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Original Article

Accuracy And Oral Health-Related Quality of Life in Patients with Selective Laser Melted Versus Conventional Metallic Maxillary Single Denture Base: A Randomized Controlled Crossover Trial

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Abstract:

Aim: To evaluate the accuracy and oral health-related quality of life in patients with selective laser melted versus conventional metallic maxillary single denture base. **Materials and methods:** Twenty-six maxillary edentulous patients were included in this study. Each patient randomly received two maxillary metallic complete dentures (selective laser melted and conventional) in a randomized crossover study design. Two groups were investigated; the selective laser melted Co-Cr group (SLM Co-Cr) and the conventional Cobalt Chromium (casted Co-Cr) group. A colour-mapping software was used to superimpose the STL (standard tessellation language) file of each metallic maxillary denture base with the reference design STL file. The root mean square (RMS) was used to evaluate the groups' accuracy. The oral health-related quality of life was evaluated in both groups at 1-week and 3-month followed-up visits using the Oral Health Impact Profile for Edentulous (OHIP-EDENT) questionnaire. **Results: The** SLM Co-Cr group showed statistically significant superior accuracy with the lowest deviations with an overall root mean square (RMS) value of 0.19 mm, while the casted Co-Cr group showed an overall RMS value of 0.38 mm. Moreover, the patients in the SLM Co-Cr group reported a significantly better oral health-related quality of life compared to those in the casted Co-Cr group. **Conclusion**: Within the limitations of this study, the selective laser melted cobalt chromium denture base may exhibit significantly superior accuracy and improved patients' oral health-related quality of life compared to the conventional cobalt chromium base in maxillary single denture cases.

Keywords: Maxillary single denture, selective laser melting, accuracy, cobalt chromium, conventional casting

Introduction

Single denture construction against natural dentition represents a great challenge to prosthodontists owing to several drawbacks like frequent prosthesis fracture, especially at the midline, dislodgement, difficulty in obtaining occlusal balance, and providing satisfactory aesthetics due to the fixed position of the opposing dentition, especially anterior natural teeth. [1,2]

Denture bases are frequently subjected to a combination of compressive, tensile, and shear stresses, causing a traumatic effect on the supporting soft and hard tissues, especially in ill-fitting dentures. Polymethyl methacrylate (PMMA) denture bases offer good mechanical, biological, and aesthetic qualities, but they may fail if subjected to large masticatory or functional stresses, especially in cases of single dentures as opposed to natural dentition. Hence, metallic denture bases can provide a better alternative in these cases. [3-5] Metallic denture bases can provide excellent strength and allow the usage of thin-sectioned metallic denture bases while still maintaining rigidity, fracture resistance, high thermal conductivity, and less interference with phonation with complete dentures. [6,7]

Digital technology in the prosthetic dental field including computer-aided design (CAD) and computer-aided manufacturing (CAM) technology has been broadly used in the fabrication of various prostheses due to its increased efficiency, automaticity, and accuracy of the entire treatment flow. [8-10] CAD/CAM technologies for metallic prosthetic fabrication eliminate the need for duplicating impressions and refractory casts required in conventional casting which may simplify the fabrication process, reduce material costs, and save time. [11] Digital fabrication including subtractive and additive manufacturing techniques; where additive manufacturing (AM) or three-dimensional printing (3D) printing techniques include stereolithography (SLA), selective laser sintering (SLS) digital light projection (DLP), jet printing, fused deposition modelling (FDM), and selective laser melting (SLM). [12-14]

The 3D printing techniques require the addition of elements in a 3D perception, increment by increment. Using this technique extremely sophisticated forms and complex geometrical shapes can be constructed which may not be feasible using subtractive techniques. Accordingly, 3D printing technologies enabled the construction of dental prostheses demanding extreme levels of accuracy. [15] 3D technologies can be utilized to construct prostheses from various materials involving metals, ceramics, and resins. [16] Regarding the 3D printing techniques used in dental prosthesis construction from metals, selective laser melting (SLM) is one of the best techniques. This technique utilizes a high-energy laser beam to fuse the powder of metal to fabricate three-dimensional items layer by layer. Concerning the metals used in the construction of dental prostheses, cobalt-chromium (Co-Cr) alloys can be a material of choice owing to their biocompatibility, erosion resistance, low cost, high hardness, fracture resistance, and strength. [17]

Retention of denture base is an extremely important quality of denture bases guaranteeing satisfactory oral functions and patient satisfaction. It depends on the anatomical structure of the residual ridge, sufficient extension, and accurate fit of the denture base to the supporting structures. The intimate contact between the supporting structures and denture base permits the formation of the physical forces of retention developed by the creation of thin salivary film and the existence of a negative atmospheric pressure established by an accurately fitted intaglio surface and good peripheral seal. These forces generate resistance to vertical dislodgment and enhanced stability of the denture base especially in maxillary dentures. [18] Accordingly, the retention and accuracy of the denture base can be primally affected by the impression technique, material, and the technique of construction of the denture base. The accuracy of digitally fabricated dentures can be described in terms of trueness or precision. [11]

Oral health-related quality of life (OHRQoL) plays an important role in research and clinical practice. WHO recognized OHRQoL as an important segment of the global healthiness program. The Oral Health Impact Profile (OHIP) questionnaire is one of the utmost precise tools employed to assess quality of life in dental patients. The Oral Health Impact Profile for Edentulous (OHIP-EDENT) is the most used questionnaire for edentulous patients, it consists of seven domains with specific questions to distinguish the influence of oral healthiness on life quality of edentulous patients before and after their dentures have been delivered. [19,20]

The digital (CAD/CAM) techniques are anticipated to be a better substitute for the conventional casting techniques utilized in metallic denture base construction with comparable or even better treatment outcomes. Although 3D-printing technologies are employed frequently in the construction of dental prostheses, research concerning the accuracy of selective laser melting techniques used in the construction of dental prostheses is scarce. Most studies that investigated the accuracy of SLM techniques were conducted to test the accuracy of partial denture frameworks. [21-23] Moreover, almost no clinical studies have been found in the literature to test the accuracy of selective laser melted Co-Cr maxillary single dentures except for a study that was conducted to evaluate the fit (adaptation) and retention of selective laser melted metallic maxillary dentures in completely edentulous patients. [24] Furthermore, studies that investigated patient satisfaction with selective laser melted dental prostheses are extremely rare. Most of the research evaluated patient satisfaction with SLM frameworks. [25-27]

Hence, a question arose whether the selective laser melted Co-Cr can provide a better denture base in single maxillary denture cases compared to conventional Co-Cr in terms of accuracy and oral-heath related quality of life. The study aimed to evaluate the accuracy and oral health-related quality of life in patients with selective laser melted versus conventional metallic maxillary single denture bases. The null hypothesis was that there would be no significant difference between Selective laser melted and conventional Co-Cr denture bases regarding their accuracy and oral-heath related quality of life in maxillary single denture cases.

