EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 3593:3600, October, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 27-07-2024 • Accept Date : 12-09-2024 • Available online: 05-10-2024 • DOI : 10.21608/edj.2024.307480.3131

EFFECT OF MANUFACTURING TECHNIQUES ON ADAPTATION OF REMOVABLE PARTIAL DENTURE FRAMEWORKS IN MANDIBULAR KENNEDY CLASS I CASES: AN IN VITRO COMPARATIVE STUDY

Ahmed Helmy[*], Amr Ismail[**] *and* Haytham Abd Elaal[***]

ABSTRACT

Introduction: Removable partial dentures (RPDs) are considered an economic and good treatment modality compared with most costly alternatives like dental implants. CAD/CAM technology has improved the fit of RPDs, improving efficiency and manufacturing results.

Aim of this study: This study was conducted to compare adaptation between 3D printed frameworks and conventionally constructed ones in mandibular Kennedy class I.

Materials and methods: A model of mandibular Kennedy class I was used. A total of 12 frameworks were constructed over the model and divided into 2 groups. Six frameworks in each group according to fabrication method: Group I, 3D printed metal frameworks; Group II conventional method (Lost-wax technique). RPD frameworks were constructed from cobalt-chromium alloy. The frameworks were optically scanned, and the distances from the original master model at various points were measured for adaption comparison.

Results: Group I showed less deviation in comparison to Group II with a statistically significant difference (p-value <0.05).

Conclusion: Within the limitations of this study it was concluded that:

The 3d printed manufactured frameworks showed higher adaptation and fitness, with smaller discrepancies relatively to that frameworks conventionally constructed by casting technique.

KEYWORDS: 3D printing, partial denture, adaptation

---

[*] Assisstnat Lecturer at Prosthodontic Department, Faculty of Dentistry, Minia University.
[**] Professor at Prosthodontic Department, Faculty of Dentistry, Minia University.
[***] Lecturer at Prosthodontic Department, Faculty of Dentistry, Minia University.

INTRODUCTION

RPDs are considered an economic and good treatment option compared with most costly alternatives like dental implants. The primary factors that contribute to the success of RPD are those that including good design, component selection, suitable materials, follow-up, and patient acceptability. Acceptable fit is necessary for a RPD to operate properly. Digital technology is evolving quickly, and it is being used to design and create restorations either a single missing tooth or an entire arch. Nowadays, with the evolution of computer software and programs, dental prostheses can be made using digital technology (1, 2).

Recently, the need for dental laboratories might be diminished, as CAD/CAM technology has improved the quality of fit of RPDs, improving efficiency and manufacturing results. The polymer or metal can be directly machined into RPD frameworks. Frameworks made of resin and wax can be casted using conventional fabrication techniques. The adaptation of the RPD frameworks have to be optimized to achieve maximum function, and aesthetics and remain biocompatible (3).

Recent techniques involve scanning the removable prosthesis and the cast, saving the scans as stereo lithographic images in the STL file format, and the STL files of each scan are superimposed by surface matching software, and then calculating the distance between the cast and the framework by slicing the scan data. Also, improvements in CAD software allow for evaluating the adaptation using a another superimposing software (4, 5).

This study was conducted to compare adaptation between 3D printed frameworks and conventio

MATERIALS AND METHODS

Cast fabrication

Acrylic resin cast simulating partially edentulous mandibular Kennedy class I with missed first, second and third molars on both sides was used.

Distal Occlusal rest seats were prepared on the first premolar and mesial of the second premolar. The rests were saucer in shape with 1.5mm in depth and 2mm in width. The crowns had a mid-buccal undercut of 0.5 mm as requirement of I bar clasp retentive tip. The distal surface of the crowns was adjusted to have zero undercut.

Partial denture design

The cast was scanned using a lab scanner to get the STL file. The scanned cast file was imported to CAD software (3Shape Removable Partial Design; Core3dcentres, USA) for RPD design.

The virtual cast was surveyed using digital software to get the proper insertion and removal direction after correction of the tilt to ensure the existence of 0.5 mm undercut in the mid-buccal surface of the second premolar (Figure 1A).

The saddle was designed with 0.4 mm relief (Figure 1B). The saddle was chain-like in shape and extended 2mm distal to the second premolars till the anterior border of retro molar bad. The saddles were connected by lingual bar major connector.

