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Original Article

A Comparative Study of the Biological and Prosthetic Complications of CAD/CAM Zirconia and Conventional Cast Implant Supported Hybrid Prostheses

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Abstract

Aim: The Target of this work was to study the different Prosthetic and Biological Complications of two different techniques of framework construction; the Casting Metal Technology and the Zirconia CAD/CAM Technology in screw-retained prostheses.

Materials and Methods: In this study, twelve patients with fully edentulous maxillae had a total of seventy-two implants inserted. Six implants were inserted in each patient's lateral incisor, first premolar, and first molar regions. Patients were randomly split into two equal groups, Group I received cast metal frameworks, and Group II received zirconium CAD/CAM frameworks. The passivity of fit was assessed for both groups using the one screw test at the time of definitive prosthetic delivery. Prosthetic and biological complications were assessed after three and six months. Moreover, calculations, analyses, and comparisons between both groups were done regarding the quantity and length of visits performed in each group.

Results: Regarding Prosthetic Complications, statistical analysis revealed a higher statistically significant percentage of screw looseness in Group I in comparison with Group II (P-value < 0.05) after 3-month and insignificant difference after 6 months. As for biological complications, Statistical Analysis at three and six months follow-up of implant failure/looseness and Peri-implantitis revealed a higher percentage in Group I than Group II but with a statistically insignificant difference (P-value > 0.05).

Conclusion: CAD/CAM restorations yielded fewer prosthetic and biological complications, less time, and number of clinical visits than the Conventional Casting group. CAD/CAM restorations should thus be considered a viable alternative to cast implant frameworks restorations.

Keywords: passive-fit, screw retained restorations, passivity, flapless surgery, computer guided surgery

INTRODUCTION

Restoration of the patient to their normal facial shape, function, esthetics, speech, health, and comfort is the ideal goal of contemporary dentistry [1]. When the passive fit is a criterion for clinical acceptability, studies by Keith et al. and Guichet et al. [2–3] noted that the fit of one-pieced standard cast metal frameworks continues to be debatable. According to Takahashi, Yoko, and Karl [4-6], cast metal frameworks are susceptible to expansion and contraction, which can lead to porosity, warpage, a lack of passivity, and/or distortion of individual castings.

Because the frameworks and abutments can be machined from solid blocks of material that are more homogeneous and have better physical qualities than conventional castings, interest in computer-aided design/computer-aided manufacturer technology for implant restorations is expanding. According to Al Fadda [7] and Drago et al [8], these technologies have eliminated traditional

waxing, casing, and finishing processes as well as the errors associated with them. In fixed detachable frameworks, attaining passivity has always been the most challenging task.

The most frequent prosthetic complication is the lack of passivity of the frameworks which creates stress and strains the bone-implant interface surrounding the implants which can lead to biological or mechanical failures such as screw loosening, screw fracture, or framework fracture [9]. Furthermore, if there are microscopic discrepancies between the two geometric components, frictional and misfit resistance can be generated within the screws leading to screw looseness and possible screw fracture. The screw bends and deforms to compensate for this strain at the interface, which reduces the clamping force that will in turn lead to subsequent screw loosening or fatigue fracture [10].

There are various possibilities for the fabrication processes used to create the frameworks of fixed detachable prostheses. A prosthetic framework can be made using any of the following methods: traditional 1-piece casting, casting and laser, electric welding, casting and spark erosion, copy, computer numeric-controlled milling, or computer-aided design and computer-aided manufacture. [11]

Three main categories were determined, according to the Pisa Consensus Conference held in March 2008 by the ICOI (International Congress of Oral Implantologists) [12]: success, survival, and failure. Implant survival conditions can be divided into two categories: implants with satisfactory survival, which do not require clinical treatment, and implants with compromised survival, which necessitates clinical treatment to decrease the probability of implant loss and/or failure. The phrase "implant failure" is used to describe implants that need to be removed or that have already been lost. [12]

MATERIALS AND METHODS

Twelve male patients were chosen from Cairo University's faculty of oral and dental medicine's Prosthodontics department's outpatient clinic. Patients recruited in this randomized control trial were chosen with the following criteria; patients had completely edentulous maxillae, a normal maxillo-mandibular relationship (Class I Angle classification), no para-functional habits, and were otherwise systemically healthy.

Sample Size Calculation

The sample size was estimated using a prior study performed by Velasco-Ortega et al. [13] that used independent cases and controls with one control for each case. Prior data showed that among controls, the incidence of exposure is (0.5). If the true probability of exposure among cases is (0.001), we need to study 6 case patients and 6 control patients to be able to reject the null hypothesis that the exposure rates for cases and controls are equal with probability (power) (0.8). The Type I error probability associated with this test of this null hypothesis is 0.05. An uncorrected chi-squared statistic was used to evaluate this null hypothesis.

