statistical analysis of modulus of elasticity of all tested groups showed that the difference among all tested groups was statistically significant as indicated by one-way ANOVA test (F=160.72, P< 0.001).Where; the highest (mean ± SD) values of modulus of elasticity were recorded for the CAD/CAM resin (Group I) (2962.3±178.25MPa), followed by the 3D printed resin (Group II) (1702.8 ±161.88MPa). The lowest (mean ± SD) value of modulus of elasticity was recorded with flexible resin (Group III) (845.5±74.21MPa). Among the groups; Tukey's pair-wise post-hoc test showed statistically significant differences (P< 0.05) among the groups. Where, the recorded P-value between CAD/CAM resin (Group I) and 3D print resin (Group II) was (P < 0.001). While, the recorded P-value between CAD/CAM resin (Group I) and flexible resin (Group III) was (P <0.001). However, the recorded P-value between 3D printed resin (Group II) and flexible resin (Group III) was (P < 0.001).

TABLE (1) Comparison of modulus of elasticity results among all tested groups.

Variable	Mean	SD	ANOVA	
			F-value	*P*-value
G1 CAD/CAM	2962.31^A	178.25		
G2 3D Printed	1702.81 ^{B}	161.88	160.72	< 0.001
G3 Flexible	845.5٣^C	74.21		

Different letter in the same column indicating statistically significant difference (p< 0.05).

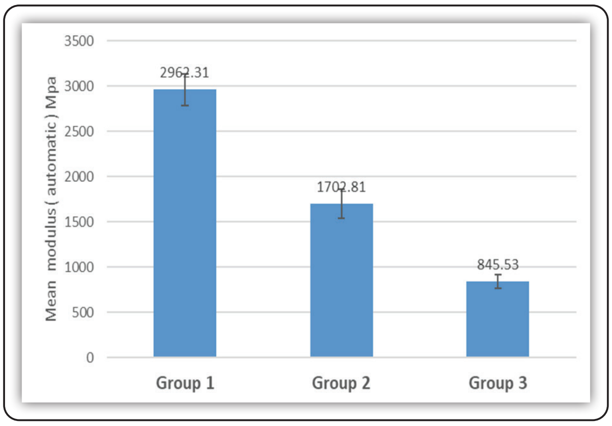

FIG (2) Column chart of the mean values of impact strength for all tested groups.

DISCUSSION

The modulus of elasticity reflects the material's stiffness and rigidity [12, 13]. Although the flexibility of the denture base is beneficial in increasing the absorbed energy before fracture, rigidity of the denture framework is a prerequisite for the ability of a denture base to equally distribute forces to the underlying structures[14] therefore, a higher flexural modulus (i.e., lower flexibility) is often advantageous in clinical settings because denture base materials with high elastic moduli are more resistant to elastic deformation, allowing the fabrication of dentures with thinner bases [15].

The three-point bend test is the most common method used for measuring modulus of elasticity of denture base materials adopted by international standards for polymer materials [15]. The used of this specification for flexural testing to compare the modulus of different denture base materials has been reported in pervious study by Uzun and Hersek [17] and Reis et al.[16, 17] Although the sample size for the three-point bending test were derived from the ISO 20795-1:2013[10].

According to the results of the present study, there was statistically significant difference between the modulus of elasticity of CAD/CAM, 3D printed, and flexible denture base resins. The CAD/CAM resin showed a statistically significant higher modulus of elasticity (2962.3±178.25 MPa) when compared to the 3D printed resin (1702.8±186.88 MPa) and flex resin (845.5±74.21 MPa).

According to the international standards for polymer materials and ISO 20795-1 for denture base polymers .The standard states that the modulus of elasticity of acrylic resins should achieve no less than 2000 MPa [10]. By using that measures, CAD/CAM milled in this present study are suitable for clinical usage, in contrast 3D printed and flexible resins not appropriate for clinical usage.

The superiority of elastic modulus in the CAD/CAM milled resin group may be relevant to the unique processing method of the CAD/CAM PMMA pucks in which high temperatures and pressure values are used for CAD/CAM PMMA polymerization [18].

Steinmassl et al, agree with our finding and reported the superiority related to pure PMMA [19].

Furthermore, the inferior elastic modulus of 3D printed resin could be related to the processing technique of 3D printing which could result in an improper bonding between the successive cured layers and a high amount of residual monomer which act as plasticizer and air bubbles which is a matter of concern as it affects the mechanical properties of the resulted denture [20-22].There was no prior research to compare with the current study's results regarding the modulus of elasticity of 3D printed resin.

This study exhibited the lowest modulus of elasticity of polyamide denture base. The lowest elastic modulus exhibited by polyamide means that it is less rigid and flexible. This is not surprising as it is indicated in certain clinical situations where flexibility is desired and this results may be related to the polyamide resin has a lower amount of cross-linking agents and crystalline nature which increases its flexibility, and a relatively amount residual monomer content which acts as a plasticizer when compared to CAD/CAM milled resin which explains its lowering in flexural modulus [14].