RPI clasp was designed on the second premolar with mesial occlusal rest, guiding plates in the disto-lingual surface, and an I bar retainer in the mid-buccal side of the second premolars (Figure 1C). On the mandibular first premolar occlusal surface bilaterally, two occlusal rests were outlined to act as indirect retainers (Figure 1D). The interproximal occlusal rests were connected to the lingual bar bilaterally by minor connectors. at the end, the *sculpt tool* was used to add or remove material from the design, and to smoothen any sharp unwanted areas. The framework was saved in STL format and sent for slicing software (Figure 1E).

Partial denture framework fabrication

Metal 3d-printed framework fabrication

The specimens were processed with approximately 10 to 30 µm of cobalt-chromium (Co- Cr dental alloy) alloy powder type 5 (Starbond easy Pulver 30, Scheftner dental) a direct metal laser melting 3d printer (Vulcantech VM120, Germany). laser beam was used to melt the powder into RPD framework geometry. The beam was controlled completely by the computer. The powder particles were condensed together layer by layer to form the framework.

The frameworks were subjected to heat treatment in a furnace with high-purity argon. Specimens were heated from room temperature to 1150^{o} C at a ramp rate of 10^{o} C/ min and held at that temperature for 6 hours in the furnace. Then, heat-treated specimens were slowly cooled to room temperature. The RPD frameworks were removed from the furnace and then finished and polished according to the manufacturer instruction (Figure 2 A&B).

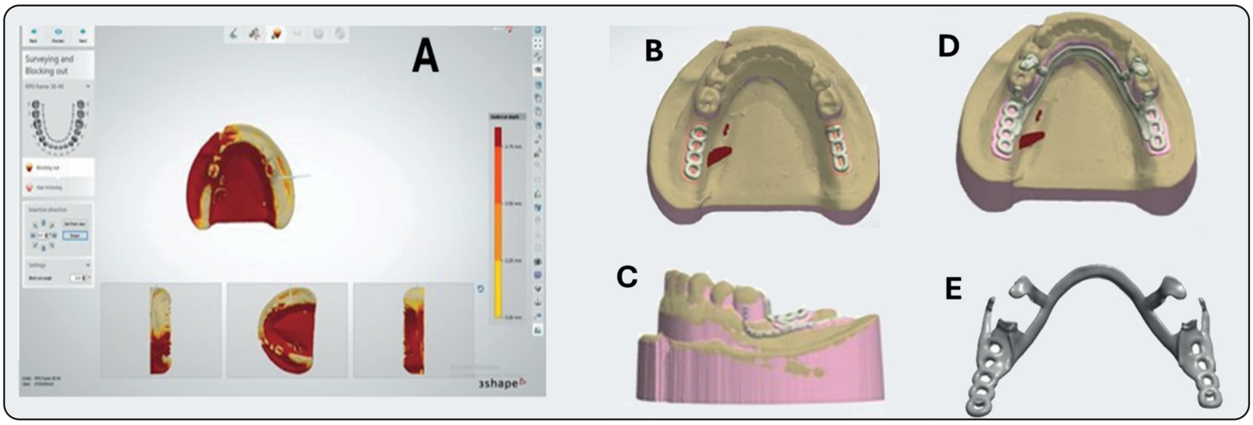

Fig. (1) A shows the path of insertion selection, B shows the saddle design, C shows the virtual waxing up of the clasp assembly, D shows the virtual framework wax up on the cast, and E shows the virtually designed framework.

