Soft Metal versus Laser Melting Metal Framework Used for Mandibular All on Four Implant Supported Fixed Complete Denture: A Pilot Study

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Abstract:

Objective: Radiographic evaluation of peri-implant bone height changes in mandibular all on-four implant supported fixed complete denture (ISFCD) regarding metal framework fabrication technique either with milling from soft metal block or additive manufacturing using laser melting. **Materials and Methods:** Ten completely edentulous patients were rehabilitated with mandibular all on-four ISFCD. Computer-guided surgical procedures were followed for placement of implants. Patients were allocated randomly into two groups according to the framework fabrication technique. Group I frameworks were milled from soft metal block and group II frameworks were fabricated with additive manufacturing using laser melting. Vertical bone height changes around supporting dental implants were evaluated for each patient using peri-apical x-ray made at T0 (insertion day), T6 (6 months after insertion), and T12 (12 months after insertion). The vertical bone height change was measured using scanora software. Data was described and analyzed using SPSS program. **Results :** showed that there was no statistically significant bone loss difference between frameworks made by laser melting and those made by milling soft metal around dental implants supporting frameworks ($p > 0.005$). However, frameworks fabricated from soft metal showed significant bone loss at T12 compared to T6. **Conclusions:** Mandibular ISFCD fabricated from soft metal block, or laser melting exhibited acceptable vertical bone height changes at six months and one year with non-significant difference between them. However, frameworks fabricated by milling from soft metal exhibited significant vertical bone height changes at one year compared to that at six months.

Introduction:

Several prosthetic treatment options exist for completely edentulous patients including complete denture, removable implant retained prosthesis or fixed implant supported prosthesis. However, compared to removable prosthesis, implant retained or fixed implant supported prosthesis offered a higher level of patient satisfaction. [1]prior to treatment planning, it is important to take into account the quantity and quality of the available bone, the number, location, and distribution of implants, the available interarch distance, the relationship between the maxilla and mandible, the nature of the opposing occlusion, the costs, as well as the amount of time needed to assemble and maintain the prosthesis.[2] The all-on-four™ concept was used to promote one specific treatment option (Nobel bio care, Goteborg, Sweden). A screw-retained hybrid prosthesis supported by four dental implants is known as a "all-on-four" prosthesis. To reduce the cantilever length and enable the use of prostheses with up to 12 teeth, the two most anterior implants are placed axially, While the two posterior implants are placed distally angled.[3]the all-on-four idea is based on the use of four implants in the anterior region of fully edentulous jaws to support a temporary, fixed, and immediately loaded prosthesis. Extremely compromised edentulous and failing dentition can be restored using the all-on-four treatment concept with a predictable, promising favorable and long-term outcome.[4]the design and fabrication of accurately fitting, strong metal frameworks to splint multiple implants is an essential part when planning fixed implant prosthesis. In order to prevent stresses from being created on the bone-implant interface by a non-passive prosthesis, a perfect fit between the prosthetic framework and the implant is essential. Frameworks also served as the base for the long-term retention of fixed implant prostheses.[5]the use of conventional lost wax casting (LWC) techniques frequently restricts the ability to create a passive fit framework.[6] it has additional drawbacks, including overly complicated processes and prolonged processing times. Some of the drawbacks of the LWC Technique have been resolved with the Development of CAD-CAM systems for the fabrication of metal frameworks.[6,7]the computer-aided manufacturing systems used in dentistry are either subtractive manufacturing technologies or additive manufacturing technologies.[8]Rotary tools and materials in the shape of blocks are employed in the subtractive manufacturing process for dental fabrication.[9] A new method has been developed for the production of metal frameworks that involves milling a presintered soft alloy (PSA).[10,11] Co-Cr metal powders are compressed using isostatic pressure to create PSA blanks. It is simpler to mill because its final mechanical properties, which adversely affect grinding, are not reached until sintering, which requires less time, less grinding, and

