Cumhuriyet Dental Journal, 26(3): 281-286, 2023
DOI: https://doi.org/10.7126/cumudj.1317851

Cumhuriyet Dental Journal

| cdj.cumhuriyet.edu.tr | Founded: 1998 Available online, ISSN: 1302-5805 e-ISSN: 2146-2852 Publisher: Sivas Cumhuriyet Üniversitesi

Comparison of the Effect of the Same Polishing Method on the Surface Roughness of Conventional, CAD/CAM Milling and 3D Printing Denture Base Materials

Didem Demirkol[1-a], Faik Tuğut[1-b*]

[1] Sivas Cumhuriyet University, Department of Prosthodontics, Faculty of Dentistry, Sivas, Türkiye.
*Corresponding author

Research Article

History

Received: 21/06/2023
Accepted: 21/08/2023

ABSTRACT

Objectives: The aim of this study was to evaluate the effect of both the same polishing method and those with and without thermal aging on the surface roughness of conventional, CAD/CAM milling and 3D printing denture base materials.

Materials and Methods: A total of 30 round shaped specimens were obtained by 3 different methods: Conventional, CAD/CAM milling and 3D printing. After applying the same polishing technique to all groups, surface roughness values were measured. Profilometer device was used for surface roughness measurement. Then, after the thermal aging of all samples, surface roughness values were measured and the roughness values between no-thermocycling and thermocycling were compared. Tukey, Mann Whitney U and Kruskal Wallis tests were used statistically. P values of ≤ 0.05 were considered significant.

Results: As a result of the same polishing process, there was a difference in surface roughness in all groups. While the highest surface roughness values were seen in 3D printing, the lowest roughness value was seen in the CAD/CAM milling and was statistically significant. Thermocycling did not show a statistically significant difference in surface roughness.

Conclusions: The same polishing process caused different surface roughness values in the denture base materials obtained with different methods, and the lowest surface roughness value was seen in the CAD/CAM milling.

Key words: Denture base material, CAD/CAM Milling, 3D Printing, Polishing, Surface Roughness.

Konvansiyonel, CAD/CAM Kazıma ve 3D Baskılı Protez Kaide Materyalleri Üzerine Uygulanan Aynı Polisaj Yönteminin Yüzey Pürüzlülüğüne Etkisinin Karşılaştırılması

Süreç

Geliş: 21/06/2023
Kabul: 21/08/2023

ÖZ

Amaç: Bu çalışmanın amacı, hem aynı cilalama yönteminin ve hem de termal yaşlandırma işlemi yapılan ve yapılmayanların geleneksel, CAD/CAM kazıma ve 3D baskılı protez kaide materyallerinde yüzey pürüzlülüğüne olan etkisini değerlendirmektir.

Gereç ve Yöntemler: Konvansiyonel, CAD/CAM kazıma ve 3D baskılı olmak üzere 3 farklı yöntemle toplam 30 adet yuvarlak numune elde edildi. Tüm gruplara aynı şekilde polisaj tekniği uygulandıktan sonra yüzey pürüzlülük değerleri ölçüldü. Yüzey pürüzlülük ölçümü için profilometre cihazı kullanıldı. Daha sonra tüm örneklere temal yaşlandırma yapıldıktan sonra yüzey pürüzlülük değerlerinin ölçümü yapıldı ve termal işlem yapılmamış ve termal işlem yapılmış örnekler arasındaki pürüzlülük değerleri karşılaştırıldı. İstatistiksel olarak Tukey, Mann Whitney U ve Kruskal Wallis testleri kullanıldı. ≤ 0,05 olan p değerleri anlamlı kabul edildi.

Bulgular: Aynı polisaj işlemi sonucunda tüm gruplarda yüzey pürüzlülüklerinde farklılık görüldü. En yüksek yüzey pürüzlülük değerleri 3D baskıda görülürken, en düşük pürüzlülük değeri CAD/CAM kazımada görüldü ve istatistiksel olarak anlamlı bulundu. Termal siklus, yüzey pürüzlülüğünde istatistiksel olarak anlamlı bir fark göstermedi.