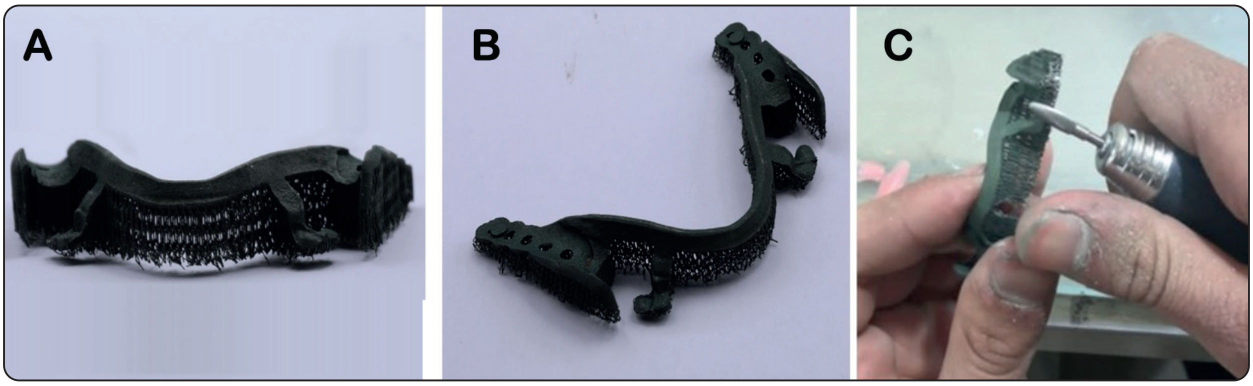

Fig. (2) A shows the metal-printed framework from an anterior view, B shows the metal-printed framework from a top view, and C shows the finishing of the metal-printed framework.

Conventional framework casting

The fabrication of the RPD framework included two steps where the resin pattern was first produced using a 3D printer (Any cubic, photon, China) (Figure 3A&B),, then the framework was casted. The pieces for the 3D printed objects were made from a photo-curable liquid resin which was cured when exposed to light by a photo-polymerization method. The resin surface area was scanned across at a 45-degree angle throughout the printing process. The part was constructed layer by layer, with a light curing system scanning each layer and an elevation mechanism elevating steps after each layer to control the process. The STL file by hyper dent program was cut the design into small slices which have this specification. The machine calibration option was selected from the home menu. The photosensitive polymer bottle was shaken for at least two minutes before opening. A suitable amount of resin was placed in the tank; platform The machine cover was closed to protect resin from being polymerized by any light source. The printer's software (ANY Cubic photon, any cubic, china) imported the framework's STL file. The file was imported in an arbitrary orientation. Adjustment of framework orientation was performed using the mouse and Move button in the software After the orientation was adjusted in the build, the addition of supporting bars was done to support print material during the printing process. Auto support function was used, and the file was sliced to be used by the printer.

Sprues were attached to the resin framework, and the whole assembly was invested using rubber casting ring (Figure 3C). The investment was mixed according to the manufacturer's instructions. The mixed investment was poured into the casting ring using a vacuum mixer. The ring was allowed to set. Casting was done by an automatic electric induction casting machine (Bego, Germany) using cobalt-chromium alloy (Argeloy NP Partial, ARGEN, Brazil). The RPD frameworks were de-vested and then finished and polished according to the manufacturer's instructions (Figure 3D).

Adaptation measurements

All finished frameworks received a light anti-glare spray coating (D-Scan, Dentify GmbH, Schenffelstr).

Scanning of the frameworks was done through:

A- each framework was scanned alone and was numbered from 1 to 6 eg. (con1, con 2,…..) and (print 1, print 2,……)

B- each framework was sit on its corresponding cast and was scanned to obtain a single STLfile combining the framework and the cast in the same file. Each scan was named from 1 to 6 eg (cast con 1, cast con 2,…….) and (cast print 1, cast print 2,…….).

C- scanning the cast alone

Using surface super-imposition software (Geomagic Control X 2022; 3D Systems), all scanned printed frameworks were initially aligned with the (cast+framework) and the scanned cast

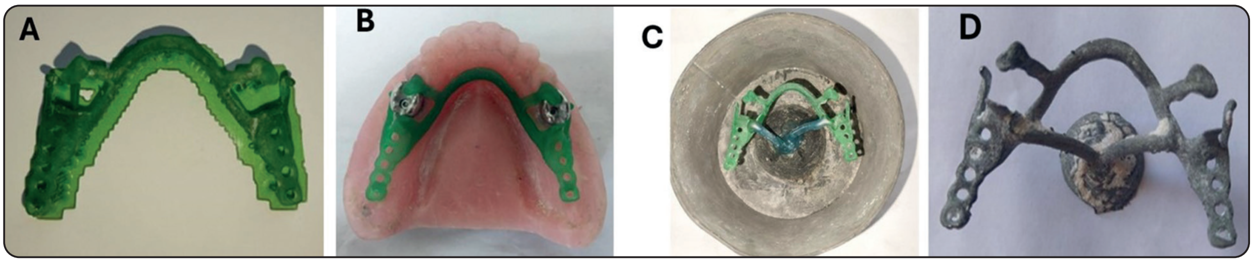

Fig. (3) A&B show the fabrication of the resin framework, C shows sprues attached to the resin framework,D shows de-vesting the framework from casting ring