This was in accord with Lee et al.[23] who evaluated the modulus of elasticity of all thermoplastic denture base resins and reported that the polyamide denture base failed to fulfill the requirements of ISO 20795-1 Type 3, which requires 2000 MPa of modulus of elasticity. Also Takabayashi et al.[24] compared some characteristics of six thermoplastic denture resin materials. In this study the modulus of elasticity of polyamide type materials were lower than what was required according to the ISO standard.

CONCLUSION

Within limitation of this investigation, it can be concluded that, CAD/CAM milled and 3D printed denture base resins showed higher modulus of elasticity when compared with injected molded flexible resin.

REFERENCES

1. Craig R, Powers J. Restorative dental materials. 11 5. th ed St. Louis: Mosby. 2002:348-70.
2. Athar Z, Juszczyk A, Radford D, Clark R. Effect of curing cycles on the mechanical properties of heat cured acrylic resins. The European journal of prosthodontics and restorative dentistry. 2009;17(2):58-60.
3. Ali IL, Yunus N, Abu-Hassan MI. Hardness, flexural strength, and flexural modulus comparisons of three differently cured denture base systems. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry. 2008;17(7):545-9.
4. Vojdani M, Giti R. Polyamide as a denture base material: A literature review. Journal of Dentistry. 2015;16(1 Suppl):1.
5. Satoh Y. Studies on a superpolyamide for denture base: Surface roughness. JJ Dent Prac Admin. 2005;39:352-7.
6. MacGregor A, Graham J, Stafford G, Huggett R. Recent experiences with denture polymers. Journal of dentistry. 1984;12(2):146-57.
7. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dental materials journal. 2009;28(1):44-56.
8. Kattadiyil M, Goodacre C. CAD/CAM technology: application to complete dentures. Loma Linda University Dentistry. 2012;23:16-23.
9. Ajaj-ALKordy NM, Alsaadi MH. Elastic modulus and flexural strength comparisons of high-impact and traditional denture base acrylic resins. The Saudi dental journal. 2014;26(1):15-8.
10. ADA. ANSI/ADA Standard No. 139 (ISO 20795-1) DB-PADA.
11. Aguirre BC, Chen J-H, Kontogiorgos ED, Murchison DF, Nagy WW. Flexural strength of denture base acrylic resins processed by conventional and CAD-CAM methods. The Journal of prosthetic dentistry. 2020;123(4):641-6.
12. Meng TR, Latta MA. Physical properties of four acrylic denture base resins. J Contemp Dent Pract. 2005;6(4):93-100.
13. Puri G, Berzins DW, Dhuru VB, Raj PA, Rambhia SK, Dhir G, et al. Effect of phosphate group addition on the properties of denture base resins. The Journal of prosthetic dentistry. 2008;100(4):302-8.
14. Ucar Y, Akova T, Aysan I. Mechanical properties of polyamide versus different PMMA denture base materials. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry. 2012;21(3):173-6.
15. Perea-Lowery L, Minja IK, Lassila L, Ramakrishnaiah R, Vallittu PK. Assessment of CAD-CAM polymers for digitally fabricated complete dentures. The Journal of prosthetic dentistry. 2021;125(1):175-81.
16. Uzun G, Hersek N. Comparison of the fracture resistance of six denture base acrylic resins. Journal of biomaterials applications. 2002;17(1):19-28.
17. Reis JMdSN, Vergani CE, Pavarina AC, Giampaolo ET, Machado AL. Effect of relining, water storage and cyclic loading on the flexural strength of a denture base acrylic resin. Journal of dentistry. 2006;34(7):420-6.
18. Al-Dwairi ZN, Tahboub KY, Baba NZ, Goodacre CJ. A comparison of the flexural and impact strengths and flexural modulus of CAD/CAM and conventional heat-cured polymethyl methacrylate (PMMA). Journal of Prosthodontics. 2020;29(4):341-9.
19. Steinmassl O, Offermanns V, Stöckl W, Dumfahrt H, Grunert I, Steinmassl P-A. In vitro analysis of the fracture resistance of CAD/CAM denture base resins. Materials. 2018;11(3):401.
20. Kohli TMA. 3D Printing in Dentistry – An Overview. ACTA SCIENTIFIC DENTAL SCIENCES. 2019;3(6):35-41.
21. Kim W-T. Accuracy of dental models fabricated by CAD/CAM milling method and 3D printing method. Journal of Oral Research. 2018;7(4):127-33.
22. Yau H, Yang T, Lin Y. Comparison of 3-D printing and 5-axis milling for the production of dental e-models from intra-oral scanning. Computer-aided design and applications. 2016;13(1):32-8.
23. Lee H-H, Lee J-H, Yang T-H, Kim Y-J, Kim S-C, Kim G-R, et al. Evaluation of the flexural mechanical properties of various thermoplastic denture base polymers. Dental materials journal. 2018;37(6):950-6.
24. Takabayashi Y. Characteristics of denture thermoplastic resins for non-metal clasp dentures. Dental materials journal. 2010:1007010034-.