

Masticatory performance and patient satisfaction of metal-reinforced and CAD/CAM-fabricated acrylic resin mandibular complete dentures

Shady M. El Naggar^a, Abdelrahman Maged^b, Ayman F. Elawady^c, Tarek AbdAllah Mahmoud^d

^aRemovable Prosthodontics Department, Faculty of Oral and Dental Medicine, Badr University, ^aRemovable Prosthodontics Department, Faculty of Dentistry, Modern University for Technology and Information, Cairo, ^bRemovable Prosthodontics Department, Faculty of Dentistry, Misr International University, Misr, ^cFixed and Removable Prosthodontics Department, Oral and Dental Research Institute, National Research Centre, Dokki, Giza, Egypt

Correspondence to Ayman F. Elawady, PhD, Department of Fixed and Removable Prosthodontics, Oral & Dental Research Institute, NRC, Dokki 12622, Cairo, Egypt. Tel: +20 111 142 5800; fax: +20 233 371 635; e-mail: monyawadys82@yahoo.com

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Background/aim

The masticatory problem of removable complete dentures had been introduced by many researchers to be assisted by many recent technologies. Solving such issues advances self-patient satisfaction, confidence, and motivation. This study aimed to evaluate masticatory performance and patient satisfaction of metal-reinforced and CAD/CAM-fabricated acrylic resin mandibular complete dentures.

Patients and methods

Sixteen completely edentulous patients were divided randomly following a 1 : 1 allocation ratio into two groups; group I received maxillary and mandibular complete dentures constructed from acrylic resin reinforced with chrome cobalt framework and group II received maxillary and mandibular rapid prototype complete dentures (3D-printed) using the CAD/CAM technique. At baseline, 2, and 4 weeks, masticatory performance using the masticatory efficiency index and patient satisfaction using Borerrigter's method of assessing patient satisfaction were evaluated at each interval for further statistical analysis using one-way analysis of variance test followed by Tukey's post-hoc test for multiple comparisons and Pearson's correlation coefficient between different variables.

Results

Regarding masticatory performance for each group, one-way analysis of variance revealed a significant difference between different intervals as a *P* value less than 0.05 with higher masticatory values for group II, while for patient satisfaction, it showed an insignificant difference for all satisfaction domains as a *P* value more than 0.05. The correlation between masticatory performance and overall patient satisfaction was calculated using Pearson's correlation coefficient and revealed a moderate to strong, positive, significant correlation in both groups.

Conclusion

The masticatory performance and patient satisfaction of mandibular complete dentures constructed by the 3D-printed CAD/CAM method were higher than acrylic resin denture bases reinforced with chrome cobalt framework, denoting that the 3D-printed CAD/CAM method can be the primary clinical treatment option for completely edentulous patients despite its overall level of satisfaction, which requires additional follow-up investigations to pronounce the positive effect of CAD/CAM dentures.

Keywords:

CAD/CAM, denture, mastication, metal, printing

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Introduction

Due to population aging in industrialized nations and poor dental care in developing nations, edentulism has been a significant public health issue in both of these areas. Edentulism has an impact on the nutritional intake and quality of life of edentulous patients. Although the age-specific rates of edentulism are expected to decline, the need for complete dentures will continue to rise in the next decades [1]. Edentulism is even categorized by the WHO as a physical impairment [2].

Masticatory performance is defined by the Glossary of Prosthodontic Terms as 'a measure of the

comminution of food attainable under standardized testing conditions [3].' Mastication's main purpose is to create a bolus that may be properly eaten [4]. In addition to breaking down solid food, mastication also entails modifying the consistency of the food to make it easier to swallow [5]. The process of chewing, or the breakdown of food by the teeth into a form that can be sent to the esophagus, is crucial [6]. Because of this, food is prepared in the mouth (mastication), then it is

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ingested. Chewing is the first stage in the digestion process because it gets food ready for swallowing and the processes of the digestive system [7]. Oral food processing is necessary for sensory perception as well [8]. The fraction of evenly dispersed food particle size following a predetermined number of chewing cycles is known as masticatory efficiency, and it is used to assess the quality of mastication. The number of teeth, occlusal pattern, type of prosthesis, and the maximal bite force can all affect how well food is chewed [9].