Sonuçlar: Aynı polisaj işlemi farklı yöntemlerle elde edilen protez kaide malzemelerinde farklı yüzey pürüzlülük değerlerine neden olmuş ve en düşük yüzey pürüzlülük değeri CAD/CAM kazımada görülmüştür.

Anahtar Kelimeler: Protez Kaide Malzemesi, CAD/CAM Kazıma, 3D Baskı, Parlatma, Yüzey Pürüzlülüğü.

[a] didemdurkn1@gmail.com https://orcid.org/0000-0001-8119-8845 [b] tugut78@hotmail.com https://orcid.org/0000-0002-6323-407X

How to Cite: *Demirkol D, Tuğut F. (2023) Comparison of the Effect of the Same Polishing Method on the Surface Roughness of Conventional, CAD/CAM Milling and 3D Printing Denture Base Materials, Cumhuriyet Dental Journal, 26(3):281-286.*

Introduction

Polymethyl methacrylate (PMMA) is the most widely used denture base material (DBM). It is still the main material used because of acceptable aesthetic results, ease of use and manipulation, non-toxicity, ease of repair and polishing. Despite its many advantages, PMMA resin has low flexural strength and low flexibility, so different methods and materials suitable for these methods have been developed.[1,2] With the advancement of technology, computer-aided design and computer-aided manufacturing (CAD/CAM) systems have started to take their place in the field of dentistry. Prostheses produced with CAD/CAM have many clinical advantages such as eliminating laboratory steps, saving time, eliminating traditional impression methods, minimizing the possibility of cross contamination, and making prosthesis in a single session compared to conventionally produced prostheses.[3,4] CAD software is used to design the prosthesis. The design is transferred to the CAM program and produced. There are two types of CAD/CAM production. One of them is subtractive (milling) and the other is additive (printing).[5] The base resin produced with both CAD/CAM and 3D printing produces a more accurate denture base than the base resin produced with the conventional technique.[6]

Surface roughness is defined as small irregularities that affect surface wetting, adhesion quality and shine quality. The surface roughness of the DBM is an important factor that directly or indirectly affects the microbial plaque formation and bacterial adhesion on the tissue surfaces of the prosthesis. Rough surfaces cause bad breath and are more vulnerable to discoloration than smooth surfaces. The roughness of the DBM is affected by the structural feature of the material, the polishing method and oral hygiene.[3,6,7]

According to ISO 4287 standards, surface roughness symbol 'Ra' unit is determined as 'µm'. Studies have indicated that a roughness of 0.2 µm can be obtained with finishing and polishing processes in laboratories. For this reason, it is imperative to finish and polish the prosthesis in order to minimize the surface roughness of the prosthesis surfaces.[7,8]

Evaluation of physical and mechanical properties is essential in determining the durability and success of these materials. For this reason, thermal cycling is used in laboratory studies to imitate the oral environment by changing the temperature.[6,9,10]

The purpose of this study was to evaluate the effect of the same polishing method on the surface roughness of DBMs manufactured by conventional, CAD/CAM milling and 3D printing before and after thermocycling. The null hypotheses were that the same polishing technique would not effect on surface roughness of the conventional, CAD/CAM milled and 3D-printing DBM, that thermocycling would affect the surface roughness.

Material and Methods

In this study, the surface roughness of the DBMs manufactured by conventional, CAD/CAM milling and 3D printing was evaluated with no-thermocycling (NT) and thermocycling (T). In addition, the effect of the same polishing method on the surface roughness was also evaluated.

In the study, DBMs manufactured by 3 different methods were used: Heat cured acrylic resin (Meliodent, Kulzer, Germany) in the conventional method, prepolymerized pink acrylic block (Yamahachi, Yamahachi Dental Mfg, Japan) in the CAD/CAM milling method and fluid resin (MACK4D, Dentona, Germany) in the 3D Printed method. In order to evaluate the surface roughness measurement in the study, a total of 30 samples were prepared (n=10), in the form of discs with a diameter of 20 mm and a thickness of 2 mm (Figure1).

