EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 3771:3782, October, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 06-09-2022 • Accept Date : 12-10-2022 • Available online: 01-10-2022 • DOI :10.21608/edj.2022.161264.2248

EVALUATION OF METAL BASE ADAPTATION AND CLINICAL RETENTION OF UPPER COMPLETE DENTURES WITH A CO-CR METAL PALATE CONSTRUCTED BY TWO DIFFERENT APPROACHES

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ABSTRACT

Purpose: The objective was to evaluate metal base adaptation and clinical retention of upper complete dentures with a CO-CR metal palate constructed by two different approaches (casting a 3d printed wax resin pattern, Selective laser melting (SLM) 3D printing technology).

Material and methods: A total of seven completely edentulous patients were included in this study, for each patient two complete dentures were fabricated. According to the approach used for the fabrication of metal palatal plate (MPP) of the maxillary denture, they divided into two groups (GI: MPP constructed by casting a 3d printed wax resin pattern ,GII: MPP constructed by direct 3d printing. (Selective laser melting (SLM)). To evaluate the adaptation of each MPP, Surface matching software was used to superimpose the scan files for each MPP on those for the corresponding processing cast. Retention force was measured one week and one month following denture insertion using a digital force gauge. The measurements were taken and subjected to statistical analysis.

Results: better adaption was found for MPP constructed via casting 3d printed resin pattern than those by direct printing approach. However, the difference between the two groups was statistically non-significant, with clinically accepted retention following denture insertion.

Conclusion: Within the limitations of this study, it was found that complete maxillary dentures with MPP constructed by casting a 3d printed resin pattern introduced better adaptation than those constructed via direct 3d printing (Selective laser melting technology. However, the difference between both groups was statistically non-significant. Both approaches revealed clinically accepted retention.

KEY WORDS: denture adaptation, retention, direct 3d printing, metal palatal plate, wax resin pattern

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INTRODUCTION

Complete dentures are commonly the first line of treatment for edentulous patients, are accepted by patients as they provide a pleasing appearance, normal speech, and support and adequate means for food mastication. [1]

Dentures are frequently subjected to a combination of compressive, tensile, and shearing stresses, which are traumatic to both soft and hard tissue of the denture bearing surface in ill-fitting dentures. [2] PMMA denture bases offer good mechanical, biological, and aesthetic qualities, but they can fail if masticatory or functional stresses are too great. In such circumstances metal denture base can be used. [3, 4]

Metals and metal alloys are cast into thin sheets and used into denture bases to increase rigidity and fracture resistance. [5] Because the metallic denture base is thinner, there is less interference with phonation. [6] These bases are more accurate and stable in terms of dimension. Enhancing tissue health is increased also due to metal bases highly thermal conductivity. [7]

Despite their numerous benefits, metal denture bases are not widely used in clinical practice. Dentures bases made of metal are more retentive, have less Occlusal discrepancy, cause lesser sore spots, have a lower incidence of fracture, feel better in the mouth, act as a stable record base, effectively preserve the residual alveolar ridge, are less porous, deform less during lateral mandibular function, and are more accurate in tissue detail. [3]

Reinforced Complete dentures (CD) with metal bases (framework) (MB) are occasionally used in rehabilitation of edentulous patients, particularly in cases of high risk of fracture caused by opposing natural dentition, also in patients with neuromuscular disorders. [8, 9] Age should not be a contraindication for CDMB fabrication, but according to the data in the literature CDMB are usually fabricated for older edentulous patients. [10, 11]

A primary goal in the production of complete dentures is to achieve a denture base that is well-adapted to the supporting tissues. Complete denture retention is dependent on good denture base adaption. [12, 13]

For metallic prostheses, the traditional lost-wax casting technique is most commonly used in dentistry. Defects and inaccuracies caused by this labor-intensive casting process, which can take up about a week to complete, need the development of innovative methods to meet client demands nowadays.

Recent research achievements in the areas of computer-aided design and computer aided manufacturing (CAD/CAM) technology have created alternative routes to fabricate dental prostheses and dental implants. [14]

Rapid prototyping techniques can be used to fabricate metal bases for complete dentures with predictable outcomes. This technology eases and speeds up the design and fabrication of complex dental prostheses with satisfactory mechanical and electrochemical properties. [15,16]

The implementation of selective laser melting (SLM) can overcome some of the difficulties related to casting. Dental prostheses fabricated by using SLM are produced by fusing layers of metal powders or polymers under the heat of a focused laser beam directed by a computer aided design (CAD) file This manufacturing method is rapid, with minimal waste of material, and generates prostheses with a highly homogenous microstructure, minimal porosities, high nominal density, good corrosion resistance, and an accuracy three times better than cast frameworks. [17,18]