Implant Planning

Construction of conventional maxillary full dentures, which were duplicated to create radiographic stents, was first performed. Cone Beam Computed Tomography (CBCT) scanning equipment was used to take radiographs of the patients' maxillae (Sanora 3D Soredex, Helsinki, Finland). DICOM files from the CT scan were imported into the Mimics software (Mimics, Materialise HQ, Technologielaan 15, 3001 Leuven, Belgium), where coronal and sagittal reformatting and panoramic images were obtained.

The radiolucent channels that had been previously constructed in the radiographic stent at the prosthetic teeth centers allowed for the identification of the desired implant sites. Bone height, width, and density, at each of the six prospective locations, were assessed. According to the available bone height and width for each patient, six implants were to be designed in the lateral incisor/Canine region, first premolar region, and first molar region. The four anterior implants had a standard height of 13 mm, while the two posterior implants had a standard height of 10 mm. The Mimics software was used to plan and design computer-guided surgical stents for all the patients in this trial where virtual planning of the implants was performed at the predicted implant sites. The resultant STL file of the 3D virtual stent was then exported to a 3D printing machine (Invision Si2, USA) to construct the stent from a photocurable resin material.

Implant Installation

The surgical equipment was sterilized by autoclaving at the time of the surgical operation, and the oral surgical sites and the tissues around the mouth were wiped with a chlorhexidine and iodine solution. At each implant location, infiltration anesthesia (Ubestesin, 3M ESPE, Germany) was administered then three fixation screws were used to secure the stent (Biomet M Fix, USA) intraorally. Following that, osteotomies were created using the traditional drilling sequence (pilot, intermediate, and final drills) and a unique "drill guide" as shown in Figure 1A. Copious manual irrigation was performed between each drill using sterile saline irrigating solution to avoid over-heating of the osteotomy sites The implants were then manually tightened through the stent until resistance was encountered, at which point a ratchet was used to complete the tightening to reach a Primary stability of at least 30 Ncm as shown in Figure 1B. A chairside soft lining procedure was carried out for each maxillary denture (Mollosil® plus, DETAX GmbH & Co. KG, Carl-Zeiss-Str. 4, 76275 Ettlingen, Germany) Patients were then permitted to wear their denture for 4 months to allow sufficient time for adequate osseointegration to be established.

Impression Taking

Patients were recalled after 4-5 months and the implants were tested for sufficient bone stability and osseointegration using the "Osstell" ISQ equipment (Osstell AB, Gamlestadsvägen 3B, SE415 02, Sweden) The next step involved recording primary impressions utilizing a closed tray technique. A verification index was created by screwing temporary titanium abutments onto the implant analogs inside the primary cast and then splinting them together with DuraLay resin (DuraLayTM, Reliance, Dental MFG Co. Worth, IL, USA). The Passivity of the Verification index was then checked in the patient's mouth. Lack of passivity necessitated sectioning of the jig and reconnecting it intraorally using Duralay. After that, the radiographic stents were modified by creating windows opposing the implants to be sued as special trays. Following that, an open tray impression was then registered, the implant analogs were anchored to the temporary titanium abutments and finally pouring with extra-hard stone was done.

Framework Construction

Patients were randomly divided into two equal groups: For Group I: Screw-retained fixed detachable frameworks were fabricated using the conventional cast metal technique. The plastic castable (Plastic burnouts Implants, ImplantDirectTM LLC Spectra-System Dental Implants Calabasas Hills CA, USA) abutments were screwed over the implant analogs, and waxing up was performed in the normal fashion which was then invested and cast into chrome cobalt alloy as shown in Figure 2A, B and C. The one-screw test was used to evaluate the fit and passivity of the final cast frames on the master cast as demonstrated in Figure 2D. Clinically, the one-screw test was used to evaluate the fit and passivity of the frames for each group. The detection of any gap found indicated the need for sectioning, fastening of the segmented framework fragments to the implants, re-connecting with Duralay chairside, and then finally soldering of the framework in the laboratory was performed as shown in Figure 3A and B.

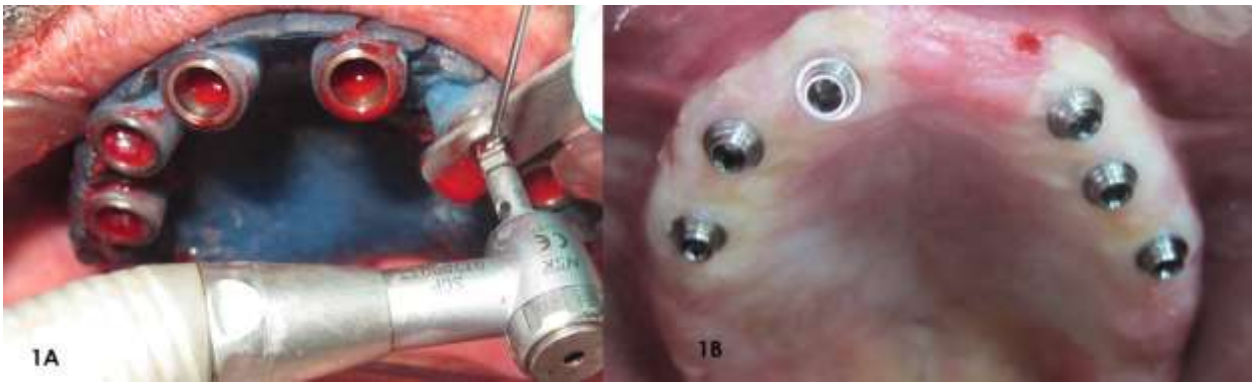

Figure 1: A: Osteotomy being performed B: Implants after being surgically installed