Metal molds were used to obtain the samples with the conventional method. First, samples were obtained by dripping wax into these molds. After the samples were muffled, negative spaces were formed by melting them. Then, heat polymerized acrylic resin (Meliodent, Kulzer, Germany) was prepared and polymerized according to the manufacturer's instructions. The muffle was placed in boiling water for the polymerization process. After the heat source was turned off, the muffle was kept in hot water for 15 minutes. Then the heat source was turned on again and the water was boiled for 20 minutes. Then It was allowed to cool slowly.

For the samples to be obtained by the CAD/CAM method, at first the design was made in the form of a disc (20mm diameter, 2mm thickness) in the CAD program (Solid Works 2022, Dassault Systemes S.A, service pack 5.0, France). After the design file was transferred to the CAM device (Redon Hybrid Full, İstanbul, Turkey), the samples were obtained by milling.

For the samples to be obtained with a 3D-Printer, at first a disc-shaped sample was designed with AutoCAD software (Autodesk, USA). The samples was created using a 3D printer (Free Shape 120 Printer, Ackuretta, China) and MACK4D resin (Dentona, Germany). After the samples were obtained, they were cleaned by keeping them in isopropyl alcohol for 5 minutes in an ultrasonic cleaner (Ackuretta Cleaning Kit, Taiwan). Then, final curing was performed in a UV light curing device (Ackuretta UV Oven, Taiwan) with a wavelength of 405 nm for 3 minutes.

After all samples were obtained, the excess was trimmed with a tungsten carbid bur. Then, one surface of the samples was sanded by one operator with 100, 120, 400, 600 grit abrasive paper (Atlas, England) respectively for 30 seconds under water. The specimens were then ultrasonically cleaned for 5 minutes to remove debris. Polishing paste (Universal Polishing; Ivoclar Vivadent) was applied for 90 seconds with a felt attached to the polishing motor (Schütz Dental, Germany) on one surface of the prepared samples. After each polishing, the sample was washed ultrasonically for 5 minutes and the residual polishing pastes were removed. After all samples were kept in distilled water at 37 ± 1°C for 48 ± 2 hours, surface roughness measurements of the polished surfaces were made. Profilometer device (Mitutoyo/Kawasaki, Japan) was used to obtain the measurement values (Figure 2). While making the measurements, measurements were made from three different points of the sample surfaces and the surface roughness value (Ra) was obtained by taking the average. All samples for which initial measurements were made were thermocycled for 5000 cycles with a dwell time of 30 seconds in water at 5°C and 55°C (Gökçeler Machinery, Turkey). After the thermal aging process, measurements were made from three different points by using a profilometer device for the final measurement values of all samples and Ra values were obtained by taking the average. The surfaces of the NT and T samples were examined under a scanning electron microscope (SEM) (Tescan MIRA3 XMU, Brno-Kohoutovice, Czech Republic) (x5000 magnification).

The obtained data were analyzed with statistical software (IBM SPSS Statistics, v22.0; IBM Corp). Analysis of variance was performed when parametric test assumptions were fulfilled in the evaluation of the data. As a result, Tukey test was used to find the groups that made a difference when the significance decision was made, and the Mann Whitney U test was used to find the groups that made a difference as a result of the Kruskal Wallis test when the parametric test assumptions could not be fulfilled (p=0.05).

Results

The mean surface roughness and standard deviation values of the samples in the study are shown in Table 1. The roughness values of same polishing on the CAD/CAM milling were significantly lower than 3D printing and Conventional in NT (p=0.024) and T (p=0.044). While the lowest surface roughness values were found in CAD/CAM milling after same polishing, the highest value was found in 3D-Printing. There is no statistically significant difference in surface roughness each groups between NT and T. However, when the values are examined, a decrease in surface roughness was observed after the thermocycling in other groups except for CAD/CAM milling. It was observed that the surface roughness values in all groups had a statistically significant affected by same polishing, while it was not affected by the thermocycling. The SEM images from all groups with NT and T after same polishing are showed in Figures 3,4,5.