Materials and methods

Sample size calculation

The minimal sample size was calculated based on a previous study aimed to determine the fit (accuracy) of complete denture bases constructed digitally or conventionally. [28] To evaluate and compare their accuracy scans were matched and compared on a colourmap software program that measured their accuracies with the root mean square (RMS). The RMS corresponds to the square root of the mean squared differences between the predicted (reference) and observed (measured) results. It is used to measure the accuracy of samples. The lower values of the RMS indicate improved accuracy of the samples. On the contrary, the higher values of the RMS indicate a greater discrepancy between the predicted and actual outcomes with inferior accuracy. [29,30] The sample size was calculated based on the former study results [28], assuming a power of 80% (β=0.20) to perceive a standardized effect size in RMS deviation (primary outcome) of 0.2777, and a level of significance 5% (error accepted =0.05), the minimum essential sample size had to be 21 patients. Next modification for a dropout percentage of 20%, the sample size was raised to 13 patients for each group. Hence, the whole sample size was 26 participants.

Patients' selection

Twenty-six patients (their age ranged from 53 to 66 years old) with edentulous maxillary arch opposed by fully dentulous mandibular arch were selected to participate in this study from the out-patient clinic of the Prosthodontics department, Faculty of Dentistry, Ain-shams University. Their inclusion criteria were: (1) maxillary edentulous patients with normal maxillomandibular relation (Angle Class I), (2) patients with good oral hygiene and Firm healthy alveolar mucosa, (3) at least 6 months since last extraction, (4) with past records of recurrent fracture of upper denture, subsequent repair, and possibly several new dentures, and (5) cooperative patients who were informed about the nature of the study and signed an approval consent.

The exclusion criteria were: (1) patients who had ridge or soft tissue pathology, (2) patient with Angle Class II or III, (3) decreased salivary flow, and a history of administration of medications changing the quality and quantity of saliva, (4) presence of severe ridge undercuts, palatal tori extended to the posterior palatal seal area, (5) uncontrolled diabetes, TMJ disorders, Parkinson's disease patients and (6) patients with unrealistic aesthetic concern or refusal to palatal metal display. All the patients were precisely informed about the nature and the design of the study. Each patient has signed a written informed consent form.

Patients' grouping and randomization

This study followed the Declaration of Helsinki and matched the guidelines specified by the consolidated standards for reporting randomized trials (CONSORT). This study was designed to be a randomized clinical trial done in a crossover manner. Patients' randomization and allocation in the study groups were performed by an independent clinician blinded by the study nature using randomly produced numbers by a software aprogram (Minitab 17.0, USA). Participants were randomly allocated into 2 groups according to the maxillary denture base's technique of construction and the sequence of treatment into the following two groups:

- ***Group I:*** Thirteen Patients who received SLM Co-Cr maxillary denture base for three months. Then, these patients had a washout period of two weeks without wearing their dentures followed by receiving a conventional (casted) Co-Cr maxillary denture base for another three months.
- ***Group II:*** Thirteen Patients who received conventional (casted) Co-Cr maxillary denture base for three months. Then, these patients had a washout period of two weeks without wearing their dentures followed by receiving an SLM Co-Cr maxillary denture base for another three months (fig.1).

The maxillary single dentures construction

Primary impressions of both maxillary and mandibular arches were recorded with stock trays packed with irreversible hydrocolloid material (Cavex CA37, Normal Set, Holland) for obtaining study models. Maxillary trial denture base and special trays were fabricated using auto-polymerizing acrylic resin (Palapress Vario Heraeus Kulzer, Hanau, Germany) on the primary model.

Bruce Technique had been used where provisional facebow and centric jaw relation records for mounting of maxillary and mandibular primary casts on an articulator (HANAU Modular; Whip Mix Corporation, Farmington Ave, Louisville, KY, USA) for setting up of the maxillary cross-linked acrylic resin (Poly Dent, MBA trading co., Slovenia) artificial teeth. The opposing mandibular natural teeth intervening with artificial teeth were altered the mandibular study cast and consequently, a transparent auto-polymerizing acrylic template was constructed on the modified mandibular study model. The opposing natural teeth were altered intraorally guided by the transparent acrylic template. The fitting surface of the template was covered with pressure-indicating paste and placed on the lower natural teeth, interferences were perceived through the template and their occlusal anatomy was reshaped to remove these interferences. This procedure was repeated till a suitable occlusal balance was reached and the template was properly seated. The altered teeth were polished, stannous fluoride gel was applied to the teeth. The final impression for the dentulous modified mandibular arch was taken with alginate and maxillary secondary impressions were made using rubber base impression material (Impergum penta soft, medium Body 3M, ESPE, USA)

Digital Designing

The maxillary edentulous master cast was fixed on the scanner table and was scanned by means of a benchtop scanner (3Shape D850 3D Scanner, Copenhagen, Denmark). The standard tessellation language (STL) file was imported, and the metallic denture base was designed using the 3Shape software program (3Shape dental designer, 3Shape A/S, Copenhagen, Denmark) (Fig.2). For each patient, two Co-Cr maxillary metallic denture bases were planned to be constructed using the same STL file digitally designed following two different manufacturing techniques (SLM and conventional casting). The STL file of the denture base was transferred to CAM software of a digital light projection (DLP) 3D-printing machine ((MOGASSAM dent 2, Egypt) to construct a castable 3D-printed resin (IFUN Dental Casting Resin, lancer 3d) denture base (fig. 3). Afterward, this 3D-printed resin base was washed twice in an ultrasonic bath containing 96% ethanol solution. Next, it was placed in a post-curing unit for half an hour then tried intraorally to be checked for proper seating.

Regarding the SLM Co-Cr group, the same STL file of the denture base design was imported to the software (Materialise Magic Print Metal for Vulcantech, Materialise HQ, Technologielaan 15,3001 Leuven, Belgium.) of an SLM 3D printing machine (VENEA V120, VULCANTECH GmbH, Germany). The machine reservoir was filled with Co-Cr powder (Starbond Easy Powder 30; Schefner GmbH) having particle sizes varying from 10 to 30 μm, with print layer thickness fixed to 25 μm. An air-cooling high-power fiber laser (IPG photonics, 200-W Fiber laser, Germany) system was utilized in fusing Co-Cr powder. The printing process began with a 30-degree build orientation angle. Printing each denture base needed one and a half hours. Afterward, the supporting arms of the denture base were cut from the platform using an air turbine handpiece (T2 turbine; Dentsply Sirona). The same procedures were repeated for the rest of the SLM Co-Cr denture bases in the group (fig.4a).

