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A COMPARATIVE GAP ANALYSIS STUDY USING STEREOMICROSCOPY BETWEEN SCREW RETAINED ZIRCONIA FRAMEWORKS, TILOP SELECTIVE LASER SINTERING FRAMEWORKS AND CONVENTIONAL CAST METAL FRAMEWORKS

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ABSTRACT

Background: The target of this in vitro study was to compare and analyze the gap between abutment finish lines and implant analogues using stereomicroscope between three different screw retained frameworks; Zirconia Frameworks, TILOP45 Selective Laser Sintering Frameworks and Conventional Cast Metal Frameworks

Materials and Methods: This In-vitro study involved the construction of a total of eight models. Three screw-retained frameworks were constructed on each model hence creating three groups; Group A, B and C. For Group A: Screw-retained frameworks were constructed using the conventional cast metal technology as For Group B: Screw-retained zirconium frameworks were constructed using the CAD/CAM technology and finally For Group C: Screw-retained frameworks were constructed using the Selective Laser sintering SLS technology TILOP 45 (TILOP = Titanium Low Oxygen Powder). Final frameworks of each group were screwed over each model and then using stereomicroscope, a gap analysis was performed.

Results: When comparing the mean gap values of the three groups, the study has shown that there was a statistically significant difference in the mean gap values between both the Zirconia and TILOP45 frameworks and the conventional cast frameworks ($p<0.001$). The highest mean gap Value was found in conventional cast frameworks while the least mean gap value was found in the Zirconia frameworks. Results also revealed that there was no statistically significant difference in the mean gap values between the Zirconia Frameworks and the TILOP45 Selective Laser Sintering Frameworks.

Conclusion: Within the limitations of this study, it can be concluded that selective laser sintering technology as well as the CAD/CAM Zirconia technology renders more passive frameworks than the conventional cast method. There seems to be a very close similarity between the accuracy of frameworks constructed with the selective laser sintering technology and the CAD/CAM Zirconia technology.

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INTRODUCTION

The ultimate objective of contemporary dentistry is to restore the patient's normal facial contour, comfort, esthetics, speech, function and health. [1] Passive fit (synonymous with "ideal fit") is assumed to be one of the most significant prerequisites for the maintenance of the proper bone-implant interface. To provide passive fit or a strain-free superstructure, Taylor et al. [2] reported that a framework should, theoretically, induce absolute zero strain on the supporting implant components and the surrounding bone in the absence of an applied external load. However, it has been concluded that an absolute passive fit cannot be obtained. For screw retained prosthesis, Carr et al. [3] stated that if the marginal gaps between the framework and abutments are excessive, large external preloads are introduced on the implant abutments and fixation screws, causing loosening or fracture. Misfit can result in bio-mechanical complications such as, fracture of the components of the system, screw loosening, bone resorption, soft tissue alterations and even loss of osseointegration as reported by Goodacre at al , Romero et al. and Gratton et al [4-6].

Studies by Keith et al. and Guichet et al. [7,8] noted that the fit of one-piece conventional cast metal frameworks continues to be controversial. The conventional cast wax technique, generally used to fabricate prosthetic superstructures on implant abutment, often results in porosity, distortion, warpage and lack of passivity as reported by Takahashi and Gunne, Yoko et al. and Karl et al. [9-11]. This may be due to the number of technical steps and the intrinsic properties of the materials as reported by Sahin and Cehreli [12]. Detection of marginal gaps was accomplished by Goll [13] using an explorer, a fit-checker, enhanced lighting and magnification as well as the presence of pain or tension as indicated by the patient. Hellden and Derand [14] advised that the detection of any gap is an indication that sectioning and soldering (or welding) is required.

For these reasons, Interest in Computer Aided Design (CAD)/ Computer Aided Manufacturer (CAM) technology for construction of the implant restorations is increasing because the frameworks and abutments may be machined from solid blocks of material, that are claimed to be more homogenous with better physical properties than conventional castings as reported by Al Fadda [15] and Drago et al [16]. CNC-milled, screw-retained zirconia frameworks were proposed by Denry and Kelly[17] as it has the advantage of being aesthetic, highly biocompatible, prevention of plaque accumulation, and with superior mechanical properties.