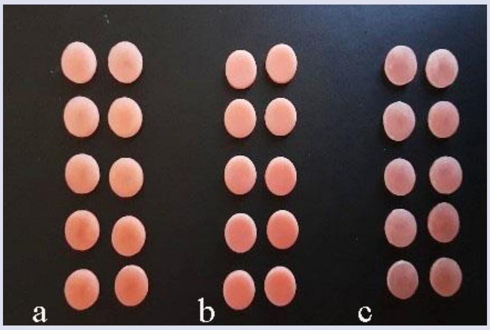

Figure 1: Samples obtained by different methods; a: CAD/CAM milling, b: 3D Printing, c: Conventional.

Figure 2: Profilometer device and surface roughness measurement.

Table 1. Surface roughness values (µm) of all groups no-thermocycling and thermocycling

Groups	No-thermocycling X±Sd(µm)	Thermocycling X±Sd(µm)	
Conventional	0.32±0.10[a]	0.30±0.05[c]	t=1.13 p=0.282
CAD/CAM Milled	0.24±0.6[a.b]	0.25±0.04[c.d]	t=1.16 p=0.276
3D Printing	0.35±0.12[b]	0.32±0.09[d]	t=0.51 p=0.617
	F=4.22 p=0.024*	F=3.79 p=0.044*	

*The difference between the means shown with the same lowercase letter in the vertical direction is statistically significant (p<0.05)

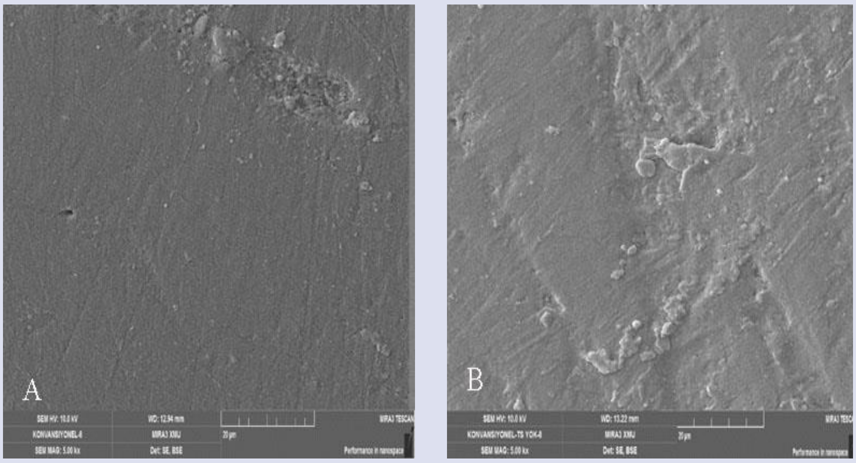

Figure 3: Image of surface properties of samples obtained by Conventional at x5000 magnification under SEM. A: No-thermocycling, B: Thermocycling.