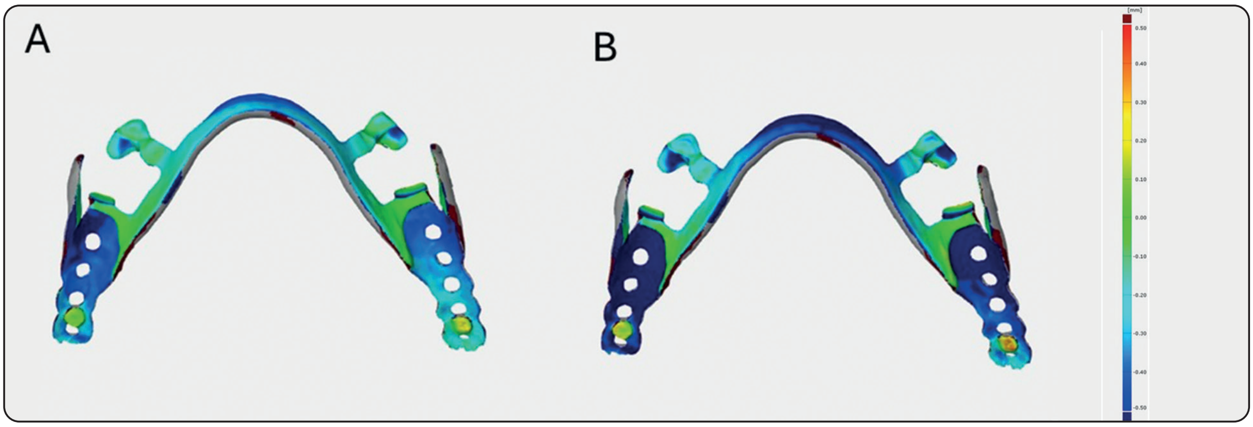

Fig. (4) Shows a color map showing the deviation of the framework fitting surface from the cast. A metal-printed framework and B cast metal framework.

through the N point alignment command. Then through the best-fit alignment command. Colour maps of the surface matching differences were done. The color-coded 3D-surface deviation spectra were set to have a maximum critical value of ±1 mm and visually displayed at each measurement site. The deviation between the scanned framework and the corresponding cast was measured in mm. Areas that were yellow to red indicate impingement of the surface inward. Blue areas indicate deviations outward. The ideal printed clasp showed an entirely green colour map, giving a measurement value of 0, which represented no space between the framework and cast. Evaluation of deviation between scanned printed framework and cast was calculated as the root mean square (RMS) (figure 4).

RESULTS

Normality test

The Shapiro-Wilk test was done to check the distribution of data as shown in Table 1. The Shapiro-Wilk Normality test's null hypothesis is that the data is normally distributed. This test was used to determine whether the data are parametric or non-parametric. If the statistical significance at the p-value was more than 0.05 (Normally distributed) therefore null hypothesis is accepted and the test used for analysing the data was an independent sample T-test, and if the statistical significance at the p-value was less than or equal to 0.05 (Not normally distributed) therefore null hypothesis was rejected and the test used for analysing the data was the Mann Whitney test.

TABLE (1) Shows the Shapiro-Wilk test to check normality

Group	p-value	Normality interpretation
Group I	0.774	Normally distributed
Group II	0.345	Normally distributed

Descriptive statistics

Group I showed less deviation in comparison to Group II with a statistically significant difference (p-value <0.05).(figure5)

TABLE (2) Shows the Mean, standard deviation (SD), and statistical significance difference between the two groups

Group	Deviation mean (mm) ±SD	p-value
Group I	0.40±0.35	0.02*
Group II	0.7±0.35	

**** Statistical significant difference ((p-value <0.05). SD=standard deviation.***

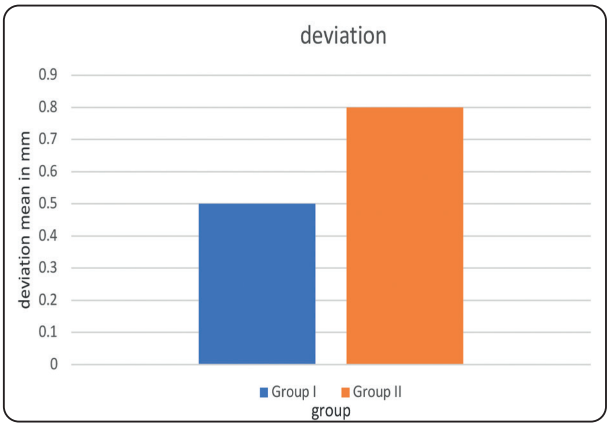

Fig. (5) Shows the deviation from the original design in mm.