The amount and location of dimensional change that happens during denture processing has been evaluated using a variety of approaches. There were 2-dimensional and 3-dimensional measurements of varying degrees of complexity among them. Laser and contact scanners have recently become common tools for determining denture base deformation. Scanned files can be superimposed and analysed using modern computer software with the help of these technologies. The validity of these evaluation approaches has been shown in certain studies. [19-20]

The objective of this study was to evaluate metal base adaptation and clinical retention of upper complete dentures with a CO-CR metal palate constructed by two different approaches (metallic palatal plate constructed by casting a 3d printed wax resin pattern, Selective laser melting (SLM) 3D printing technology) to determine which technique produces the most accurate, retentive denture base.

Null hypothesis

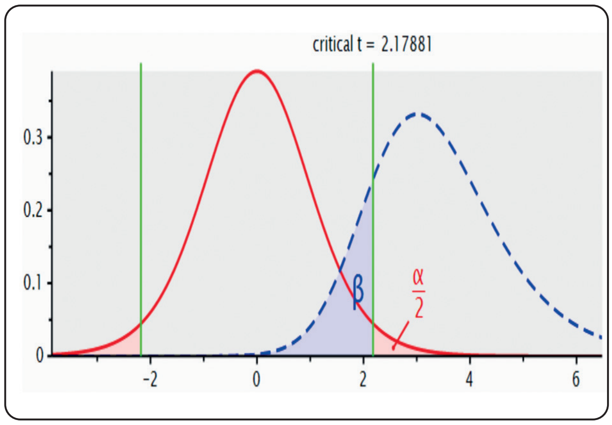
The null hypothesis was that no differences between the two approaches (metallic palatal plate constructed by casting a 3d printed wax resin pattern, Selective laser melting 3D printing technology) as regard to metal palatal plate adaptation and denture retention

MATERIALS AND METHODS

This study was carried out in the department of prosthodontics, faculty of oral and dental medicine zagazig university.

The present study was accepted by the ethical committe of sini university, with protocol code Proth 1-4-022. Informed consent was obtained from all patients invoved in the study. A total of seven completely edentulous patients were included in this study,all patients recieved two successive complete dentures with two different approaches for the fabrication of metal palatal plate.(cross over study)

Sample size calculation was based on average adaptation on Posterior palatal seal between groups retrieved from previous research (Goodacre et al., 2016). Using G*power version 3.0.10 to calculate sample size based on effect size of 1.70, 2-tailed test, α error =0.05 and power = 80.0% then total sample size will be 7 in each group at least .



The patients were selected with age range 45 to 60, free from systemic diseases which can affect denture retention, have healthy mucoperiosteum without any signs of inflammation, patients free from any temporomandibular joint disorders.

The preliminary phases of metal base denture construction did not differ significantly from conventional resin-base techniques. Preliminary impressions of the edentulous maxilla and mandible were made with alginate impression material (Cavex medium set, Cavex dental, Holland) and plaster cast was poured for the construction of a custom special tray. The peripheral tracing procedures were accomplished with green stick impression compound (HiFlex tracing compound, Prevest den pro, India) and the secondary impression was made with zinc oxide eugenol impression material (Cavex, Caves dental., Holland). Master cast was made with dental stone Type III (GH dental stone, Egypt). Master casts were duplicated using silicone (Coloresin, Egypt) for cobalt-chrome-molybdenum metal base fabrication. After this procedure refractory copies of the master casts were provided. The casts were scanned with laboratory scanner (iSeries scanner, Dental Wing Inc, USA), and the scanned Stl file then transferred to the design software (Geometric Control x, 3D system Inc.) to be used in designing the complete maxillary plate. Figure (1-a, 1-b)

According to the approach used for the fabrication of metal palatal plate, two groups were recognized:

Group I: maxillary dentures with a metallic palatal plate constructed by casting a 3d printed wax resin pattern (casting).

Group II: maxillary dentures with a metallic palatal plate constructed by direct 3d printing. (Selective laser melting (SLM) 3D printing technology) (laser).