Rapid prototyping (RP) technoa logies` are based on layer by layer additive technique where 3D CAD models are transformed into physical parts. Selective laser melting (SLM), selective laser sintering (SLS) and laser engineered net shaping (LENS) are some of the technologies used today for construction of metal objects [18-20].

The fabrication of metal dental prostheses and implants by rapid prototyping is one of its important applications. Titanium and its alloys are considered to be optimal materials for dental implant because of their known biocompatibility and high strength to weight ratio [21]. In selective laser melting, a powder (of single component) is melted and solidified by scanning of a CO2 or an Nd:YAG laser onto a powder bed, which is different from SLS that uses metal powder encapsulated with a polymer. (22)

Additive manufacturing technology has lately been the matter of significant attention because it has the potential of drastically changing the industrial development making it much faster resulting in substantially reducing total production cost. Titanium is considered to be one of the most suitable materials to which additive manufacturing technology can be applied. Due to its high quality and spherical nature, TILOP = Titanium Low Oxygen Powder is eminently suited to this promising field of additive manufacturing. (23) The TILOP 45 has the highest ductility due to a relatively high density and low oxygen content. (24)

MATERIALS AND METHODS

In this In vitro study, the sample size calculation was carried out by a "power and sample size" program (G*Power program (University of Düsseldorf, Düsseldorf, Germany).This In-vitro study involved the acquisition of a total of eight stone casts from Eight patients. Patients were selected from the outpatient clinic of the Prosthodontics Department, Faculty of Oral and Dental Medicine, Cairo University according to an adequate inclusion criteria for implant placement. Conventional steps of complete denture construction and radiographic stent fabrication was then pursed. Patients were then radiographed using Cone Beam Computed Tomographic (CBCT) scanning machine (Scanora 3D Soredex, Helsinki, Finland). For each patient, four implants were planned in the lateral incisor/Canine region and and second premolar region according to the available bone height and width. 3D designing of the virtual stents was then performed followed by 3D printing (Invision Si2, USA). At the time of surgery, the computer guided stent was fixed in place and then Implant surgery was carried out in a classical method.

After 4-6 months, the patients were recalled and the Implants were checked for adequate osseointegration. The snap-on Implant plastic transfer copings supplied with the implants were placed over each implant and impressions were then taken using a closed tray technique with medium body rubber base impression material (Impregum, 3M ESPE, AG Dental Products D-82229 Seefled, Germany). The implant analogues were then snapped on over the Plastic transfer copings inside the impression and then the impression was poured using extra hard stone (Type III Dental Stone, Lascod SPA, Sestofino (FI), Italy) to obtain a total of eight stone casts.

Three screw-retained frameworks were constructed on each model hence creating three equal groups; Group A, B and C. For Group A: Screw-retained frameworks were constructed using the conventional cast metal technology as For Group B: Screw-retained zirconium frameworks were constructed using the CAD/CAM technology and finally For Group C: Screw-retained frameworks were constructed using the Selective Laser sintering SLS technology TILOP 45 (TILOP = Titanium Low Oxygen Powder).

Procedures of Framework construction for GROUP A:

Plastic castable abutments (Plastic burnouts Implants, ImplantDirectTM LLC Spectra-System Dental Implants Calabasas Hills CA, USA) were fastened to the analogues. The plastic abutments were connected with Duralay resin to form a rigid frame. Final waxing up was done to produce a final pattern which was then invested and cast into chrome cobalt alloy.

Procedures of Framework construction for GROUP B:

Over each implant, long screws; used for the open tray technique; were screwed over each implant. Scanning of the cast was then performed using the D710 3 Shape Dental scanner (D710 3Shape Dental scanner Holmens Kanal 7. 1060 Copenhagen K Denmark). The STL file for each cast was then imported into the software called Rhinoceros (Rhinoceros ® North Seattle, WA 98103 USA). The plastic Burnout abutment specific for the ScrewIndirect Implants used in this study were drawn virtually using the tools available in this program to obtain a virtual 3D image of each abutment.