Therefore, every step of the denture construction process should be given appropriate attention as retention plays a crucial part in the success of the entire denture. The denture base must have intimate mucosal contact to achieve effective retention. The majority of dentures are made of polymethyl methacrylate (PMMA), which is the material of choice. Dimensional shrinkage of the resin happens during polymerization. The denture base lifts away from the posterior palate as a result of polymerization due to shrinkage, which is brought on by the disparity in densities of the monomer and the polymer [10].

Increased patient awareness of retention and stability has been listed as advantages of utilizing different retentive means [11], improved patient satisfaction [12], and reduction in the prosthesis' displacement during use [13].

The drawbacks of heat-cured PMMA can be solved with alternative materials and methods, such as metal alloys and digital technology. In comparison to PMMA, metal alloys offer better mechanical and physical qualities. They have greater fatigue and fracture strengths, making them stronger. They can also be cast in thin portions without losing their stiffness or ability to resist fracture. This quality gives patients a natural 'feel' of the prosthesis in addition to its high thermal conductivity [14].

In addition to biocompatible, dimensionally stable, and polished to a high degree, metallic denture bases make it easier to maintain hygiene. They are especially helpful in circumstances when there is a high danger of fracture, and the denture base needs to be strengthened, such as when bruxism is present or when wearing single maxillary dentures [15].

Prosthodontics has seen extensive use of CAD/CAM technology. Complete denture production with CAD-CAM is characterized by the simplicity of fabrication and minimal laboratory processes. In addition, it results

in standardized fabrication and greater dimensional precision [16].

Denture bases with adjustable and minimal thickness thanks to the digital design are guaranteed to be the same thickness. In addition, the availability of digital data makes it possible to fabricate dentures in the future in case of lost ones [17].

The present study aims to evaluate masticatory performance and patient satisfaction between metal-reinforced and CAD/CAM-fabricated acrylic resin mandibular complete dentures.

Patients and methods

Patients

The present study enrolled 16 patients, who visited the Diagnostic Clinic and Dentistry Unit at the Faculty of Dentistry, Modern University for Technology and Information, and the Medical Excellence Centre at the National Research Centre in Cairo, Egypt.

Patients must meet the following requirements to be included: they must be between the ages of 45 and 75 years, have been completely edentulous for at least a year, and have a normal maxillomandibular connection, healthy mucosa, and normal salivary flow. Patients who smoked, had pathologies of the hard or soft tissues, had significant ridge undercuts, or had had radiation to the head and neck region were excluded.

Study design

This study was conducted (16 patients) as a randomized clinical trial following a 1 : 1 allocation ratio into two groups as follows:

Group I: eight patients received mandibular complete dentures constructed from acrylic resin reinforced with a chrome cobalt framework.

Group II: eight patients received maxillary and mandibular rapid prototype complete dentures (3D printed) using the CAD/CAM technique.

Ethical approval

The Medical Research Ethics Committee granted permission for the study to be conducted, which meets the National Research Centre and operates following the relevant Egyptian laws, the Helsinki Declaration, good laboratory and medical practice guidelines, and WHO regulations regarding the ethics of scientific research, with approval number: 8887082022. A written informed consent was

provided by each participant before their inclusion in the study.

Sample size calculation

A research of a continuous response variable was planned to utilize independent controls and experimental patients, with one control for each experimental participant. In a previous study [18], the responses within each participant group had a standard deviation of 10.69 and were normally distributed. To be able to reject the null hypothesis that the population means of the experimental and control groups are equal with a probability (power) of 0.8, we must study eight experimental patients and eight controls (a total of 16 patients) if the true difference between the experimental and control means is 16. The test of this null hypothesis has a type I error probability of 0.05.

Methods

Construction of metal-reinforced complete denture (group I)

Irreversible hydrocolloid impression material was used to make primary impressions. Proper border molding with a green stick compound was done followed by the secondary impression using a silicone impression material. Facebow was utilized to mount the maxillary cast on the articulator device. Jaw relation was recorded at the previously measured vertical dimension of occlusion using the wax wafer technique. Accordingly, the mandibular cast was mounted relying on the centric occluding relation. Duplication of the master cast using silicone material was done to obtain a refractory cast for the construction of the metal framework. Holes were made on the cast and adapted the wax pattern on it. Two rows of mesh wax patterns were adapted on the refractory cast, followed by spruing, investing, burning out, and casting of the metal framework. The metal framework was returned to the master cast and checked for adaptation, as shown in Fig. 1. After setting artificial teeth and try-in, models were waxed-up, invested in the flask, wax eliminated, and packing and curing of acrylic resin followed by finishing and polishing of the final acrylic denture were done.