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no water cooling.[12] The waste of the original material used in manufacturing was viewed as a drawback of subtractive techniques.[13]Rapid prototyping CAM machines are an alternative to additive manufacturing methods.[9] Selective laser melting (SLM), which involves applying a laser beam to a pool of metal powder to selectively melt and connect the powder particles, can be used to create metal frameworks. Up until the entire framework is created, the process is repeated numerous times in layers. SLM's ability to create highly customized work pieces without taking a lot of time or requiring a lot of labour is what makes it special. Minimal material waste, passive production without the use of force, and possibly improved precision are additional benefits. The SLM frameworks' potential additional benefit is their roughened surface, which was produced by the additive fabrication process and improved the mechanical bonding between the acrylic material and the framework.[14]Although the fit accuracy of frameworks produced through PSA and SLM was studied in vitro,[15,16] more clinical research is needed to find out the situation. As previously stated, there is a correlation between the fit of the framework and the stresses at the bone implant interface. Studies assessing bone height changes around dental implant supporting PSA and SLM are thus needed hence emerged the aim of this study. This study aimed to compare between peri-implant vertical bones heights of PSA versus SLM frameworks used for mandibular all on four implant supported fixed complete denture. The null hypothesis was that no difference would be found between the two techniques in relation to the bone height changes values around the dental implants of fabricated FCDs.

Material and Methods:

Study design and Patients´ criteria:
This prospective pilot clinical study was conducted to compare two mandibular ISFCD whose frameworks were constructed with two different techniques either milled from soft metal block or fabricated with additive manufacturing using laser melting. Peri-implant vertical bone height changes were assessed and compared for both ISFCDs. The Study was approved by ethical committee in faculty of Dentistry, Mansoura University, No (A03010222).Ten completely edentulous patients aged 45-65 years with mean age 55 were selected from the Outpatient Clinic of the Prosthodontics' Department, Faculty of Dentistry, and Mansoura University. The following prerequisites had to be met in order for patients to be included: Patients were healthy and free from diseases that affect Osseo-integration, free from oral pathological conditions which were verified by pre-operative panoramic radiograph, with U shaped arch, moderate size mandibular alveolar ridge covered with even compressibility healthy mucosa and gingival thickness, Adequate residual alveolar bone quality (D2) bone type in the anterior and premolar regions, and Angel’s class I maxilla-mandibular relation with moderate inter-arch space (20 mm) confirmed through tentative jaw relationship. Patients with absolute contraindications, such as uncontrolled diabetes mellitus, generalized osteoporosis, recent myocardial infarction, and radiotherapy patients, were excluded from the surgical placement and Osseo-integration of implants. Patients with relative contraindications were also excluded, including those with uncontrolled diabetes mellitus, alcoholism, smoking, and TMJ dysfunction. All patients signed participation consent forms after receiving information about all procedures.

Implant planning and placement: Preoperative cone beam computed tomography (CBCT) was used for every case to evaluate bone quality and quantity (height and width) at mandibular anterior and premolar regions. Maxillary and mandibular acrylic complete dentures were constructed, and after radiopaque markers were applied, they were used for CBCT scanning and implant placement planning. The Implant distribution was virtually planned for all on four concepts where the posterior implants were tilted distally by 30 degree in front of mental foramina while two anterior implants were made straight. The surgical stent was fabricated using rapid prototyping machine. Four 4*12 mm implants (Dentium Superline, Dentium, Co. Ltd., Korea) were placed guided by the surgical stent and were threaded to their final position using hand rachet till being ½ mm below bone crest. Multiunit abutments were connected to implants. Panoramic x-ray was taken to verify implant abutment connection. Temporary abutments were connected and the hollowed out mandibular denture was modified to an implant supported interim fixed prosthesis.

Mandibular fixed complete denture construction: Three months later, prosthetic procedures were started to construct mandibular ISFCD against the existing maxillary complete denture. Mandibular final impression was made using open tray (pickup) impression technique with splinting. Screwing the impression transfer copings to the multiunit Abutments and splinting them by ligature wire and composite resin filling were performed. A self-perforating plastic stock tray was used after opening the holes corresponding to transfer copies such that the screw of the impression posts project out of the holes. The impression was made by additional silicon polyvinyl siloxan impression material (Elite Impression Material, Zhermack, Italy) using putty wash single step technique. The multiunit analogues were screwed to the transfer copings and impression was poured using double pour impression technique (an initial pour of stone was made to have a cast with gingival mask to replicate soft tissue around abutments then second pour was performed).Verification jig was constructed on the master cast by attaching transfer copings to the multiunit analogues, which were then splinted with dental floss and minimal shrinkage acrylic resin (Dura Lay Inlay pattern Resin - reliance dental MFG CO). Once resin was polymerized it was finished and polished then disk was used to section each of copings

Figure1: Soft metal milled framework try in in the patient mouth.