The long screws screwed over the implants were used to exactly determine the vector of each implant in space. The finish line of each abutment was also marked with points and the long axis of each abutment was superimposed over the vector of each implant. The virtual abutments were then moved along these superimposed lines to finally reach the points drawn representing the implant's finish line. Connections were then drawn virtually using the tools available in the Software Rhinoceros with a trapezoid cross section and following the soft tissue profile between each implant.

The 3D Virtual frameworks were then exported as STL Files. STL files for each case were then imported into specific CAM software called SUM3D Dental (SUM3D Dental, Roland Digital CAM, CIM Systems Viale Fulvio Testi, Milano, Italy) to transform these STL files into files readable by the 5 Axes milling machine Roland (ROLAND DWX-50 ® 5 axis milling machine, Roland DG Corporation, Hamamatsu-shi, Shizuoka-ken Japan). The CAM files were then milled from Zirconia blocks (Whitepeaks Dental Systems GmbH & Co. KG, Langeheide Essen, Germany). The frameworks were then tried on the actual casts and checked for passivity.

Procedures of Framework construction for GROUP C:

The same steps performed for group B were exactly repeated except that the final framework STL files were exported and then manufactured using the Selective Laser sintering SLS technology machine (M3Linear, Concept-laser, Germany) using TILOP 45 (TILOP = Titanium Low Oxygen Powder).

The frameworks for all groups were checked individually for fit and passivity using the single screw test following the technique recommended by Sahin and Cehreli [12]. The technique involved screwing the framework from the most distal abutment and check for possible lifting of the framework on the other side of the framework which if present, indicated lack of passivity of this framework. In case the framework remained stable in place, the middle screw was then placed, and so forth of the rest of the screws. After placing screws one by one, a final 180 degree turn is performed to reach a torque of 10 Ncm for complete screw seating. If more than a half turn (180 degrees) was needed to provide seating of the screw, the framework was considered misfit. The presence of any gap as detected by a probe and appropriate lighting indicated that sectioning with a disc, re-connecting with Duralay resin and soldering was performed.

In this study, all finished frameworks were considered passively seated over their corresponding implants in all groups except for three frameworks in Group A; which were considered non-passively fit according to the one screw test. These three frameworks were sectioned and re-soldered and tried again on their casts and checked again using the single screw test.

The Final finished frameworks of the three groups were all screwed over their corresponding implants on each cast and using stereomicroscope (SMZ-1500, Nikon, Tokyo, Japan) the buccal aspect the four abutments installed over the four implants of the framework was checked for the presence of any gap. The measurements were done using a zoom stereomicroscope with 3.0 megapixel CCD cameras (Moticam 2300, Motic, Hong Kong) at a ×125 PC-monitor magnification. Calibrated image software (Motic Images plus 2.0) (lesica software). The Software generated a series of numbers every 0.25mm on each buccal aspect for each group. A total of 20 measurements were obtained on the buccal aspect of each of the four implant analogues. The mean gap width values of each implant was obtained then tabulated and statistically analyzed.

Statistical analysis and methods

Data analysis was performed using Statistical Analysis Systems SPSS software (version 13.1: SPSS Inc). Probability values ≤0.05 to indicate significant relationships between variables. Quantitative data were explored for normality by checking the data distribution and using Shapiro-Wilk tests Gap width data showed normal distribution. Data were presented as means and standard deviations. One way Anova test was used to compare the Gap width between the three groups

RESULTS

When comparing gap width values of the three studied groups at each implant location there was a statistically significant difference in mean gap values between the three groups. Results showed that the highest mean gap values were recorded in Group A (Conventional cast group) (P=0.00) as shown in Table 1. Furthermore, when comparing the total mean gap widths of all implants in the three studied groups, statistical analysis also revealed a statistically significance difference between the three groups (p value =0.000). Similarly, results also showed the highest mean gap values in Group A (conventional sating group) (P = 0.00) as shown in Table 1

When comparing the mean gap values of Group A (conventional casting) with Group B (Zirconia CAD/CAM), the study has shown a statistically significant difference in the mean gap values between the two groups (p<0.001) where the mean gap difference was -0.164656 mm. The highest mean gap value was found in Group A.