Construction of the 3D model (group II)

Following the basic protocol for CDs, maxillary and mandibular preliminary impressions were sent to a dental laboratory for the fabrication of custom trays and occlusal rims. Occlusal rims and custom trays were made on the same stone casts. The borders were

Figure 1



Metal-reinforced mandibular complete denture.

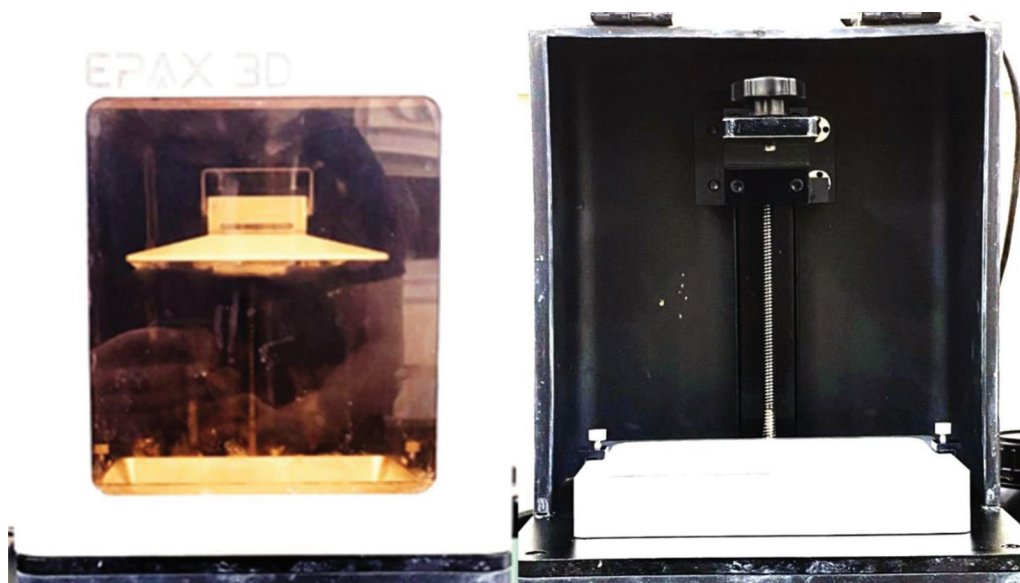
functionally molded with the green stick impression compound. The custom tray was loaded with a zinc oxide-eugenol-based impression paste and then poured to obtain the upper and lower master cast. Data were obtained by scanning upper and lower master casts with an extra-oral scanner (Medit T710, Seoul, Korea). The occlusion blocks were sprayed with scanner spray and then fitted on their master cast. Following that step, the same device was used to scan the blocks.

Designing procedures for files in standard tessellation language (STL) format of master casts and jaw relation records were imported to the Exocad software platform. The software enabled virtually simultaneous mounting and aligning. This in turn allowed further analysis and design to be completed. Each denture had two STL files that were printed separately; one for the denture base and one for the teeth using a 3D printer. Manufacturing procedures for the designed dentures STL files were sent to the 3D printer software. The dentures were printed with Stereolithography Apparatus technology using a desktop 3D printer (EPAX3D, Morrisville, North Carolina (NC), USA) as shown in Fig. 2. Pink denture base resin was used to print denture bases, whereas white teeth resin was used for teeth printing. Afterward, teeth were attached to recessed pockets in the denture base by means of a resin followed by finishing. Eventually, the denture was placed in the postcuring unit as shown in Fig. 3.