For the first group, After the designing process was completed, the design Stl file was send to PreForm software (Formlabs, USA) to add the supporting structures and to prepare the design for a 3D Nesting software translates and rotates automatically a collection of 3D parts inside the printing space (the 3D build) in order to minimize empty space and optimize the quality of the printed parts, after that the orders were send to the 3D printer (Formlab2, formlabs, USA) to print the patterns design, a castable wax resin cartridge (Formlabs, USA) was loaded into the printer before the printing process. After printing process completed, the patterns were washed with isopropyl 99% concentration for 15 min, and after that the supporting structures were removed using a separating disc, and the patterns were prepared rapidly for casting, to avoid contraction of the wax resin. [21]

On the refractory cast the denture base resin pattern was adapted and the sprues were attached Figure (2-a, 2-b) & invested. The denture base was casted with nickel - chromium metal. The denture base covered the palate and residual ridges in the maxillary cast with retentive loops extending on the ridges and the posterior palatal seal area for mechanical retention of acrylic resin and teeth to the metal. Figure (3)

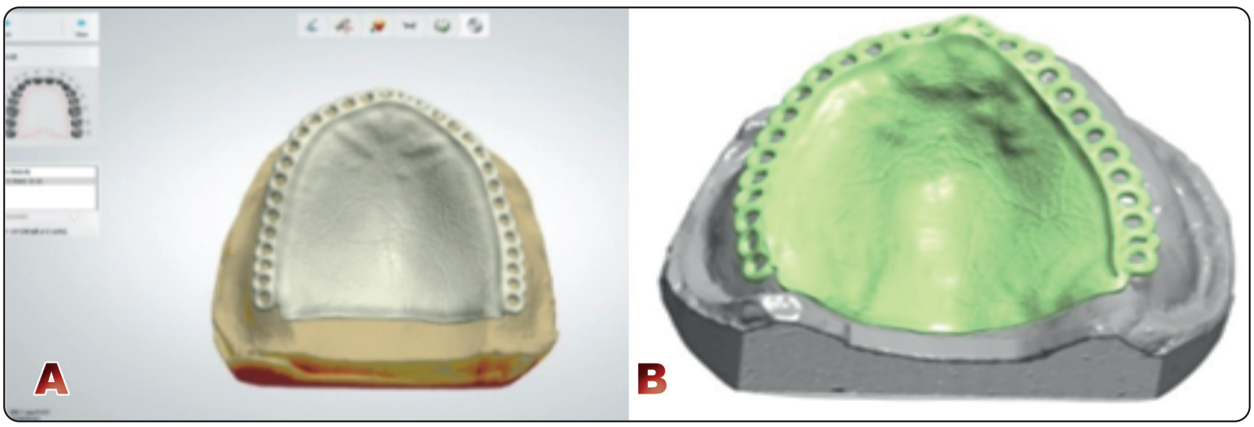


Fig. (1). Designing the complete maxillary plate,

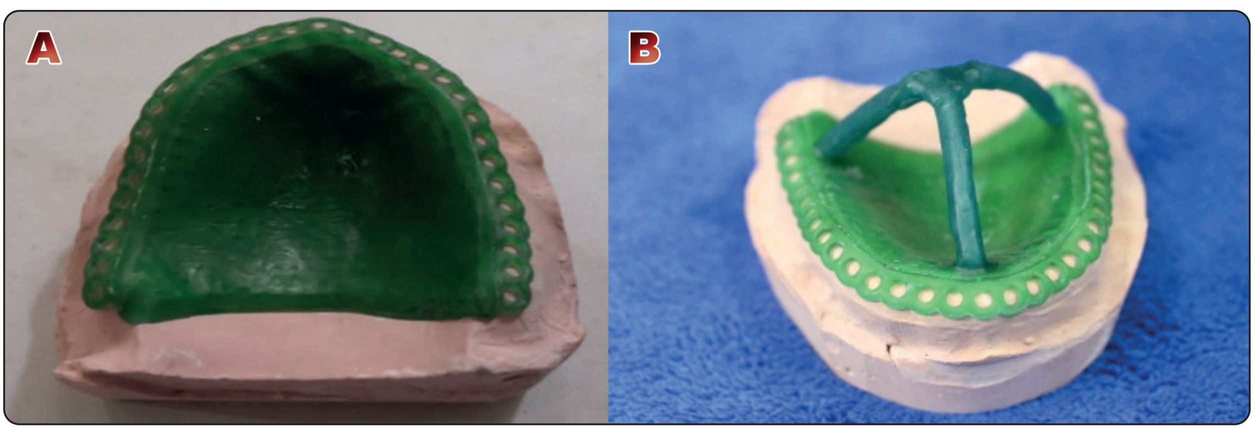


Fig. (2). 3d printed &sprued resin pattern,

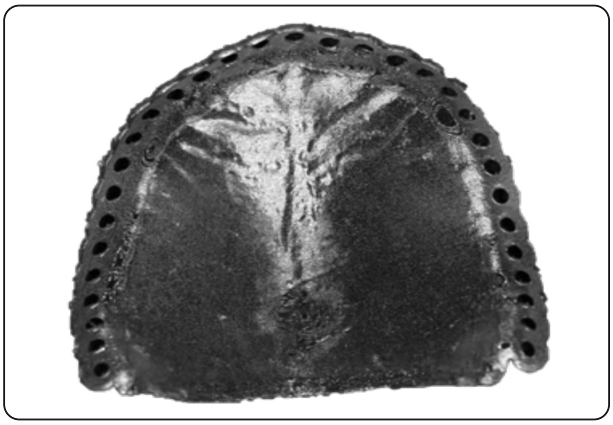


Fig. (3). The casted metal palatal plate.