DISCUSSION

This study was conducted to compare the adaptation of two techniques in the construction of a RPD framework.

The Mandibular Kennedy class I model was selected due to the high incidence of this situation (6).

The cast was manually surveyed to ensure parallel guiding planes of the main abutments.

Also, rest seats were prepared to simulate the clinical situation and to provide an area for measuring adaptation (7).

Digital surveying was conducted to ensure the proper path of insertion.

The RPD frameworks were designed using CAD technology to ensure standardization between frameworks.

Conventional frameworks were constructed through the casting of 3D-printed resin frameworks. This eliminates dimensional changes due to duplication material and refractory cast. Also, human errors during waxing were eliminated (8).

The model and the finished frameworks were scanned for adaptation measurement by the same scanner, so dimensional changes were neglected (9).

A blue light extra oral scanner was used for scanning the frameworks and the reference cast to perform the evaluation procedures. Because the materials used in cast fabrication or scan body are frequently transparent and short-wavelength blue light is not transmitted, it is reflected from the surface, making blue light the best scanning method for making the projected border readable. Blue light scanners are less sensitive to heat than white light scanners since they employ LEDs. More significantly, a scanning device that uses structural blue light can obtain a good reading inside small spaces (10).

Fitness evaluation of RPDs was done by fit matching software. The software uses different scans for the tested objects (prostheses and model) to measure the gap between them. The evaluation was introduced in colour mapping images to provide information about accuracy and adaption of the prostheses (11).

Creation of resin frameworks in the conventional technique allowed for clinically try in and modification before conventional processing using the lost wax technique. Resins were recommended to overcome the problems of free hand waxing (standardization). Resins offer higher strength, dimensional stability, lower flow than wax patterns and minimal distortion.

A combination of dimensional variations in the casting wax and the refractory cast may affect the framework's accuracy and fit. This issue was resolved by using 3D-printed resin patterns (12).

Recent improvements in software also allow the measurement of the adaptation (space between the prosthesis fitting surface and its corresponding cast) using superimposing software. Reference best-fit analysis was found to provide accurate and reliable information about fitness between specific objects. Also provide better idea bout internal discrepancies of the RPD frameworks. (13).

The discrepancies in fitness could be due the multiple steps in construction of the RPD framework. For example, metal powder size, distribution, laser beam size, support design, depth of powder bed and laser beam velocity (14).

Conventional casting technique is characterized by solidification and thermal shrinkage of metal alloys. Setting and thermal expansion of the investment cannot be equal to the shrinkage monitored (15, 16).

The current results are similar to that reported by **Tasaka A et al 2020 and Stamenković D et al 2023** who found that higher accuracy and adaptation was recorded in 3d printed metal structures than conventionally casted. This was due to the small grain size and the higher homogeneity of 3d printed metals than that with conventional technique (17, 18).

However, another study by **Bajunaid et al,** which found that there is no statistical difference between 3d printed metals and conventional casting technique. This difference may be due to using silicone material to fill a gap difference and then evaluated by digital microscope. This evaluation method showed less accuracy compared to the virtual superimposition technique (19).

The current study contradicts with **Arnold C et al**, which recorded higher fitness and accuracy in conventional casting over 3d printed. The lower accuracy of 3 d printed was claimed to the fitness imperfections. Also, light microscope was used in that study to measure the gap difference. This technique is considered lower than digital superimposition technique. In addition, that study used a different frame component for example the clasp arm to assess fitness (20).

CONCLUSION

Within the limitations of this study it was concluded that the 3d printed manufactured frameworks showed higher adaptation and fitness, with smaller discrepancies relatively to that frameworks conventionally constructed by casting technique.