Masticatory performance assessment

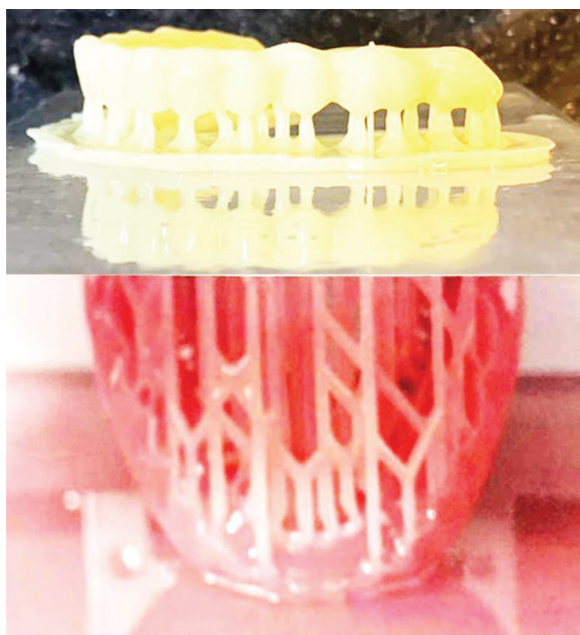
The patients were asked to sit upright in a dental chair, relaxing, and given one sample of carrot with 3 g in weight and asked to chew it on the patient's preferable side for 20 strokes counted by us, and asked never to

Figure 2



Stereolithography apparatus technology using a desktop 3D printer.

Figure 3



Additive manufacturing process of complete denture base.

swallow. The patient is asked to stop and spit the content of his mouth in a plastic cup, the denture is removed and inspected for any remnants, 20 ml of tap water was given to the patient, and the patient was asked to rinse his mouth and spit in the plastic cup. The oral cavity is inspected for any remnants. The collected material of each specimen was evacuated in 100 ml graduated laboratory specimen collection containers.

The carrot was spread over an absorbent filter paper and left for 1 h in a closed room to allow for drying. After 1 h the materials were ready for examination.

The total weight (T) in grams of the test sample is retrieved from the patient mouth after mastication (equals the sum of the weight of the materials in the three sieves and pan). The sum of the weight in grams of the chewed material accumulated on the sieve with an aperture of 4 mm was referred to as the coarsest fraction (X). The sum of the weight in grams of the chewed material accumulated on the sieve with an aperture of 2.8 and 1.4 mm was combined and referred to as the medium fraction (Y). The participant was instructed to chew a carrot (3 g) and then peanuts (3 g), to prefixed numbers of strokes (15 strokes) of mastication on the artificial teeth, and then spit the chewed sample (chewed test portions) in a container. The participant was asked to rinse with water and make a new expectoration of waste and then intraoral inspection to verify the absence of waste. The particles were washed and left to dry by air in a container and then recorded the weight of the particles. Vibration analysis through sieves of 4, 2.5, and 1.5 mm opening for 120 s. The weight of particles retained on each sieve was recorded.

The masticatory efficiency index $R=[1-x+y2T-x]$, where R =percentage of masticatory performance, X =weight in grams of material in the coarse fraction, Y =weight in grams of material in the

middle fraction, and T =total weight in grams of the test portion after chewing [18].

Patient satisfaction assessment

Patient satisfaction was assessed for each participant with their new complete denture prosthesis and their impact on psychological, esthetic, and functional rehabilitation. A designed patient questionnaire was given to each participant at baseline (delivery day of prosthesis), after 2 weeks and then after 4 weeks according to Borerriqter's method of assessing patient satisfaction with complete dentures. The questionnaire included five main domains as follows: functional complaint about the denture, overall masticatory ability, masticating ability for different types of food, effect of mental and daily life, and overall denture satisfaction, as shown in Fig. 4.

Each domain connected with many questions as domain 1 consisted of 13 questions, domain 2 of six questions, domain 3 of three questions, domain 4 of seven questions, and the last domain of nine questions. For the first two domains' scores were given from 1 to 4: (1=never, 2=sometimes, 3=often, 4=always). Domain 3 scored from 1 to 3 (1=well, 2=moderately, 3=badly). Domain 4 scored from 1 to 5 (1=never, 2=hardly ever, 3=occasionally, 4=fairly often, 5=very often), the last domain scored by the visual analog scale, and its last two questions were by yes or no. All scores were recorded and averaged and then reviewed by the statistician for data analysis.