Regarding the conventional (casted Co-Cr) base group, the 3D-printed resin base was sprued and then invested with a phosphate-bonded investment material (VarseoVest P^{plus}, GmbH & Co.KG, Germany) and casted in Co-Cr alloy (WIRINIUM®, BEGO GmbH & Co.KG, Bremen, Germany) following the lost wax (casting) technique. The same procedures were repeated for the rest of the casted Co-Cr denture bases in the group (fig.4b).

To guarantee standardization, minimum finishing and polishing of the external (polished) surface were accomplished in both study groups' denture bases. The same technician performed the procedure using the same finishing and polishing procedures in the two groups utilizing rubber finishing wheels (Rubber-Wheels; SAE-Dental Vertreps GmbH, Germany) and brushes plus polishing paste (Tiger Brilliant polishing paste; DT&SHOP Dent aurum GmbH, Germany).

Accuracy assessment

All denture bases' accuracy was assessed in both groups using comparative 3D-analysis. First, the bases were sprayed with a special anti-glare spray (SHERA scan spray; SHERA Werkstoff-Technologie GmbH Co) and then scanned in the same laboratory with the same laboratory scanner (E series, 3Shape, Denmark). The inner fitting surfaces of casted Co-Cr and SLM Co-Cr denture bases were scanned by a single experienced examiner blinded by the study design and nature. The scan datasets were exported as STL files. The latter STL files together with the STL files of the reference design were imported to a 3D analysis software (Geomagic ® Control X ™, Arctec 3D, Luxembourg). Using this surface-matching software, the STL file of each scanned denture base was superimposed with the original STL file of the reference design through the best-fit alignment. The reference design STL file was assigned to be the reference data while the scanned denture base was decided to provide measurement data. To evaluate the adaptation and correspondence of the metallic denture bases with the original reference design, the software was programmed to examine and compute the vertical deviations between the superimposed STL files. The measurements were done by a software engineer blinded by the study's nature. The deviation of the scanned base from the reference design STL file was measured in millimetres (mm). This deviation was calculated using the software as the root mean square (RMS) values and was reported for the negative (blue) and positive (red or yellow) deviations. The maximum critical value was set at ±0.3mm. The results were in the form of colour maps calculated at specific 20 measuring points for each of the metallic denture bases at the median palatine, incisive papilla, crest of the ridge, and rugae areas. These colour maps were evaluated visually to determine whether the deviation was negative or positive. Finally, the overall RMS value of the whole denture base (SLM or casted) was also calculated.