Fig. (4). The 3D printing of the metal palatal plate

For the second group, An SLM 3D printing machine was used (Vulcantech VM120, Hanover, Germany) to complete the 3D printing of the metal palatal plate using Co-Cr alloy powder as the printing material. Figure (4).

Superimposition

Hydration of metal bases were done for 24 hours, making sure that the intaglio surfaces of the metal plates were not finished or polished. The intaglio surfaces of each were then lightly sprayed with anti-glare spray (3-D laser scanning anti-glare spray; Helling) with an average particle size of 2.8 mm to lower the reflectivity and albedo of the intended surface. and scanned using the (iSeries scanner, Dental Wing Inc,USA) which produced an STL file for each intaglio surface. Using surface matching software (Geomagic Control X; 3D Systems, Inc), each denture's STL file was superimposed on the STL file of the associated processing cast. Measurements were taken at 20 places for each of the 14 palatal plates using this software, with an overlay guide to confirm the position of the measurements. Figure (5-a,5-b) Furthermore, colour surface maps were developed to visually demonstrate the metal base's adaptation to the cast.

Surface matching and measurements were used to assess fit discrepancies in the crest of the ridge, palate, and posterior palatal seal area, as well as the incisive papillae. Figure (6)

The Denture bases with metal palatal plate were fabricated. Trial denture base and occlusion rim were fabricated. Jaw relation records were used to mount and confirm the positions of the maxillary and mandibular casts at this point.

Denture manufacturing was carried out utilizing a traditional procedure including the use of a heat cure resin poly methyl methacrylate and a metal framework at each maxillary cast. To improve the strength of the metal-acrylic junction, a butt joint was formed palatal to the crest at the junction of the two materials. This helps in creating a smooth joining of acrylic with metal avoiding any step formation, thus making it comfortable for the patient. [22]

After the flask was removed from the injection machine, the flask was left to bench cooling for at least 30 minutes. Laboratory remount was carried out before finishing and polishing of dentures. Figure (7-a)

Maxillary denture was inserted into the patient's mouth after the occlusal adjustment, and proper care and maintenance of the prosthesis instructions were given to the patient.

Retention clinical evaluation

For all patients one week after denture insertion,

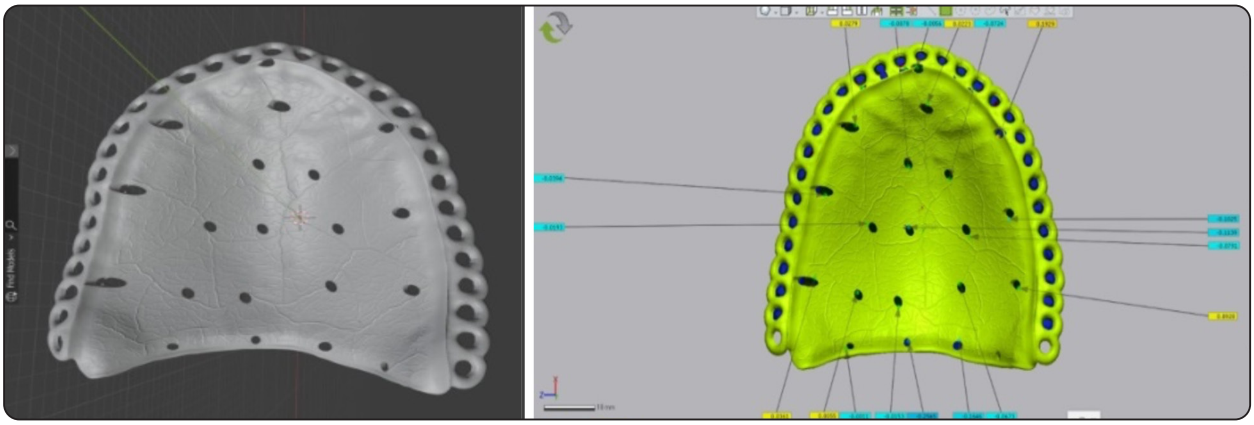


Fig. 5 (a,b). An overlay guide to verify the location of the 20measurements.