Statistical analysis

All data were presented as means and SDs. Statistical analysis of the given data was performed using IBM SPSS software package, version 24.0 (IBM Corp., Armonk, New York, USA) and GraphPad Prism (GraphPad Software Inc., Boston, USA). Shapiro–Wilk and Kolmogorov–Smirnov tests were used to examine the given data for normality, and the results showed that the significant level (P value) was insignificant because the P value more than 0.05, which meant that all of the data came from a normal distribution (parametric data) that resembled a normal Bell curve. As a result, the independent t test was used to compare two groups, and the one-way analysis of variance (ANOVA) test was used to compare different intervals, followed by Tukey's post-hoc test for multiple comparisons. In addition, Pearson's correlation coefficient was used for all correlations.

Results

The masticatory performance of group I and group II at different intervals is presented in Table 1. At baseline, 2, and 4 weeks, group II revealed higher insignificant performance than group I using the independent t test revealing an insignificant difference at P value more than 0.05. Repetitive one-way ANOVA was used to compare different intervals, which revealed a significant increase in masticatory performance in both groups as P value less than 0.5, followed by Tukey's post-hoc test for multiple comparisons, which revealed that masticatory performance was

Figure 4



(a) Upper and lower edentulous arch before denture insertion, (b) denture satisfaction evaluation after insertion.

Table 1 Mean and SD of group I and group II regarding masticatory performance at baseline and different intervals

	Follow up	Group I (metal reinforced)		Group II (3D printed)		P value
		Mean	SD	Mean	SD	
Masticatory performance	Baseline	35.71 ^a	2.32	36.24 ^a	2.98	0.69
	2 weeks	38.65 ^{ab}	3.59	38.94 ^{ab}	3.45	0.87
	4 weeks	40.56 ^b	3.48	41.21 ^b	3.79	0.72
	P value	0.02*		0.02*		

All means with different superscript letters (a,b,c) in the same column are significantly different as *P* value less than 0.05. *Significant difference as *P* value less than 0.05 using analysis of variance test.

Table 2 Mean and SD of all domains and overall, regarding patients' satisfaction in both groups at different intervals and comparison between them

Patient satisfaction	Follow-up (N=8)	Group I		Group II		P value*
		Metal reinforced		3D printed		
		Mean	SD	Mean	SD	
Function complains	Baseline	17.11	3.8	16.85	3.74	0.89
	2 weeks	17.03	3.78	16.57	3.68	0.81
	4 weeks	16.98	3.77	16.31	3.62	0.72
	P value**	0.99		0.95		
Masticatory ability	Baseline	9.01	2	8.88	1.97	0.89
	2 weeks	8.65	1.92	8.12	1.8	0.57
	4 weeks	8.12	1.8	7.85	1.74	0.76
	P value**	0.64		0.52		
Chewing ability	Baseline	4.62	1.03	4.32	0.96	0.55
	2 weeks	4.45	0.99	4.18	0.93	0.58
	4 weeks	4.32	0.96	3.89	0.86	0.36
	P value**	0.81		0.63		
Effect on mental and daily life	Baseline	11.39	2.53	11.16	2.48	0.85
	2 weeks	11.12	2.47	10.91	2.42	0.86
	4 weeks	10.98	2.44	10.28	2.28	0.56
	P value**	0.94		0.72		
Overall	Baseline	13.58	3.02	13.19	2.93	0.79
	2 weeks	13.22	2.94	12.99	2.89	0.87
	4 weeks	12.89	2.86	12.67	2.82	0.88
	P value**	0.89		0.93		

P* value using Student's *t* test in each row. *P* value using analysis of variance test in each column.

significantly the lowest at baseline, while it was significantly the highest after 4 weeks in both groups.

Patient satisfaction was assessed by using a questionnaire using five domains for group I and group II and presented in Table 2. Comparison between both groups by using the independent *t* test revealed higher insignificant of group I than group II regarding all domains and overall, at different intervals as *P* value more than 0.05. Repetitive one-way ANOVA was used to compare different intervals, which revealed insignificant differences (insignificant decrease in mean values equals insignificant improvement in satisfaction) in both groups regarding all domains as *P* value more than 0.05.

The correlation between masticatory performance and overall patient satisfaction was calculated using

Pearson's correlation coefficient and revealed a moderate to strong, positive, significant correlation in both groups, as presented in Table 3.

Discussion

An essential measure of a prosthesis' effectiveness in terms of functionality and psychological comfort is how well it performs during mastication and how satisfied the patient is with it. Mastication is a significant element, which has a significant impact on patient satisfaction, and hence it was recorded together with patient satisfaction [10].