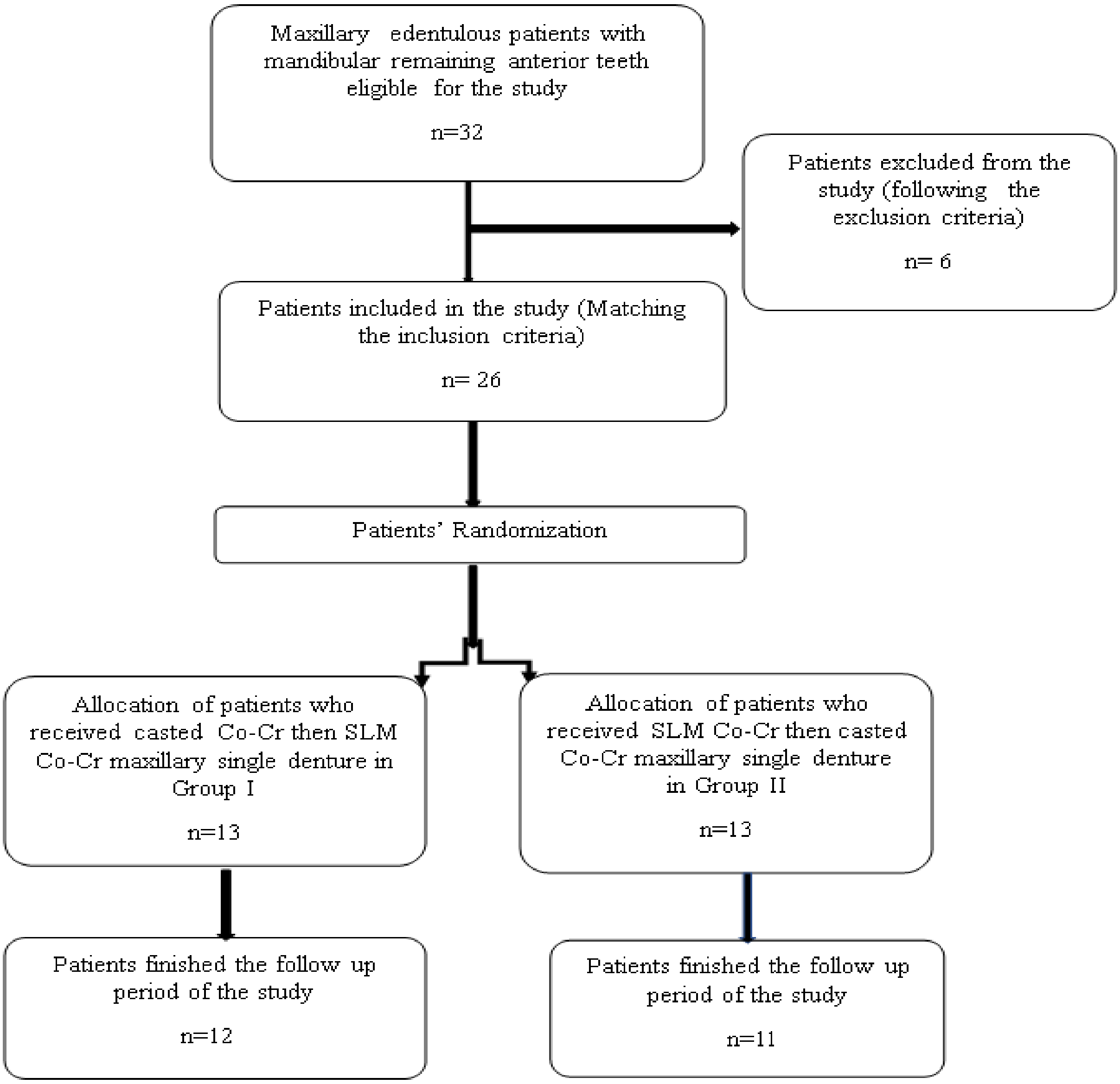

Figure 1. Flow diagram of the study

Figure 2.The virtual design of the metallic maxillary denture base

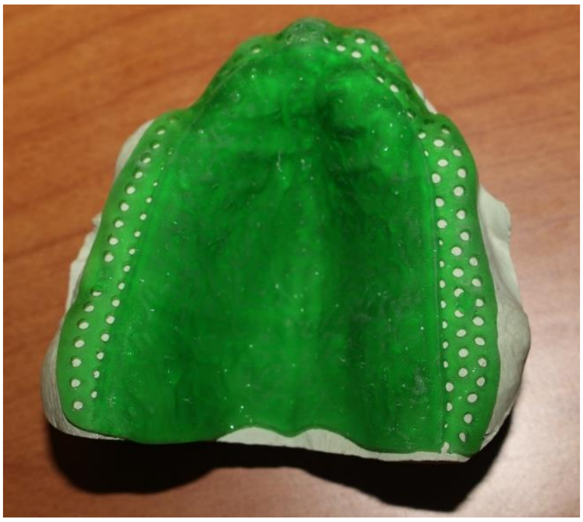

Figure 3. The 3D-printed castable resin base

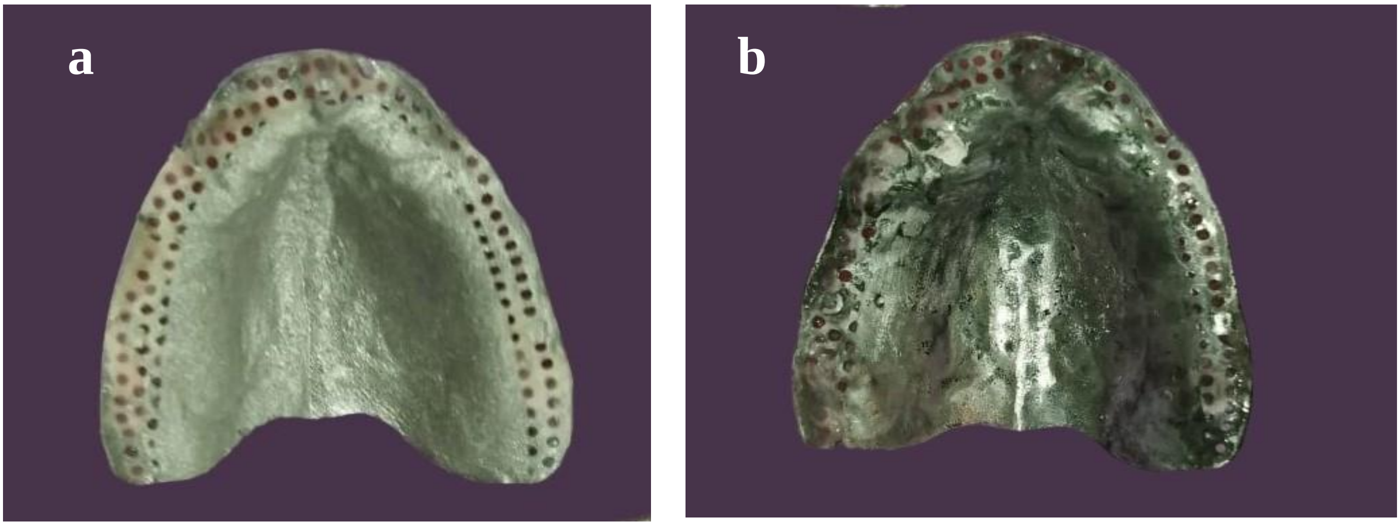

Figure 4. (a) The SLM Co-Cr maxillary denture base,
(b) The casted Co-Cr maxillary denture base

Fabrication of final maxillary single denture

The finished and polished maxillary SLM and casted Co-Cr denture bases were tried in the patient's mouth to check their adaptation and fit. The maxillomandibular relationship was recorded using the wax wafer technique. Setting up of cross-linked acrylic resin teeth, waxing up of the denture base, and try-in were performed. Next, processing of the waxed-up maxillary single dentures was done in heat-cured acrylic resin (Vertex Regular and Vertex Implacryl, Vertex Dental B.V., Zeist, The Netherlands). Finishing and polishing of the denture base resin were done following conventional technique (fig.5). Either the SLM or casted Co-Cr maxillary single denture was delivered to each patient according to the randomization protocol. Post-insertion instructions were given to each patient. The first follow-up visit was scheduled 1 week later, then once every month for a three-month follow-up period. Each patient was instructed to take off his denture for a 2-week washout period. At the end of this period, each patient was given the other denture (SLM or casted) to wear for another three months. The first follow-up visit assigned to be after 1-week post insertion and once a month for the next three-month follow-up period.

Oral health-related quality of life (OHRQoL) assessment

The oral Health-related Quality of Life (OHRQoL) was assessed by a seven-domain questionnaire with nineteen questions named the Oral Health Impact Profile for Edentulous (OHIP-EDENT) at the 1-week and 3-month post-insertion follow-up visits. It was interpreted in the Arabic language and then recited to the patients to be answered by them. The domains were functional limitation, psychological discomfort, physical disability, handicap, physical pain, psychological, and social disability (fig. 6). All questions offer choosing from five answers; each answer is provided with a score (0 = never; 1 = seldom; 2 = fairly often; 3 = often; 4 = very often). The total OHIP-EDENT questionnaire score varies from 0 to 76 calculated by adding the scores of the answer to each question. The lower score represents an oral situation with an individual's improved perception and consequently a better oral health-related quality of life. [31]

Statistical analysis

Data of each study group (SLM or casted) were gathered, tabulated, and analyzed using statistical analysis software (IBM SPSS statistics 22.0; IBM Corp., Armonk, NY, USA). Shapiro-Wilk and Kolmogorov-Smirnov tests have been utilized to test the normality of the data. The accuracy data showed a normal distribution, while the OHIP-EDENT Data did not follow a normal distribution. Accordingly, the normally distributed (parametric) data were analysed using the paired T-test. On the other hand, the data that did not show normal distribution (non-parametric) were analysed by the Wilcoxon signed-rank test. The data were presented as mean ± standard deviation (STD). A p-value less than 0.05 ($p<0.05$) indicates statistical significance.

Results

Twenty-six patients received two sets of maxillary single dentures (SLM Co-Cr and casted Co-Cr) following a randomized crossover study design. Three patients dropped out of the study and didn't complete the whole study period for either medical or logistic reasons. All patients reported satisfaction with the maxillary single denture. Moreover, the patients with SLM Co-Cr denture bases reported that their dentures had a significantly lower weight compared to the casted ones.