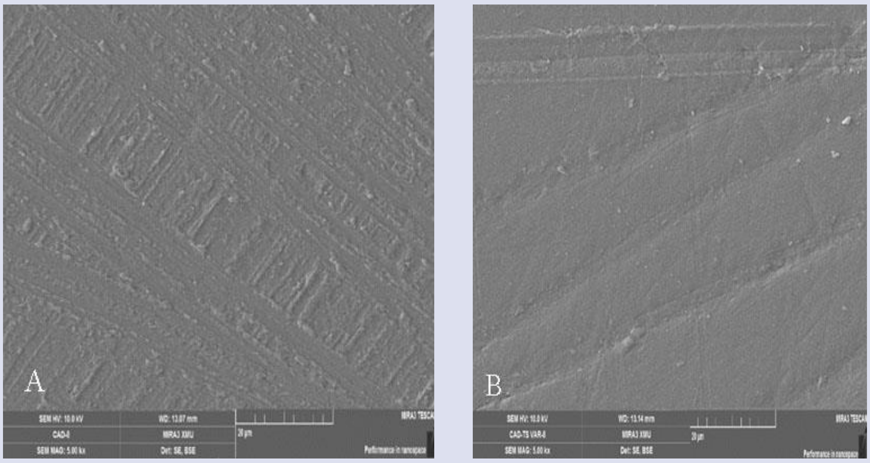

Figure 4: Image of surface properties of samples obtained by CAD/CAM milling at x5000 magnification under SEM. A: No-thermocycling, B: Thermocycling.

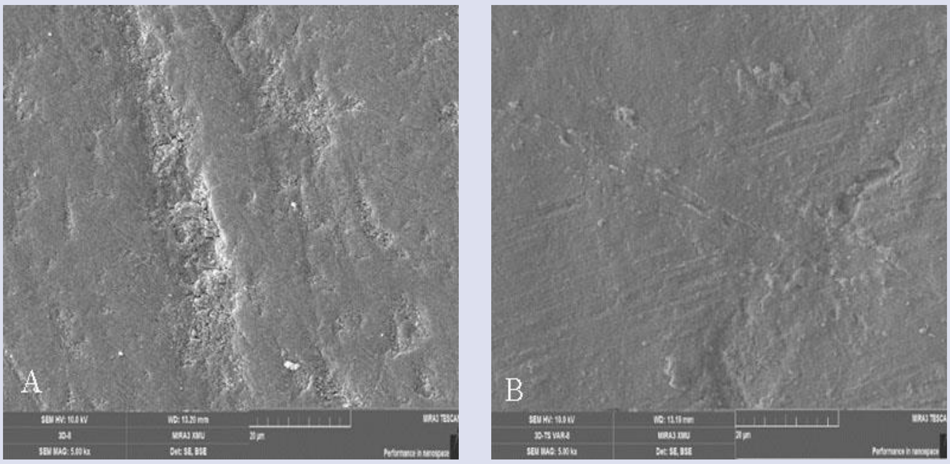

Figure 5: Image of surface properties of samples obtained by 3D printing at x5000 magnification under SEM. A: No-thermocycling, B: Thermocycling.

Discussion

The effect of both the same polishing method on the denture materials produced by conventional, CAD/CAM milling and 3D printing and the thermocycling on the surface roughness were evaluated. The null hypotheses, that no difference would be found in the surface rougness of the Conventional, CAD/CAM milled and 3D printing resins, that thermocycling would affect the surface roughness, and that same polishing would not affect the surface roughness, were rejected.

The surface roughness of the materials is very important since the base materials are related to the oral tissues.[11] The surface roughness of DBMs is an inherent physical property that varies depending on the person's dexterity, polishing method and the structure of the material.[3,12] Polishing increases the smoothness of acrylic resins. Polishing protocols must be chosen correctly to avoid high roughness protocols. If the current protocol does not affect the Ra values after polishing, this indicates that the polishing protocol is not suitable for each type of denture base.[13] For this reason, in study, we aimed to see how the same polishing technique would affect the base materials obtained by different methods.

In the study, while 3D printing showed a high Ra value, smoother surface in CAD/CAM milling was similar to Helal *et al.*[14] and Gad *et al.*[15] studies. The increase in roughness in 3D printing may be due to decreased polymerization degree and monomer leakage and increased porosity.[16] 3D printing produces progressive edges between layers in addition to layered printing.[16-18]

In the study of Murat *et al.*[19] comparing the surface roughness values of the base materials obtained by the CAD/CAM milling method and the heat polymerized method, the Ra values were measured after applying the thermal aging process to the samples. In the results obtained, it was seen that the CAD/CAM milling method showed lower values than heat-polymerized acrylic resins. In the study of Al-Fouzan *et al.*[20], they found that the samples produced by the CAD/CAM milling method showed less surface roughness than conventional heat-polymerized acrylics. It is similar to the results of the above studies.