The efficiency of chewing and satisfaction of the patient with the removable prosthesis (Table 3) has a direct relation to prosthesis accuracy, fit, and resulting in more retentive dentures, which was provided by

Table 3 Correlation between masticatory performance and overall patient satisfaction at different intervals in both groups

	<i>r</i>	<i>P</i> value	Indication
Group I			
At baseline	0.65	0.010*	Moderate – positive – significant
After 2 weeks	0.72	0.001*	High – positive – significant
After 4 weeks	0.86	0.002*	High – positive – significant
Group II			
At baseline	0.68	0.002*	Moderate – positive – significant
After 2 weeks	0.69	0.010*	Moderate – positive – significant
After 4 weeks	0.81	0.0003*	High – positive – significant

r, Pearson's correlation coefficient. *Significant correlation at *P* value less than 0.05.

CAD/CAM 3D-printed removable dentures more than packable heat-polymerized resin prosthesis. The retention has a great impact on performing functions of the removable denture; to function well the denture must have adequate retention at first, which was provided in CAD/CAM 3D-printed dentures than in other types of denture materials [19,20].

Masticatory performance improvement is highly affected by interocclusal relation and accuracy of occlusal contact of the corresponding molar teeth depending on the careful positioning within the planed plane regarding the neutral zone. Movement of the previously positioned teeth during the fabrication of the prosthesis affects harmonious occlusion and impairs chewing efficiency and mastication performance [21].

Changes and deviation of arranged teeth are usually found in molar teeth, especially in traditional compression packable methods, while noncompressing techniques such as the 3D-printing method still provide fewer teeth movement and less effort for adjustment of the occlusion with clinical remounting [22].

Chewing efficiency after denture insertion was improved by time in both groups, listed in Table 1, as it mainly depends on the patient accommodation and intimate tissue fit with the recently fabricated dentures whatever their type, which agrees with the hypothesis that patients show improved functioning with a recent prosthesis by the passage of time [23].

Higher masticatory performance values of group II were attributed to the wear resistance of denture teeth. Wear of the occlusal surface of the artificial teeth has a dramatic decrease in chewing ability and masticatory performance as teeth occlusal contact will be altered, considering this fact the wear resistance should be adequate to preserve its efficiency. The 3D-

printed resin teeth used in fixed partial dentures and complete dentures have accepted wear and fracture resistance values [24,25].

Satisfaction, comfort, and improved speech of the patients in Table 2 are directly related to the uniform thin thickness of the prosthesis, which was provided by CAD/CAM-fabricated removable dentures depending on their high modulus of elasticity and toughness behavior [17].

However, contrary to the findings of our investigation, different outcomes were found in other studies. Researchers have examined the patient satisfaction, retention, and adaptability of denture bases between digitally printed denture bases and traditional denture bases, and they indicated highly predicted outcomes over conventional dentures. Besides, they stated that digital data from impression scans are far more accurate than that from cast scans in terms of precision [26].

The build direction (layer orientation) of a 3D-printed object impacts the material's mechanical characteristics. This is because additive manufacturing uses incremental layers, which might cause cracks to spread and cause the printed material to fail structurally. Furthermore, it is critical to realize that the layer-to-layer bond is weaker than the layer-to-layer bond. The quantity of residual strains and porosities that build up during UV polymerization and material shrinkage explains this [27].

An accurate examination is advised with the use of a checklist, at least initially, because various mistakes have been observed while checking the digital design of a tooth setup virtually from a laboratory perspective. Finally, a significant drawback of this procedure for digital dentures is the challenge of creating a balanced occlusion. Only a lingualized centric occlusion is now possible; research is still being done on balanced occlusion in protrusive and lateral motions [28].

Conclusion

Within the constraints of this study, it could be determined that the manufacture of CDs using 3D-printed CAD/CAM enhances the masticatory performance rather than the conventional reinforced one. The masticatory performance and patient satisfaction of a mandibular complete denture constructed by the 3D-printed CAD/CAM method were higher than heat-polymerized denture bases reinforced with chrome cobalt framework, denoting that the 3D-printed CAD/CAM method can be the primary clinical treatment option for completely edentulous patient's despite its overall level of satisfaction, which requires additional follow-up investigations to pronounce the positive effect of CAD/CAM dentures.

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Nil.

Conflicts of interest

There were no conflicts of interest.

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