Additionally, when comparing the mean gap values of Group A (conventional casting) and C (SLS), statistical analysis revealed a statistically significant difference in the mean gap values between both groups where the mean gap width difference was -0.155375 mm (p=0.000). The highest mean gap value was found in Group A. (Table 1)

Moreover, when comparing between the Group B (Zirconia) to Group C (SLS), the mean gap width difference was found to be -0.009281 mm with a non-statistically significant difference between the two groups (p value =0.831). (Table 1)

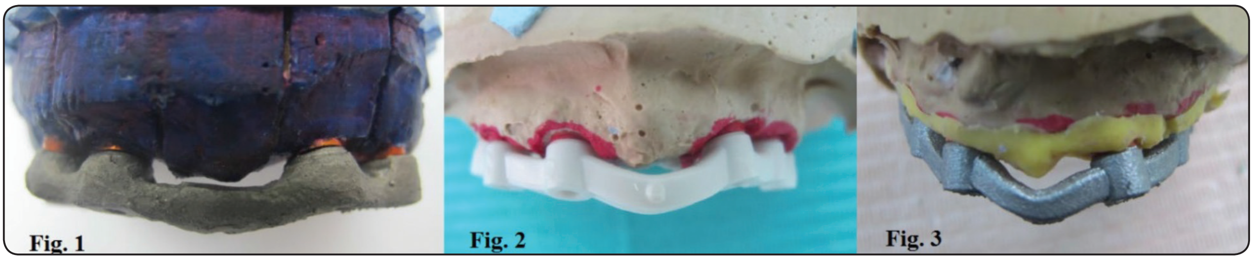
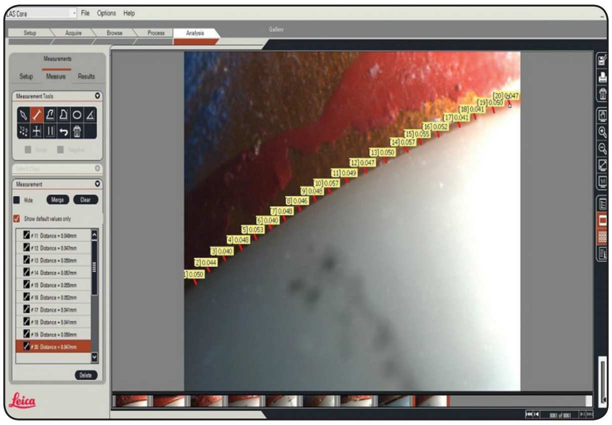


Fig. (1) Conventional Cast metal Screw-retained frameworks Fig. (2) CAD/CAM Zirconium Screw-retained frameworks Fig. (3) Selective Laser sintering SLS TILOP 45 Screw-retained frameworks

Table (1) The mean (mm), and standard deviation comparing between the Gap widths values of the three studied groups at each implant Location

Implant	CAD /CAM Zirconia		SLS TILOP		CC		P value
	Mean	St dev	Mean	St dev	Mean	St dev	
1	.05075	.020624	.05038	.017427	.12788	.033438	**.000**
2	.04113	.018856	.04925	.024453	.10575	.040574	**.000**
3	.12613	.040650	.13338	.037755	.36000	.058554	**.000**
4	.10575	.040574	.12788	.033438	.38875	.088227	**.000**
Total mean	.08094	.047447	.09022	.049672	.24559	.142988	**.000**



11 Distance = 0.049mm
12 Distance = 0.047mm
13 Distance = 0.050mm
14 Distance = 0.057mm
15 Distance = 0.055mm
16 Distance = 0.052mm
17 Distance = 0.041mm
18 Distance = 0.041mm
19 Distance = 0.050mm
20 Distance = 0.047mm

Fig. (4) Twenty gap width measurements obtained on the buccal aspect of the implant analogues using a zoom stereomicroscope with 3.0 megapixel CCD cameras