The accuracy outcome

The colour maps of the denture bases in both groups with positive and negative deviations interpreting the clinically significant areas are shown in Fig. 7 & 8. These colour variations were represented with numerical values. The green colour (acceptable deviation and good fit) indicated deviations of less than

0.1 mm, while the yellow colour (positive deviation) indicated deviations between 0.1 to 0.25 mm. On the other hand, the red colour (positive deviation) indicated deviations more than 0.25 mm. The blue colour (negative deviation) indicated deviations of more than 0.1 mm. The negative deviation (blue) showed areas of tissue compression which implies that the tested (experimental) measurements are greater than the reference measurements which may indicate strong tissue contact and might suggest tissue compression below the denture base. This compression especially at the posterior palatal seal area may offer a tighter seal and improved retention of the denture. On the other hand, the positive deviation (yellow and red) indicated the tested (experimental) measurements are smaller than the reference measurements which may indicate gaps and space between the denture base and the supporting tissues (misfit with space) and may reduce denture retention. The green colour area corresponded to ideal intimate contact between the reference design and the denture base. [32-35]

The areas of green colour in the SLM group were greater compared to the casted group which implied higher accuracy and superior fit. The yellow and red colour areas were more in the casted group compared to the SLM group indicating lower accuracy and inferior fit. These areas of yellow and red colours were situated closer to the posterior ridges' crests in the SLM group. The blue colour areas were more at the posterior areas of the palate situated around the midline in the SLM group (fig.9).

The measurements of accuracy were made for each denture base group at the chosen areas (the median palatine raphe, incisive papillae, right and left ridge crests). The assessed areas exhibited both negative and positive absolute deviations and their root mean square (RMS) values were calculated. The results were represented as mean ± STD in Table 1. The overall RMS was a representation of the whole denture base accuracy. The RMS values of the selected areas were significantly lower in the SLM Co-Cr group compared to the casted Co-Cr group ($p<0.05$). Likewise, the overall RMS value in the SLM Co-Cr group was significantly lower compared to the casted Co-Cr group. ($p<0.05$). This lower value of the RMS indicated higher accuracy and superior fit in the SLM Co-Cr group compared to the casted Co-Cr group.

The oral health-related quality of life (OHRQoL)

Each patient stated an overall satisfaction following the insertion of the maxillary denture. At the first week post-delivery follow-up visit, the mean total OHIP-EDENT score of the SLM Co-Cr and casted Co-Cr groups were 25.56 and 28.09 respectively (Tab. 2). There was no statistically significant difference between the total OHIP-EDENT score of the SLM Co-Cr and casted Co-Cr group at the 1-week follow up visit ($p>0.05$). On the other hand, there was a significant decrease in the mean total OHIP-EDENT score of the SLM Co-Cr and casted Co-Cr groups which were 11.55 and 16.95 respectively at the 3-month compared to the 1-week follow-up visit individually denoting improved oral-health related quality of life. Moreover, a statistically significant difference was found between the total OHIP-EDENT scores of both groups at the 3-month follow-up visit compared to each other ($p<0.05$).

Each domain scores were compared individually between the SLM Co-Cr and casted Co-Cr groups at the 1-week follow-up visit, no statistically significant difference was found between each domain scores of both groups compared separately ($p>0.05$). On the other hand, all domains' scores decreased significantly at the 3-month compared to the 1-week follow-up visit in both groups ($p<0.05$). Accordingly, the oral health-related quality of life was enhanced significantly in both groups. On comparing each domain scores individually between the SLM Co-Cr and casted Co-Cr groups at the 3-month follow-up visit, a statistically significant difference was found between each domain scores of both groups compared separately (p<0.05) except in the physical disability domain where no statistically significant difference was found (p>0.05). Hence, the oral-health related quality of life at the 3-month follow-up visit was significantly better in the SLM group compared to the casted group in all domains except in the physical disability domain. In the latter domain, the scores decreased in both groups significantly (improved quality of life) but compared to each other, no significant difference was found.