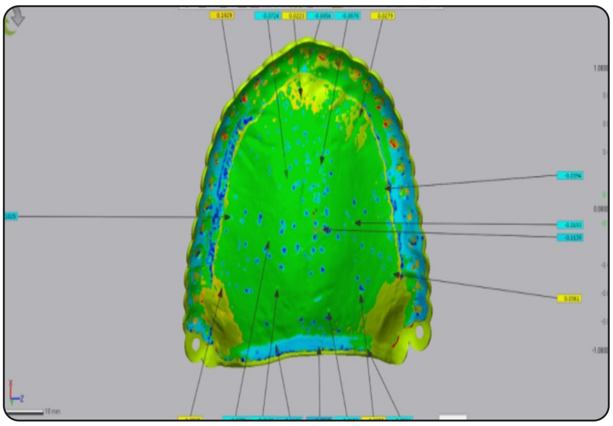


Fig. (6). Color surface mapping.

a readymade metallic bar was attached to the contact area between upper second premolar and upper first molar bilateral using self-cure acrylic resin, its center coincides with the geometrical center of the denture. The geometrical center of the maxillary denture was determined by drawing intersection of two lines the first one (midline) extended between the incisive papilla anteriorly and fovea palatine posteriorly and the second line horizontally extended between the contact of second premolar and the first molar bilaterally. Figure (7-b)

Retention was measured using digital force gauge. The device was prepared first, the unit of measurement was chosen to be in Newton and the peak hold option was selected.

The desired adaptor tension hook was attached to the sensing head. The display before each measurement was adjusted to be zero via the zero buttons.

The tested denture was rinsed thoroughly with water prior to its insertion. The patient was asked to rinse his mouth with water too.

The maxillary denture was inserted in the patient's mouth and allowed to remain for settling time of 5 minutes before the notch of the metallic bar was engaged. The tip of the metal rod of the gauge was painted with pressure indicating paste.

The patient was seated upright in the dental chair with his mouth open and the lips relaxed, the palate and the maxillary ridge were nearly 45^{o} to the horizontal plane and the mandible nearly parallel to the floor. The dislodging force was applied to the denture and increased gradually till the denture was dislodged. Figure 8(a,b)

Retention force was measured as the maximum force needed to completely dislodge the maxillary denture. This step was repeated three times, three readings were taken and the average was recorded for each patient in both groups. The bar was removed at the end of the visit and the denture was given to the patient.

The same measuring procedures were repeated one month after denture delivery. Data collected was tabulated and statistically analyzed. [23]

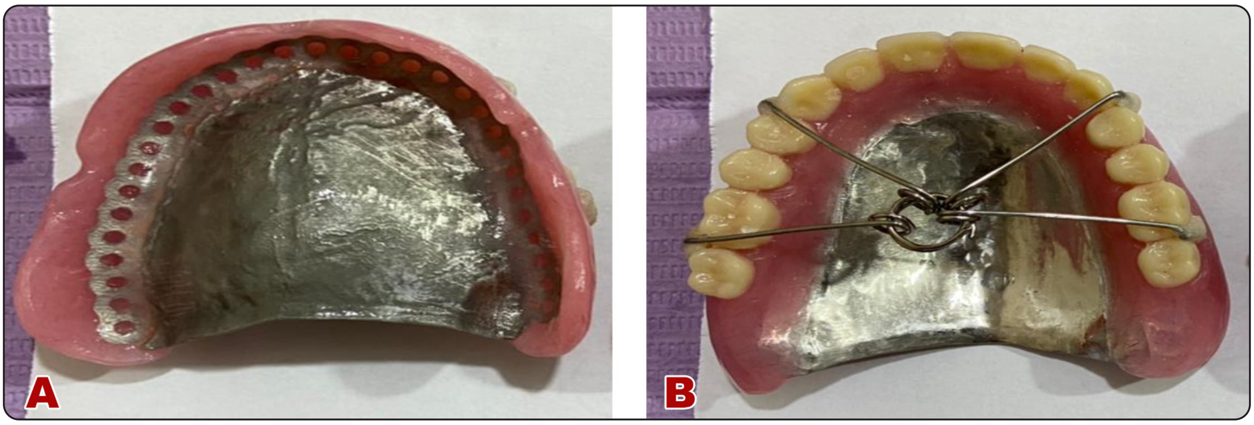


Fig. (7) a. finished maxillary denture; Figure 7-b. finished maxillary denture with metallic bars

Fig. 8 (a,b). The casted metal palatal plate, Figure 4. the 3D printing of the metal palatal plate

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using number and percent. Quantitative data were described using median (minimum and maximum) and mean, standard deviation for normally distribute data after testing normality using Kolmogrov-Smirnov test. Significance of the obtained results was judged at the (0.05) level.