Figure 2: Laser melting metal framework try in in the patient mouth.

from one another. Verification jig was then tried in the patient mouth then the resin was used to reconnect transfer copings together. It was tried in on the master cast to verify the accuracy of implant transfer before framework construction. Mandibular Record block was made to record maxilla-mandibular relations with the maxillary denture. UCLA abutments were connected to multiunit abutments; lower record block was opened opposite to it and shortened during jaw relation registration. Vertical dimension was adjusted and then centric relation was recorded. Maxillary denture was mounted on a semi-adjustable articulator using mounting jig made previously and mandibular cast was mounted using centric inter-occlusal record. Jaw relations were scanned using extra-oral scanner (Dof swing scanner, South Korea).Master cast was scanned and framework with appropriate dimension was designed virtually using CAD software (exocad Dental DB 2.2 Valletta, Germany). Framework was then milled into resin and tried in intraorally for passivity testing. Patients were divided randomly into two groups according to the framework fabrication technique Randomization was performed by the same researcher who applied all treatments, using a card system that maintains complete randomness of the allocation of a patient to a particular group. Group I included five patients whom frameworks were milled from soft metal block and group II included five patients whom frameworks were fabricated with additive manufacturing using laser melting. CAM Manufacturing of the framework was done according to technique selected in each group: For group I; the framework was milled by dry Milling of CO-CR soft metal blocks (Ceramill Sintron, Germany) and then was sintered at 1280 degree Celsius for 5 hours under argon atmosphere in sintering oven, (Figure 1). For group II; the framework was made by using selective laser melting technique. The design data were used for framework production with the Co-Cr alloy powder (Starbond Easy Powder 30) in a laser melting machine (VULCAN TECH, Vm 120 PBF-LB AM machine, Germany) with a 200 w Air Cooling Fiber Laser. The Co-Cr powder applied to stainless-steel plate and laser-melted upward in Subsequent layers, each of 20mm in thickness, until the definitive product was generated, (Figure 2). Abutments were cemented to metal framework using DTK cement (Bredent - DTK adhesive, Germany). Metal framework was then tried intra-orally for passivity testing using digital periapical x-ray, and then secured to master cast, and the denture teeth were arranged. The occlusion was refined and wax contour was done. Final try in was made to check esthetics and jaw relations. The mandibular prosthesis was processed to heat polymerized acrylic resin (acrostone dental factory, Egypt). Laboratory remount was done to adjust occlusion, and then finishing and polishing were made. Mandibular ISFCD was checked in patient mouth for occlusal adjustments in centric and eccentric then screwed in position and screws were tightened(Figure 3).

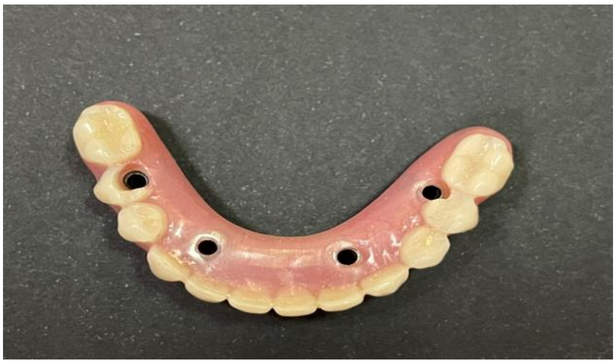

Figure 3: Final denture with framework.

Screw opening was closed using Teflon and composite resin filling material. Evaluation of vertical bone height changes: Vertical bone Height changes around implant fixtures were measured using periapical x ray parallel cone technique made at day of insertion (T0), after 6 months (T1), and one year after fixed complete denture insertion (T2).

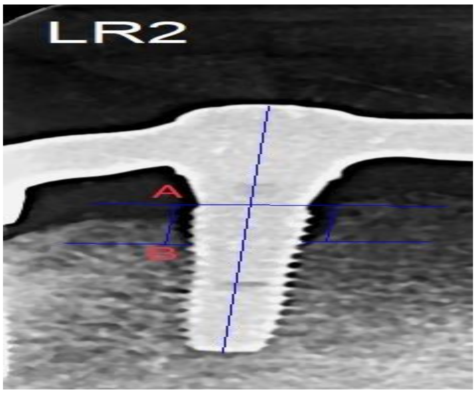

Figure 4: Tracing of the bone loss on periapical film.