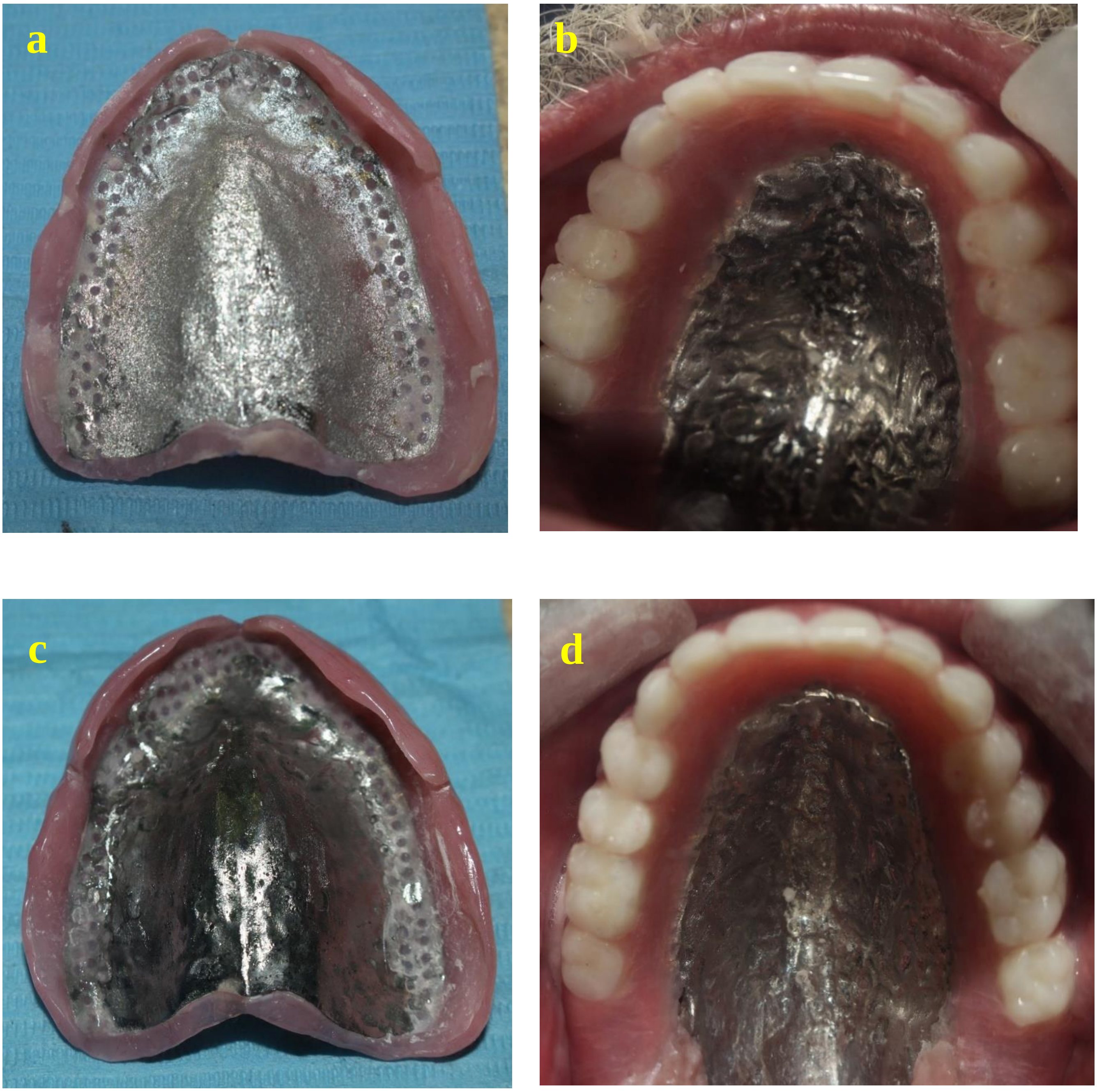

Figure 5. a) The fitting surface of SLM Co-Cr denture base, b) The SLM Co-Cr denture base intraorally, cc) The fitting surface of casted Co-Cr denture base, and d) The casted Co-Cr denture base intraorally.

Domain	OHIP-EDENT-N question (Baseline)
FL	1. Have you had difficulty chewing any foods because of problems with your teeth, mouth or dentures?
FL	2. Have you had food catching in your teeth or dentures?
P1	3. Have you had painful aching in your mouth?
P1	4. Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?
P1	5. Have you had sore spots in your mouth?
FL	6. Have felt that your dentures have not been fitting properly?
P1	7. Have you had uncomfortable dentures?
P2	8. Have you been worried by dental problems?
P2	9. Have you been self-conscious because of your teeth, mouth or dentures?
D1	10. Have you had to avoid eating some foods because of problems with your teeth, mouth or dentures?
D1	11. Have you been unable to eat with your dentures because of problems with them?
D1	12 Have you had to interrupt meals because of problems with your teeth, mouth or dentures?
D2	13. Have you been upset because of problems with your teeth, mouth or dentures?
D2	14. Have you been a bit embarrassed because of problems with your teeth, mouth or dentures?
D3	15. Have you avoided going out because of problems with your teeth, mouth or dentures?
D3	16. Have you been less tolerant of your partner or family because of problems with your teeth, mouth or dentures?
D3	17. Have you been irritable with other people because of problems with your teeth, mouth or dentures?
H	18. Have you been unable to enjoy other peoples company as much because of problems with your teeth, mouth or dentures?
H	19. Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures?

Figure 6. The OHIP-EDENT-N questionnaire domains, FL functional limitation, P1 physical pain, P2 psychological discomfort, D1 physical disability, D2 psychological disability, D3 social disability, H handicap.