Data analysis

Qualitative data

- Student t-test was used to compare 2 independent groups
- Paired t test to compare between 2 studied periods.
- Mann-Whitney U test was used to compare 2 independent groups

RESULTS

The results of this study led to the partial acceptance of the null hypothesis , study confirmed difference between the two different approaches (metallic palatal plate constructed by casting a 3d printed resin pattern, Selective laser melting 3D printing technology as regard to metal palatal plate adaptation and denture retention. With only differences in adaptation at crest of ridge , incisive papilla

Table (1) showed better adaption was found for

MPP constructed via casting 3d printed resin pattern than those by direct 3d printing approach (Selective laser melting), However the difference between the two groups was statistically non-significant in the midline and denture foundation , A statistically significant difference was found for Crest of the ridge and Incisive papilla median values with higher median value among laser than casting group.

The first group (casting 3d printed resin pattern) had the narrowest distribution of dimensional distortion which was located closest to zero, it was an evident that it produced the most uniform adaptation of the denture base to the cast, and statistical analysis of the measurements confirmed this finding, therefore it was the most accurate technique as shown in figure 12.

TABLE (1): comparison of adaptation between casting and laser

Adaptation/mm	Casting	Laser	test of significance
Posterior palatal seal	-0.005±0.027 -0.008(-0.046, 0.046) (-0.162 , -0.005)	0.020±0.039 0.012(-0.037, 0.088) (0.007, 0.052)	z=1.86 p=0.073
Crest of the ridge	-0.028±0.026 -0.011(-0.063,-0.003) (-0.051 , -0.003)	-0.077±0.047 -0.0929(-0.126 ,- 0.0139) (-0.113 , -0.0139)	z=2.38 p=0.017*
Incisive papilla	0.0079±0.005 0.006(0.0013,0.0123) (0.0013 , 0.0123)	0.025±0.015 0.024(0.0076, 0.0438) (0.0076 , 0.0438)	z=2.63 p=0.008*
Palate	0.0311±0.039 0.0342(-0.054 ,0.061) (-0.032, 0.056)	0.0595±0.059 0.0628(-0.0426, 0.1415) (0.033, 0.094)	z=1.35 p=0.209
total	0.002±0.033 0.00039(-0.063 , 0.06) (-0.0106, 0.0272)	0.007±0.066 0.0121(-0.126 ,0.142) (-0.031 , 0.0438)	z=1.05 p=0.294

Adaptation described as mean±SD, Median(Range)

Z:Mann Whitney U test ,*statistically significant

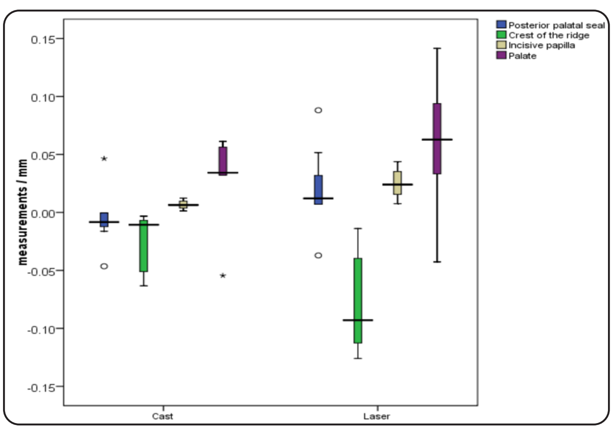


Fig. (9) Box & Whisker plot showing median adaptation /mm among studied groups

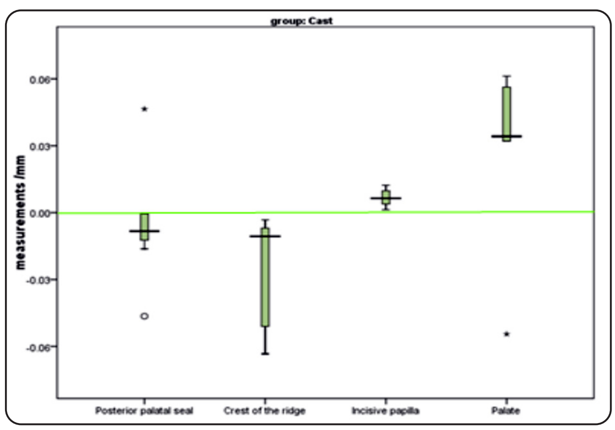


Fig. (10) adaptation by locations .Bold, black horizontal line within each box represents median value for the first group (casting metal from resin pattern) yellow horizontal line at zero represents ideal contact with cast