Freitas *et al.*[21] In the study in which the surface roughness values of the base materials produced by heat polymerized, CAD/CAM milling and 3D printing methods were examined, they concluded that the samples produced by the 3D printing method had the highest surface roughness value. In the study by Fiore *et al.*[13], heat cured acrylic resin, CAD/CAM milling method and 3D printing method were compared and stated that CAD/CAM had the lowest roughness. Meirowitz *et al.*[22] also stated in their study that CAD/CAM milling had the lowest roughness value. The above studies show parallelism with our study. In our study, CAD/CAM samples showing lower Ra values compared to other groups were confirmed in the images at x5000 magnification under SEM (Figure 3,4,5).

In the study, it was determined that the thermal cycle increased the surface roughness in CAD/CAM milling, but no significant result was obtained, and although it decreased in conventional and 3D printing, there was no significant difference. Gad *et al.*[15] ınterlayer thicknesses may vary in 3D printing due to temperature changes and changes in water absorption during the thermal cycle. The thickness of each layer indicates that it has a great influence on the surface roughness. however, reducing the layer thickness reduces the surface roughness but increases the machining time.[23,24] We can also say that the polishing method used can make a difference in roughness.

Limitations of the study include that the in vitro situation does not fully reflect the clinical situation. In addition, polishing by the operator may affect the roughness. The denture base materials obtained by different methods have different properties and a single polishing method should not be seen as a definitive result. Different polishing methods should also be tried and compared.

Conclusions

Based on the findings of this in vitro study, the following conclusions were drawn:

1. CAD-CAM milled showed lower surface roughness than conventional and 3D-printing denture base specimens both before and after thermocycling.
2. Thermocycling did not cause a statistically significant effect on surface roughness.

After the same polishing applied, the lowest surface roughness was seen in the CAD/CAM milled, while the highest value was seen in 3D Printing.

Acknowledgments

This study was prepared by using the PhD thesis of Didem Demirkol. The authors gratefully acknowledge the financial support provided by the Scientific Research Project Fund of Sivas Cumhuriyet University Project DİŞ-2022-296.

Conflicts of Interest Statement

The authors declared that there is no conflict of interest.

References

1. Al-Rafee MA. The epidemiology of edentulism and the associated factors: A literature Review. J Fam Med Prim Care 2020; 9: 1841-1843.

2. Zafar MS. Prosthodontic Applications of Polymethyl Methacrylate (PMMA): An Update. Polymers 2020; 12: 2299.

3. Al-Dwairi ZN, Tahboub KY, Baba NZ, Goodacre CJ, Ozcan MA. Comparison of the Surface Properties of CAD/CAM and Conventional Polymethylmethacrylate (PMMA). J Prosthodont 2019; 28: 452-457.