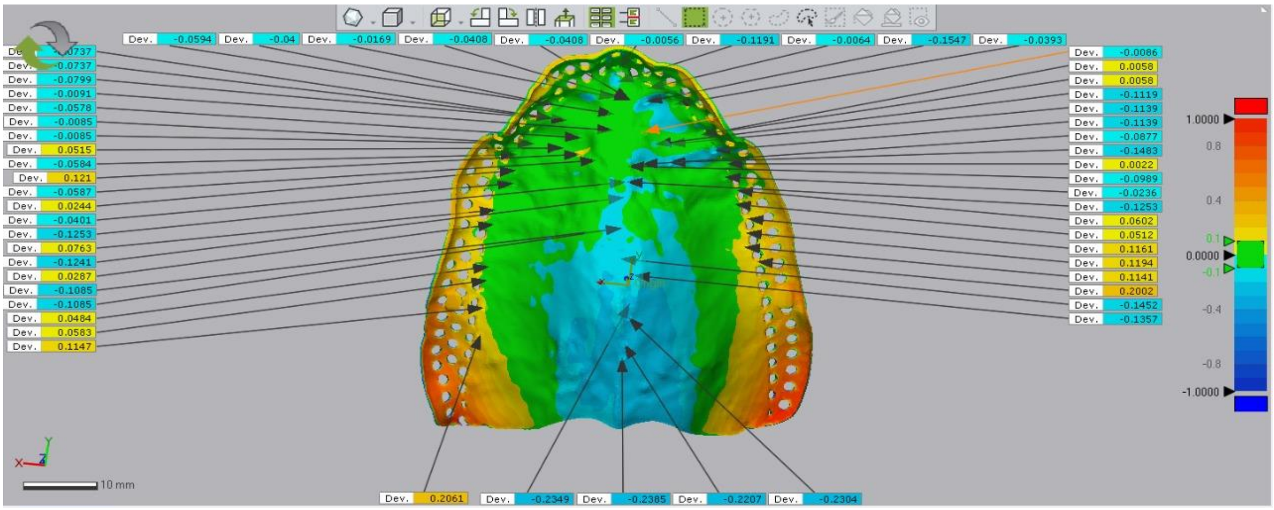

Figure 7. The colour map of the SLM Co-Cr denture base

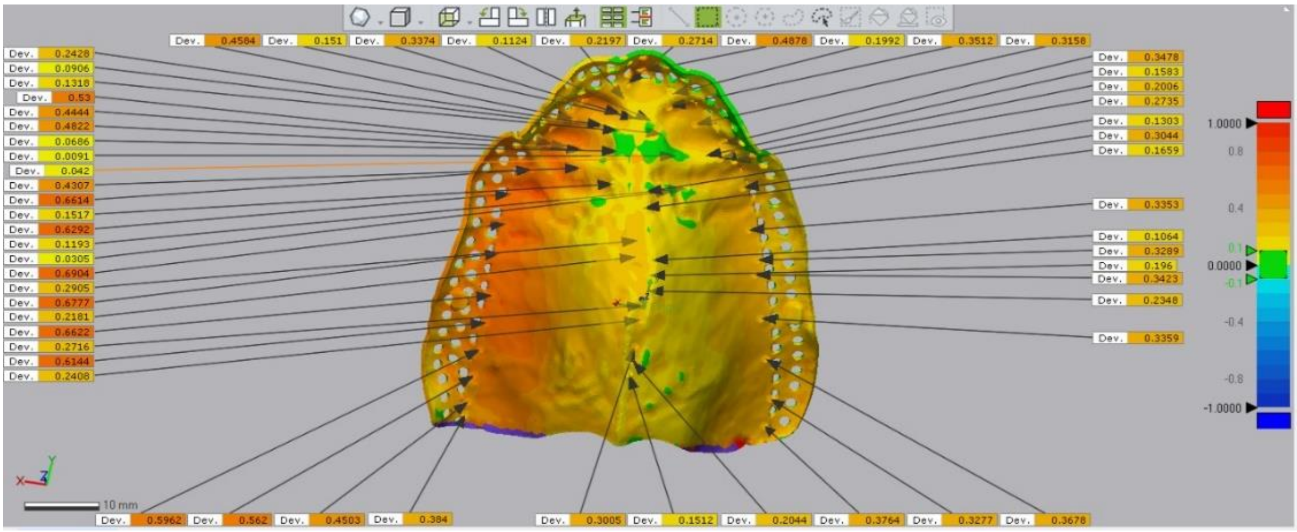

Figure 8. The colour map of conventional casted Co-Cr denture base

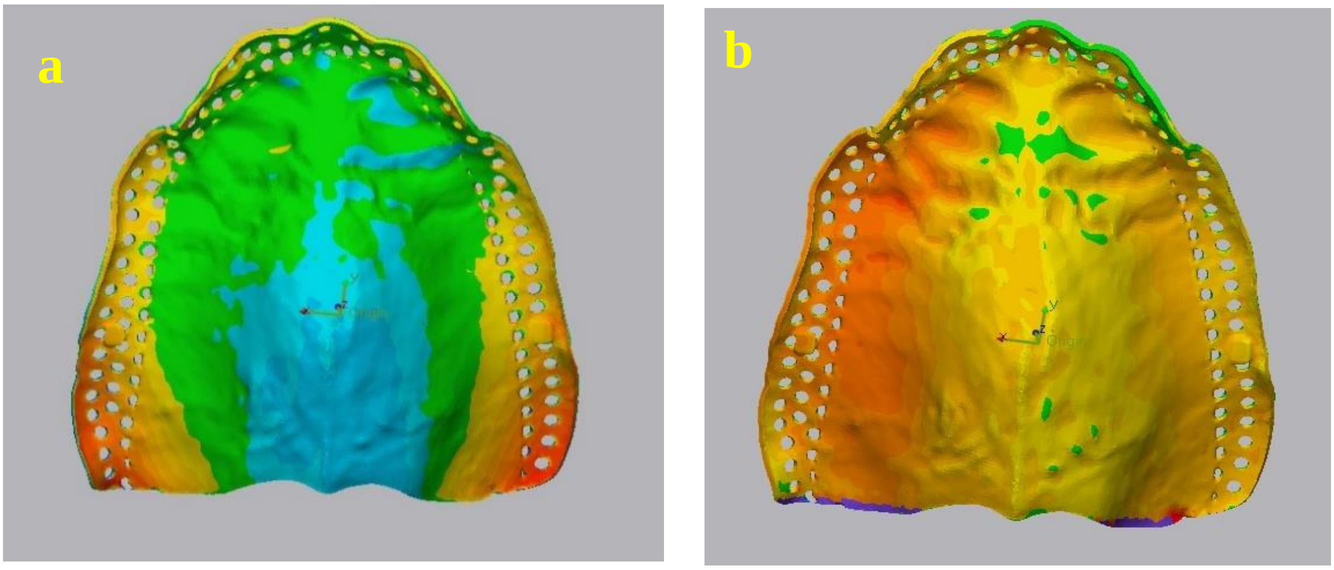

Figure 9. The colour maps of the Co-Cr denture bases; a- SLM Co-Cr denture base and b- the casted Co-Cr denture base

Table (1): The RMS (mean ± STD) values for the SLM Co-Cr and casted Co-Cr groups at the selected areas

Areas of measured accuracy	SLM Co-Cr Group	casted Co-Cr Group	Paired T-test value
	RMS mean ±STD (mm)	RMS mean ±STD (mm)	
Median palatine raphe	0.18 ± 0.06	0.29 ± 0.11	< 0.001*
Incisive papilla	0.07 ± 0.05	0.22 ± 0.06	0.0021*
Right ridge crest	0.10 ± 0.08	0.48 ± 0.14	0.0060*
Left ridge crest	0.08 ± 0.05	0.34 ± 0.24	< 0.001*
Overall RMS (Overall accuracy)	0.19 ± 0.07	0.38 ± 0.19	< 0.001*

***p< 0.05 is considered statistically significant**

Discussion

The accuracy measurements and Oral health-related quality of life in patients with maxillary single denture base were significantly different in the SLM Co-Cr group compared to the casted Co-Cr group. Accordingly, the construction technique of the metallic single denture base can affect the accuracy and the Oral health-related quality of life. Hence, the null hypotheses were rejected.

The prosthetic fabrication of a maxillary single complete denture represents a challenge due to heavy occlusal loading from the opposing natural dentition on the edentulous maxillary arch and the denture base material. Moreover, a traditional material of the denture base such as polymethyl methacrylate (PMMA) with its vulnerable mechanical qualities may fracture due to microcracks in the denture base. Hence, metallic denture bases used as a reinforcement of the conventional acrylic resin denture bases may reduce the risk of midline fracture besides dimensional stability improvement, retention enhancement, and better accuracy of the final maxillary single denture. [36]

Metallic alloys, for example, Titanium, nickel-chromium, and cobalt-chromium are the most used metallic materials to fabricate metallic denture bases with high stiffness, strength, fracture resistance, and good adaptability to supporting tissues. Metallic denture bases may have some disadvantages involving difficulty in construction, inferior aesthetics, impediment of rebasing and relining the prosthesis, extra time consumption, and cost. [7,36-38]

The conventional method of fabrication of metallic denture bases is casting (lost wax technique) but this method has several drawbacks and is time-consuming. Thus, improving and introducing new techniques for fabrication was essential to produce accurate denture bases providing a better quality of life for patients, especially in cases with maxillary single dentures. The digital era to produce metallic denture bases including designing and fabrication may provide a good solution to the drawbacks of the conventional method. [24]

Digital additive techniques such as rapid prototyping eliminate many physical stages such as duplicating, waxing-up, and investing steps in the conventional methods. Hence, it can provide rapid designing and production of accurate metallic denture bases with satisfactory biological and mechanical properties [39]

The 3D-analysis software was used to evaluate accuracy as it can identify the qualitative and quantitative 3D-deviations between the reference design STL file and the scanned SLM and casted Co-Cr denture bases' STL files. The qualitative analysis was accomplished by reviewing and interpreting of the colour maps produced by the software reports indicating the surface negative and positive 3D-deviations. The quantitative analysis was denoted as a root-mean-square (RMS) value. The "best fit" of these two surfaces was produced by colours indicating the various sizes of gaps or indentations between the metallic denture bases and the model at 20 different points. [40-45]