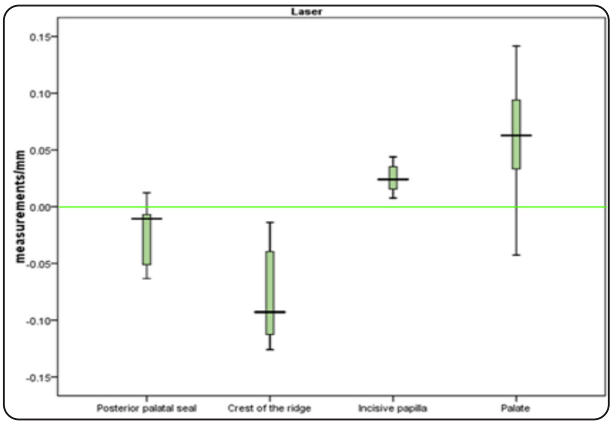


Fig. (11) adaptation by locations, Bold, black horizontal line within each box represents median value for the second group (direct 3d printing metal alloy) yellow horizontal line at zero represents ideal contact with cast

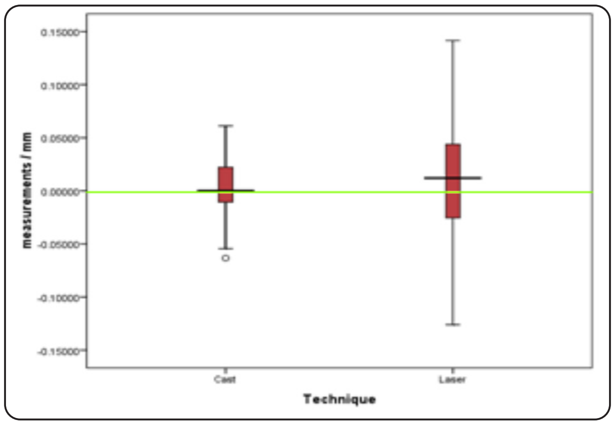


Fig. (12) Overall adaptation results comparing the two techniques. yellow horizontal line at zero represents ideal contact with cast

Table (2) shows that there is no statistically significant difference between the casting 3d printed resin pattern and direct 3d printing groups (casting and laser groups) as regarding retention at insertion and after one month. For casting group ; there is statistically significant increase of mean retention from 27.14 at insertion to 28.57 after one month and for laser group ; there is statistically significant increase from 25.86 to 26.86. Figure.13

TABLE (2): comparison of retention between casting and laser

Retention	Casting	Laser	Test of significance
Retention at insertion	27.68.1±14	25.86±1.07	t=1.71 p=0.113
Retention One month later	28.62.1±57	26.86±0.89	t=2.45 p=0.031*
Paired t test	t=4.80 p=0.003*	t=4.58 p=0.004*	

retention described as mean±SD

t: Student t test,*statistically significant

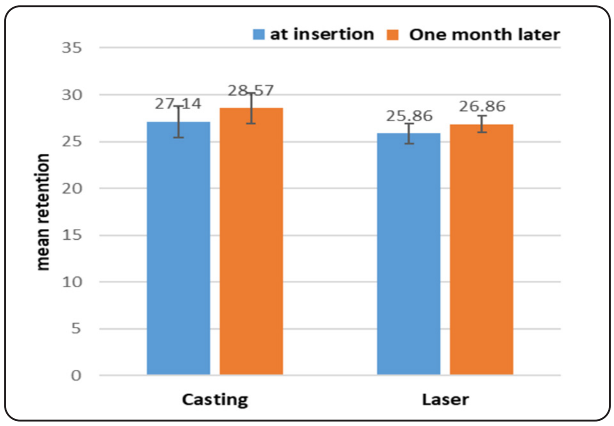


Fig. (13) means retention value of the studied groups

DISCUSSION

A primary goal in the construction of complete dentures is to achieve a denture base that is well-adapted to the supporting tissues. Complete denture retention depends on good denture base adaption. [13, 14]

According to previous study, Dentures distort during processing, resulting in decreased retention, stability, and support. [24] This decrease in retention, stability, and support has a negative impact on the patient’s comfort, and it increases the clinician’s chair time due to the adjustments that must be made.