For the purpose of evaluating bones, an acrylic bite register (reference index) was created using auto-polymerized acrylic resin. It was put on a film holder, and the patient was instructed to bite down in a centric manner to leave a print of the teeth's occlusal side. This enabled the film to be repositioned in the same location each time an x-ray was taken.[17] Bone loss was measured according to Rasouli Ghahroudi et al.[18] Vertical bone height (AB) was defined as the distance between implant shoulder (A) and bone to implant contact (B) measured parallel to the implant long axis. Data was analyzed by scanora software (Scanora 5.2.6, Finland). Radiographic vertical bone loss (VBL) was estimated by subtracting radiographic AB at T6 and T12 from values at T0. Actual VBL was calculated by multiplying the actual implant Length by the radiographic VBL and dividing the Result by the radiographic length of the implant In order to account for magnification error, (Figure 4).

Statistical analysis: The SPSS statistical package for social science version 22 (SPSS Inc., Chicago, IL, USA) was used for data analysis. Shapiro-Wilk test was used to test the normality of the actual VBL values. The data was parametric and normally distributed. Descriptive statistics were performed in terms of mean (M) and standard deviation (±SD). Paired samples t-test was used to test significant difference of VBL in between time intervals for each implant position. Independent samples t-test was used to compare VBL between groups and between implant position in each group. P is significant if < 0.05 at confidence interval 95%.

Results:

Comparison of vertical bone loss between soft metal group and laser melting group and time intervals for anterior implants showed non-significant difference of VBL between groups at T6 and T12**,** (Table 1).

Table1. Comparison of vertical loss between groups and time intervals for anterior implant

	6 months after insertion (T6)		**12 months after insertion (T12)**		**Paired samples t-test**
	Vertical bone loss				
	X	±SD	X	±SD	
Group I	.158	.052	.272	.160	.049*
group II	.139	.013	.216	.053	.208
Independent samples t-test	.591		.568		

X; mean, SD; standard deviation, *P value is significant at 5% level

Table 2: Comparison of vertical bone loss between groups and time intervals for posterior implants

	6 months after insertion (T6)		**12 months after insertion (T12)**		**Paired samples t-test**
	Vertical bone loss				
	X	±SD	X	±SD	
Group I	.120	.007	.269	.092	.022*
Group II	.323	.240	.411	.273	.100
Independent samples t-test	.216		.411		

X; mean, SD; standard deviation, *p value is significant at 5% level

Comparison of vertical bone loss between groups and time intervals for posterior implants showed that there was no significant difference between groups at T6 and T12, (Table 2). Comparison of vertical boneloss between implant positions at different times for group I (soft metal) showed that there was non-significant difference between implants positions at T6 and T12, (Table 3).

When comparing vertical bone loss between implant positions at different times for group II (laser melting) it was found that there was non-significant difference between implant positions at T6 and T12, (Table 4).

Discussion:

Getting an accurate implant framework with passive fit has been linked to biologic implant success because poorly fitting frameworks put stress on the prosthesis, cause marginal bone loss around the implant, and raise the possibility of complications.[19] Numerous laboratory steps are used in conventional casting, which raises the risk of mistakes.[20,21] In this study, alternative computerized framework fabrication methods such as selective laser melting technology and milling from soft metal blocks were proposed to address some of the drawbacks of conventional

Table 3. Comparison of vertical bone loss between implant positions for soft metal group

	6 months after insertion (T6)		12 months after insertion (T12)	
	Vertical bone loss			
	X	±SD	X	±SD
Anterior implants	.158	.052	.272	.160
Posterior implants	.120	.007	.269	.092
Independent samples t-test	.275		.981	

X; mean, SD; standard deviation, *p value is significant at 5% level

Table4. Comparison of vertical bone loss between implant positions for laser melting group

	6 months after insertion (T6)		12 months after insertion (T12)	
	Vertical bone loss			
	X	±SD	X	±SD
Anterior implants	.139	.013	.216	.053
Posterior implants	.323	.240	.411	.273
Independent samples t-test	.254		.290	