4. Srinivasan M, Schimmel M, Naharro M, et al: CAD/CAM milled removable complete dentures: time and cost estimation study. J Dent 2019; 80: 75-79.
5. Nadin Z. Materials and processes for CAD-CAM complete denture fabrication. Curr Oral Health Rep 2016; 3: 203-208.
6. Niem T, Youssef N, Wostmann B. Energy dissipation capacities of CAD-CAM restorative materials: A comparative evaluation of resilience and toughness. J Prosthet Dent 2019; 121: 101-109.
7. Azuma A, Akiba N, Minakuchi S: Hydrophilic surface modification of acrylic denture base material by silica coating and its influence on Candida albicans adherence. J Med Dent Sci 2012; 59: 1-7.
8. Jin NY, Lee HR, Lee H, et al. Wettability of denture relining materials under water storage over time. J Adv Prosthodont 2009; 1: 1-5.
9. Pinto JR, Mesquita MA, Henriques GE. Evaluation of varying amounts of thermal cycling on bond strength and permanent deformation of two resilient denture liners. J Prosthet Dent 2004; 92: 288-293.
10. Gale MS, Darvell BW. Thermocycling procedures for laboratory testing of dental restorations. J Dent 1999; 27: 89-99.
11. Barreto JO, de Alencar-Silva FJ, Oliveira VC, da Silva-Lovato CH, Silva PG, Regis RR. The effect of a continuous mechanical polishing protocol on surface roughness, biofilm adhesion, and color stability of acrylic resin artificial teeth. J Prosthodont 2019; 28: 110-117.
12. Corsalini M, Boccaccio A, Lamberti L, Pappalettere C, Catapano S, Carossa S. Analysis of the performance of a standardized method for the polishing of methacrylic resins. Open Dent J 2009; 3: 233–240.
13. Di Fiore A, Meneghello R, Brun P, Rosso S, Gattazzo A, Stellini E, Yilmaz B. Comparison of the flexural and surface properties of milled, 3D-printed, and heat polymerized PMMA resins for denture bases: An in vitro study. J Prosthodont Res 2021; 66: 502–508.
14. Helal MA, Fadl-Alah A, Baraka YM, Gad MM, Emam AN. In-vitro comparative evaluation for the surface properties and impact strength of CAD-CAM milled, 3D-printed, and polyamide denture base resins. J Int Soc Prev Community Dent 2022; 12: 126.
15. Gad MM, Al-Thobity AM, Fouda SM, Näpänkangas R, Raustia A. Flexural and surface properties of PMMA denture base material modified with thymoquinone as an antifungal agent. J Prosthodont 2020; 29: 243-250.
16. Lee S, Hong SJ, Pack J, Pae A, Kwon KR, Noh K. Comparing accuracy of denture bases fabricated by injection molding, CAD-CAM milling and rapid prototyping method. J Adv Prosthodont 2019; 11: 55-64.
17. Gad MM, Fouda SM, Abualsaud R, Alshahrani FA, Al-Thobity AM, Khan SQ, et al. Strength and surface properties of a 3D-printed denture base polymer. J Prosthodont 2022; 31: 412–418.
18. Kaplan BA, Goldstein GR, Vijayaraghavan TV, Nelson IK. The effect of three polishing systems on the surface roughness of four hybrid composites: a profilometric and scanning electron microscopy study. J Prosthet Dent 1996; 76: 34-38.
19. Murat S, Alp G, Alatalı C, Uzun M. In vitro evaluation of adhesion of Candida albicans on CAD/CAM PMMA-based polymers. J Prosthodont 2019; 28: 873–879.
20. Al-Fouzan AF, Al-Mejrad LA, Albarrag AM. Adherence of Candida to complete denture surfaces in vitro: A comparison of conventional and CAD/CAM complete dentures. J Adv Prosthodont 2017; 9: 402-408.
21. Freitas RFCP, de Duarte S, Feitosa S, Dutra V, Lin W, Panariello BHD, Carreiro AFP. Physical, Mechanical, and Anti-Biofilm Formation Properties of CAD/CAM Milled or 3D Printed Denture Base Resins: In Vitro Analysis. Journal of Prosthodontics 2022. https://doi.org/10.1111/jopr.13554.
22. Meirowitz A, Rahmanov A, Shlomo E, Zelikman H, Dolev E, Sterer N. Effect of denture base fabrication technique on Candida albicans adhesion in vitro. Materials 2021; 14: 221.
23. Shim JS, Kim JE, Jeong SH, Choi YJ, Ryu JJ. Printing accuracy, mechanical properties, surface characteristics, and microbial adhesion of 3D-printed resins with various printing orientations. J Prosthet Dent 2020; 124: 468-475.
24. Campbell RI, Martorelli M, Lee HS. Surface roughness visualisation of rapid prototyping models. Comput Aided Des 2002; 34: 717-725.