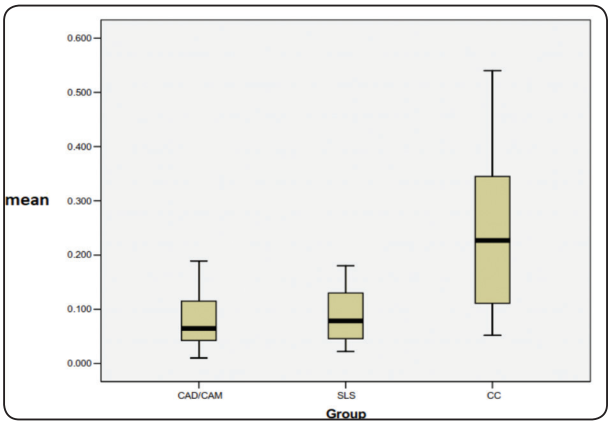


Fig. (5) The mean (mm), and standard deviation comparing between the Gap widths values of the three studied groups at each implant Location

DISCUSSION

In this Vitro study, a total of 32 implants were placed in the edentulous maxillae of eight patients; four implants per maxilla. Implants were nominated from 1 to 4 starting from the right side to the left side of each model. Each model received three different types of screw retained implant supported maxillary framework; Group A, B and C. For Group A: Screw-retained frameworks were constructed using the conventional cast metal technology as For Group B: Screw-retained zirconium frameworks were constructed using the CAD/CAM technology and finally For Group C: Screw-retained frameworks were constructed using the Selective Laser sintering SLS technology TILOP 45 (TILOP = Titanium Low Oxygen Powder).

When comparing gap width values of the three studied groups at each implant location as well as of the total mean gap values, results revealed the highest mean gap values in Group A (conventional casting group). This was in accordance with a study performed by Almasri et al. [25] where they demonstrated better precision of CAD/CAM frameworks compared to the cast frameworks fabricated with the conventional lost-wax technique, with respect to the volumetric misfit values. The conventional cast wax technique, generally used to fabricate prosthetic superstructures on implant abutment, often results in porosity, distortion, warpage and lack of passivity as reported by Takahashi and Gunne, Yoko et al. and Karl et al. [9-11].

When comparing the mean gap values of Group A (conventional casting) with Group B (Zirconia CAD/CAM), the study has shown a statistically significant difference in the mean gap values between the two groups; Additionally, when comparing the mean gap values of Group A (conventional casting) and C (SLS), statistical analysis revealed a statistically significant difference in the mean gap values between both groups; In both situations, the highest mean gap values was found in Group A. This was agreed upon by a study performed by Tan et al. [26] who did an in vitro comparison of vertical marginal gaps of CAD/CAM titanium, WAX/CAM titanium and conventional cast restorations (WAX/CAST). The results showed a statistically significant difference between the WAX/CAST group and the remaining groups and no difference between the vertical marginal gaps of the CAD/CAM and WAX/CAM [26].

Another prospective study performed by Tersello et al [27], to compare the lost wax technique frameworks, cast titanium superstructures laser welded to prefabricated titanium copings, Proceras Implant Bridge, Cresco Ti System and CAM StructSUREs Precision Milled Bar. The computer-aided procedures analyzed in the present study were able to produce a precision-fitting framework, with no significant differences among them and, at the same time, showed a greater precision compared to the traditional casting methods which was in accordance with results obtained in this current study.

Moreover, when comparing between the Group B (Zirconia) to Group C (SLS), the mean gap width difference was found to be -0.009281 mm with a non-statistically significant difference between the two groups; the higher gap width value was found in Group C (SLS TILOP 45). This was in accordance with a comparative study performed between the CNC-milled Titanium and Zirconia Frameworks performed by Abduo et al [28], the zirconia was frameworks produced significantly less strain than titanium. There are indications from the strain gauge analysis and gap measurements that zirconia frameworks have the tendency to exhibit superior fit than titanium frameworks [28].

CONCLUSION

Within the limitations of this study, it can be concluded that selective laser sintering technology as well as the CAD/CAM Zirconia technology renders more passive frameworks than the conventional cast method. There seems to be a very close similarity between the accuracy of frameworks constructed with the selective laser sintering technology and the CAD/CAM Zirconia technology. CAD/CAM frameworks as well as SLS Titanium frameworks should be considered as a viable alternative to conventional cast frameworks for implant supported screw retained restorations. Further laboratory and clinical studies are necessary to evaluate the degree of fit obtained with other machines, as well as the biologic tolerance for clinically acceptable implant frameworks.

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