REFERENCES

1. Mousa MA, Abdullah JY, Jamayet NB, El-Anwar MI, Ganji KK, Alam MK, Husein A. Biomechanics in removable partial dentures: a literature review of FEA-based studies. BioMed research international 2021;2021.5699962
2. Akl MA, Stendahl CG. Removable partial denture frameworks in the age of digital dentistry: A review of the literature. Prosthesis 2022;4(2):184-201.
3. Saad AS, Abbas FS, Elgharabawy SH. Clinical evaluation of removable partial denture constructed from 3d printed resin pattern designed using CAD CAM technology. Alexandria Dental Journal 2019;44(2):15-21.
4. Im C-H, Park J-M, Kim J-H, Kang Y-J, Kim J-H. Assessment of compatibility between various intraoral scanners and 3D printers through an accuracy analysis of 3D printed models. Materials 2020;13(19):4419.
5. Pereira ALC, de Medeiros AKB, de Sousa Santos K, de Almeida ÉO, Barbosa GAS, Carreiro AdFP. Accuracy of CAD-CAM systems for removable partial denture framework fabrication: A systematic review. The Journal of prosthetic dentistry 2021;125(2):241-248.
6. Al-Angari N, Algarni S, Andijani A, Alqahtani A. Various classes of removable partial dentures: A study of prevalence among patients attending a dental and educational institute in Riyadh, Saudi Arabia. The Saudi Dental Journal 2021;33(7):656-660.
7. Chen H, Li H, Zhao Y, Zhang X, Wang Y, Lyu P. Adaptation of removable partial denture frameworks fabricated by selective laser melting. The Journal of prosthetic dentistry 2019;122(3):316-324.
8. Ahmed N, Abbasi MS, Haider S, Ahmed N, Habib SR, Altamash S, Zafar MS, Alam MK. Fit accuracy of removable partial denture frameworks fabricated with CAD/CAM, rapid prototyping, and conventional techniques: A systematic review. BioMed research international 2021;2021(1):3194433.
9. Waldecker M, Rues S, Behnisch R, Rammelsberg P, Bömicke W. Effect of scan-path length on the scanning accuracy of completely dentate and partially edentulous maxillae. The Journal of Prosthetic Dentistry 2022.131(1):146-154
10. Kim D-Y, Lee K-E, Jeon J-H, Kim J-H, Kim W-C. Evaluation of the reproducibility of various abutments using a blue light model scanner. The journal of advanced prosthodontics 2018;10(4):328.

11. Katheng A, Kanazawa M, Iwaki M, Arakida T, Hada T, Minakuchi S. Evaluation of trueness and precision of stereolithography-fabricated photopolymer-resin dentures under different postpolymerization conditions: An in vitro study. The Journal of Prosthetic Dentistry 2022;128(3): 514-520.
12. Zakaria NH, Hammad IA, Aly YM. Influence of wax and resin patterns on the color of IPS e. max Press ceramic: an in vitro study. Alexandria Dental Journal 2023;48(3):118-123.
13. Negm EE, Aboutaleb FA, Alam-Eldein AM. Virtual evaluation of the accuracy of fit and trueness in maxillary poly (etheretherketone) removable partial denture frameworks fabricated by direct and indirect CAD/ CAM techniques. Journal of Prosthodontics 2019;28(7): 804-810.
14. Yager S, Ma J, Ozcan H, Kilinc H, Elwany A, Karaman I. Mechanical properties and microstructure of removable partial denture clasps manufactured using selective laser melting. Additive Manufacturing 2015;8:117-123.
15. Jin Z, Cao F, Cao G, Zhang C, Qiu Z, Zhang L, Shen H, Jiang S, Huang Y, Ma M. Effect of casting temperature on the solidification process and (micro) structure of Zr-based metallic glasses. Journal of Materials Research and Technology 2023;22:3010-3019.
16. Khan MAA, Sheikh AK, Al-Shaer BS, Khan MAA, Sheikh AK, Al-Shaer BS. Evolution of metal casting technologies—a historical perspective: Springer; 2017:1-43
17. Tasaka A, Shimizu T, Kato Y, Okano H, Ida Y, Higuchi S, Yamashita S. Accuracy of removable partial denture framework fabricated by casting with a 3D printed pattern and selective laser sintering. Journal of prosthodontic research 2020;64(2):224-230.
18. Stamenković D, Djuričić KO. Dentistry 4.0 concept in designing and manufacturing removable partial denture frameworks. Vojnosanitetski pregled 2023;80(08).
19. Rues S, Tasaka A, Fleckenstein I, Yamashita S, Rammelsberg P, Boehm S, Schwindling FS. Fit and Retention of Cobalt–Chromium Removable Partial Denture Frameworks Fabricated with Selective Laser Melting. Journal of Functional Biomaterials 2023;14(8):416.
20. Arnold C, Hey J, Schweyen R, Setz JM. Accuracy of CAD-CAM-fabricated removable partial dentures. The Journal of prosthetic dentistry 2018;119(4):586-592.