X; mean, SD; standard deviation, *P value is significant at 5% level

casting and enhance the marginal fit as suggested by prior publications.[12,15] Little is known about the effect of the Co-Cr framework made using these techniques on the marginal bone in terms of clinical performance; therefore, this study was carried out. The aim of this study was to compare the vertical bone loss ofCo-Cr framework for screw-retained implant-supported fixed complete denture fabricated by milling from soft metal block, and selective laser melting technology. All frameworks presented an amount of bone loss at T6 and T12 that was considered insignificant. Accordingly, the hypothesis that there would be no difference in the vertical bone loss of Co-Cr screw-retained implant supported fixed complete denture frameworks fabricated by the two techniques was accepted. The accuracy of the impression is also crucial when it is required for multi-implant restorations. This is because frameworks will be constructed from the master cast. In this study, the accuracy of the impression was achieved by using open tray impression techniques, as there was no need to screw in the coping again as it came along with the impression and is useful in patients with angulated implants.[22] Splinting impression coping with rigid material[19] using polyvinyl siloxan impression material as it exhibits good resistance to deformation and good flexibility also were performed for impression precision.[23,24] The accuracy of the impression was verified by the use of verification jig.[25] These procedures were standardized for all patients in this study. This study measured peri-implant vertical bone loss using the periapical x-ray long cone parallel technique. The low exposure dose and being the least invasive of all radiographic techniques are the main benefits of standard periapical radiographs. In addition to being affordable, it is dependable for measuring linear distances, easily accessible, and manageable for dentists.[26] Using an X-ray positioner correctly results in a fixed position for the focal point and a perpendicular alignment of the x-ray cone through the film.[27]It was observed in this study that the vertical bone height loss values for both groups were accepted because the generally accepted standards for implant-induced bone loss since the late 1980s are less than 1.5 mm for the first year after implant loading and less than 0.2 mm for each additional year; this value was considered statistically insignificant. Studies have shown that, up to 36 months after implant loading, there is a mean crestal bone loss of 0.6 mm during the first year and 0.2 mm during the following years.[28] It was observed that, there was a significant difference between time intervals for soft metal group only. Vertical bone loss at T12 was significantly higher than vertical bone loss at T6. Higher misfit values in the soft block as a result of the milling process carried out in the pre-sintered stage may be the most likely cause. According to Pas ali et al.[29] the pre-sintered metal block contracts by about 10% during the sintering process.The finding of this study revealed that there was non-significant difference of VBL between SLM and PSA frameworks at both T6 and T12. This could be explained by the fact that both fabrication techniques have similar fit accuracy, as revealed by Revilla-Leo'n et al.[30] who compared full arch Co-Cr implant frameworks made using milling technology and addition manufacturing, and observed no statistically significant difference in the mean total distortion between the two fabrication techniques, with 54.1 ± 7.7 mm for the addition manufacturing group and 54.7 ± 9.8 mm for the SM group. Further research revealed that the mechanical characteristics of the selective laser melting SLM and the milling/post sintering (ML/PS) were fairly comparable.[31] Also, the fit of three-unit Co-Cr FDPs made using 4 different fabrication techniques—conventional lost-wax method, milled wax with lost-wax method, milled Co-Cr, and additional manufacturing direct laser metal sintering—was also compared by Ortorp et al.[32] They discovered that the addition manufacturing group had the best marginal fit. However, the frameworks were cemented in place, and the marginal gap was measured with a stereomicroscope. Svanborg et al. [33] asserted that 3D printed screw-retained implant-supported frameworks made of Co-Cr and Ti were more precise than milled frameworks made of the same material.It was observed that there was no statistically significant difference between the peri-implant VBL associated with a straight implant and that of a tilted implant in the same group. This was in line with a previous study by Monje et al.[34] Which came to the conclusion that the short- and medium-term marginal bone loss around tilted implants that were splinted to support fixed prostheses was not significantly different from that around straight implants. Del Fabbro et al.[35] Confirmed this non-persistence difference's for up to 5 years of function but were unable to make long-term conclusions. In a comparison of the behaviour of tilted and straight dental implants in function for more than three years, Alccayhuaman et al.[36] Discovered that MBL was 0.03 mm higher for tilted implants. Another study involved 20 patients with severely atrophic posterior mandibles

Who were treated with an immediately loaded full-arch fixed prosthesis supported by four interforaminal implants. For axial and tilted implants, respectively, bone loss averaged 0.6, 0.3, and 0.7, 0.4 mm. There was no statistically significant difference.[37]The limitations of this study include the small sample size and the short evaluation period. Further studies including clinical trials with larger sample size and longer evaluation period are needed to validate the effect of manufacturing techniques of framework on peri implant bone tissue changes.

Conclusions:

Within the limitations of this clinical study the following conclusions can be made: Full arch screw retained implant-supported Cr-Co fixed complete denture frameworks fabricated with milling from soft metal block, or addition manufacturing using laser melting technology techniques exhibited acceptable vertical bone loss during six months and one year follow up. Further prospective studies are needed to evaluate framework fabricated by milling from the soft metal group.

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