The significantly lower RMS values and greater green colour areas (acceptable deviation) good fit in the SLM Co-Cr group compared to the casted Co-Cr group proved the superior accuracy of the SLM group. On the other hand, the casted Co-Cr group showed significantly greater yellow and red (misfit with space) areas compared to the SLM Co-Cr group which indicated lower accuracy and inferior fit. This finding might be attributed to the digital designing and manufacturing techniques that might have led to improvements over conventional techniques, including reduced laboratory steps, ease of usage, efficient use of resources, and reduced time of construction. Moreover, 3D printing techniques can produce larger complex items with irregular surfaces, and undercuts. Hence, this technique can be suitable for the fabrication of metallic denture bases and frameworks. The passive nature of this fabrication technique, due to the absence of force application and vibration of the machine throughout the construction of the workpiece, permits the fabrication of thin and complicated structures. [46,47] Takaichi et al. [48] study stated that the mechanical properties of SLM Co-Cr can be equal to or slightly superior to casting. The SLM-fabricated prostheses showed enhanced surface properties, such as a consistent microstructure, hardness, and adequate corrosion resistance. [49] The enhanced homogeneous microstructure of SLM-fabricated alloys might be due to layer-by-layer building structure with local melting and rapid solidification of the metal powder in contrast to casted alloys which possess a dendritic microstructure. [17,50]

Table (2) Means and standard deviations of total OHIP-EDENT scores in SLM Co-Cr and casted Co-Cr groups at the different follow-up visits.

OHIP-EDENT Domains	Study groups	1-week Follow-up visit (mean ± STD)	Wilcoxon signed rank p-value	3-month Follow-up visit (mean ± STD)	Wilcoxon signed rank p-value
Total OHIP-EDENT	SLM Co-Cr	25.56 ± 14.67 [a]	0.768	11.55 ± 3.04 [b]	0.015*
	casted Co-Cr	28.09 ± 12.17 [a]		16.95 ± 5.48 [b]	
Functional limitation	SLM Co-Cr	4.43 ± 1.27 [a]	0.324	1.56 ± 0.84 [b]	0.004*
	casted Co-Cr	5.29 ± 2.06 [a]		2.71 ± 1.76 [b]	
Physical pain	SLM Co-Cr	6.96 ± 1.37 [a]	0.986	2 .98 ± 1.02 [b]	< 0.001*
	casted Co-Cr	6.53 ± 2.27 [a]		3.41 ± 1.87 [b]	
Psychological discomfort	SLM Co-Cr	2.43 ± 1.13 [a]	0.580	1.09 ± 0.95 [b]	< 0.001*
	casted Co-Cr	2.16 ± 1.46 [a]		2.04 ± 1.86 [b]	
Physical disability	SLM Co-Cr	3.37 ± 1.98 [a]	0.630	2.36 ± 1.61 [b]	0.981
	casted Co-Cr	4.39 ± 0.25 [a]		2.80 ± 1.25 [b]	
Psychological disability	SLM Co-Cr	1.39 ± 0.967 [a]	0.081	1.01 ± 0.59 [b]	0.021*
	casted Co-Cr	2.24 ± 0.76 [a]		1.36 ± 1.51 [b]	
Social disability	SLM Co-Cr	4.57 ± 1.61 [a]	0.068	2.07 ± 1.37 [b]	< 0.001*
	casted Co-Cr	4.81 ± 0.70 [a]		2.74 ± 1.88 [b]	
Handicap	SLM Co-Cr	2.41 ± 0.80 [a]	0.091	0.57 ± 0.69 [b]	0.031*
	casted Co-Cr	2.67 ± 1.70 [a]		1.89 ± 1.45 [b]	

*** p-value < 0.05 is statistically significant**
Different superscript letters in rows indicate statically significant difference.

The current study results agree with the results of several studies that investigated the accuracy of SLM versus conventional techniques in the construction of partial denture frameworks. These studies stated that SLM techniques can provide a more accurate prosthesis compared to conventional (casting) techniques. [21,22,51] Furthermore, Forrester et al. study investigated the accuracy of SLM for the fabrication of a palatal coverage metal framework that resembled the full coverage in metallic denture bases. The latter study stated that the accuracy of SLM-fabricated frameworks was comparable to or even better than that of conventionally casted ones. [52] On the other hand, the present study results contradict the results of two studies which concluded that the accuracy of SLM-fabricated frameworks might possess inferior accuracy compared to conventional or milled frameworks. The first study stated that the SLM-constructed frameworks might possess inferior accuracy in comparison to milled frameworks. [23] Moreover, the second study investigated the accuracy of CAD/CAM combined with casting techniques using a light microscope which was a different method of evaluation from the 3D analysis software used in the current study. [53]

The OHIP-EDENT questionnaire was elected for the assessment of edentulous patients' quality of life and satisfaction as it could detect changes in the quality of life of denture wearers after the insertion of new prostheses, showing favourable receptiveness. [54] There was no significant difference in domain scores in the studied groups at the 1-week follow-up visit but a significant decrease in domains scores at the 3-month follow-up visit. This finding may be due to better adaptation, improved oral functions, and neuromuscular control with time in both groups, which improved patients' oral health-related quality of life. As time passed, the participants became more familiar with procedures during the observation period. Regarding each domain scores when compared individually between the two studied groups, the SLM Co-Cr group showed better health-related quality of life than casted Co-Cr group. This outcome can be attributed to the superior accuracy investigated earlier in the study. This superior accuracy (lower deviations and greater green areas) might have enhanced the fit and adaptation of the denture bases to the underlying supporting structures and improved the seal, especially in the posterior palatal seal area (blue areas with slight tissue compression) in the SLM group. Accordingly, the retention of the SLM bases was enhanced which in turn improved functions (mastication and speech), psychological acceptance, and confidence in patients. Moreover, the improved mechanical properties such as yield strength and ultimate tensile strength might have led to the superior performance in the SLM denture base group. [48,55-59] The current study's finding agrees with those of other studies which concluded that digitally constructed dentures can provide significantly superior patients' oral health-related quality of life with better satisfaction. [60,61]

The limitations of this study were the relatively small sample size with a short follow-up period. Another limitation is the restricted outcomes evaluated. Accordingly, future studies with greater sample sizes and longer follow-up periods are required to assess the effect of denture bases' construction technique (SLM or conventional) on their accuracy, oral health-related quality of life, prosthetic complications, retention, and biocompatibility.

Conclusion

Within the limitations of this study, the selective laser melted cobalt chromium denture base may exhibit significantly superior accuracy and improved patients' oral health-related quality of life compared to the conventional cobalt chromium base in maxillary single denture cases.

Conflict of interest

The authors declare no conflict of interest.

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Ethics

This research protocol was approved by the Faculty of Dentistry, Ain Shams University ethical committee on 26 January 2023, approval number: (FDASU-RecIR 012338).

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