In the design and manufacture of fixed and removable prostheses, computer-aided design and, computer-aided manufacturing (CAD/CAM) technologies are commonly utilized. RPD frameworks can be milled directly from metal or polymer. The framework for a resin or wax pattern can be 3D printed and then processed using traditional fabrication processes. [25]

As a result, the rapid prototyping technique (RP) was utilized in this study because it has lately gained popularity and offers a variety of innovative procedures. [26]

The current study recommends that complete dentures with metal palates be developed with An extended distal edge of metal framework for improved stability and natural mastication and speech. [27] This was based on the findings of Ohkuba et al study, which found that patients were more likely to accept CDMB if the complete denture was designed in a classic-conventional style. [28]

Because Cobalt-chromium (Co-Cr) alloys have been widely used in dentistry for removable partial dentures and metal frames, mainly because alloys are strong, resistant to corrosion, and relatively inexpensive, when compared to gold alloys, more tissue tolerant and resistant to deformation than acrylic denture base, a metal palate cast from Cobalt-chromium (Co-Cr) alloys had been used as a complete denture palate in this study. [29-31]

The intaglio surface of the frameworks was not finished or polished to maximise the validity of the investigation and reduce induced human error during manufacture. This methodology was based on a study by Brudvik and Reimers, who found that after finishing and polishing Co-Cr frameworks, an average of 127 m of metal was lost from the surface. [32]

A disadvantage of previous approaches for evaluating the fit and accuracy of cobalt-chromium palatal plates is that these measurements were taken in specific locations and so do not reflect the true overall fit of the framework. We were able to acquire many data points and determine the greatest possible fit between the master cast and the palatal plates using our process, which involved digital superimposition of the STL format of the scanned models. Furthermore, colour mapping was used to detect sections of the frameworks that were over-pressed or misfit. Overall, the CAD-RP frameworks had more gaps, but the cast frameworks had more tissue contacts and compressibility.

Based on the result attained in the present study, the MPP constructed by conventional casting from resin pattern introduced better adaptation than those constructed by direct 3d printing with a statistically non-significant difference between the two groups ($p=0.294$). Casting from resin pattern showed smaller mean for gaps (0.002 ± 0.033) compared to direct 3d printing (0.007 ± 0.066).

However both results produced a clinically acceptable fit and retention.

These results were in agree with studies of Pooya Soltanzadeh [33] and Arnold et al [34] who found that no significant differences were found in the accuracy of fit between conventionally cast metal palate from resin or printed frameworks (from direct digitizing scans), with the CAD-printing frameworks exhibited the highest discrepancies but were within clinically acceptable limits. This could be due to software errors caused by the STL files being processed. [35]

A measurement value of zero indicates that there has been no processing deformation and that the denture base has adapted perfectly to the cast. The optimal processing technique is determined by the ability of the processing procedures to create a denture that is accurate, with a median value close to zero, with the smallest interquartile range possible.

To summarize the ranking results from the median and interquartile range, the casting 3d printed resin pattern approach median and interquartile range values were more consistently localized around zero at the four locations (-0.0106, 0.0272) for casting group and (-0.031 , 0.0438) for the laser group. Therefore, of the two techniques evaluated, the casting 3d printed resin pattern technique (cast) demonstrated the most uniform distribution of adaptation, while the 3d direct printing technique (laser) showed the least uniform distribution of adaptation.

Also, color mapping and statistical analysis revealed compression areas and negative values, specifically in the casting 3d printed resin pattern technique (cast). These regions mean closer contact areas more importantly at the posterior palatal seal area, indicating there would be potentially more tissue compressibility clinically, that was represented later by better retention for the casting group.

The results revealed clinically accepted retention values for maxillary complete dentures constructed by both approaches. However increased retention mean values were found for maxillary dentures with MPP constructed by casting a resin pattern with non- statistically significant difference between the two groups at insertion and one month later. It's possible that this is due to the flexibility of human oral mucosa and gingival tissue. Even if there are certain deviations between the metal palatal plates and the dental cast, the soft tissue will create an adequate non uniform deformation to compensate for the gap after wearing a denture.

However, the more MPP deviations there are, the more adaptive non-uniform deformation in the soft tissue occurs. As a result, an improvement in retention in both groups emphasises neuromuscular coordination, physical factors, and posterior palatal seal effectiveness. [36, 37]

CONCLUSION

Within the limitations of this study, it was found that complete maxillary dentures with MPP constructed by casting a 3d printed resin pattern introduced better adaptation than those constructed via direct 3d printing (Selective laser melting (SLM) technology . However the difference between both groups was statistically non-significant. Moreover both approaches revealed clinically accepted retention following insertion and one month later.

Conflict of interest

The current study exhibited author self-funding, without any conflict of interest.

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