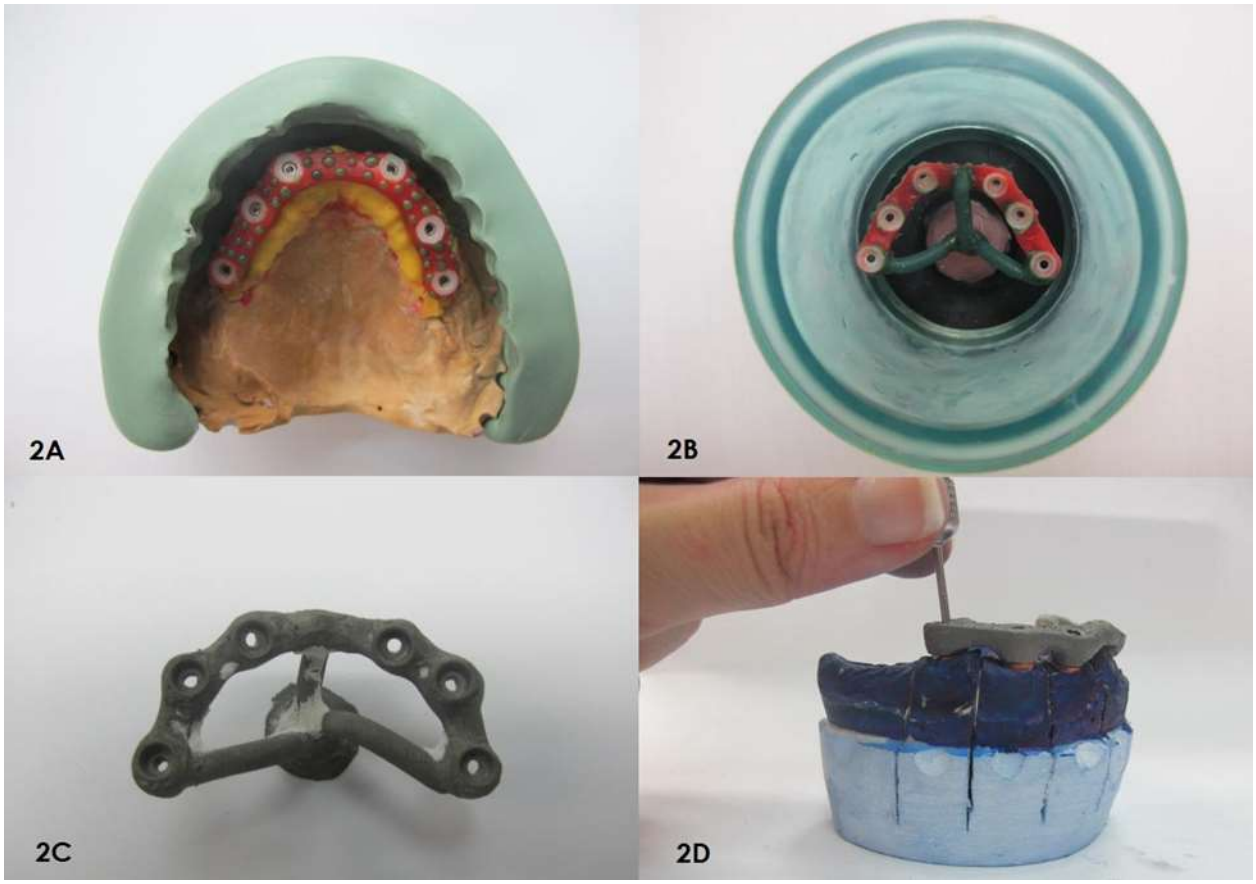

Figure 2: A: Waxing Up of the Cast Metal Framework. B: Sprueing of the Wax pattern. C. Cast Metal Framework. D. One-Screw Test performed on the Master Cast.

Figure 3: A. Non-Passive Cast Framework tried on the Master Cast. B. Sectioning of the Cast

For Group II: Screw-retained fixed detachable CAD/CAM zirconia frameworks were constructed. Scanning of the master casts was done using the D710 3Shape Dental scanner (D710 3Shape Dental scanner, Copenhagen Denmark). Designing of the zirconia screw-retained frameworks was performed using the Rhinoceros software (Rhinoceros ® North Seattle, WA 98103 USA) where the virtual plastic Burnout abutment was navigated to be seated accurately over each virtual implant analog after digitally using Rhinoceros. The resultant 3D Virtual frameworks were then milled from Zirconia blocks (Whitepeaks Dental Systems GmbH & Co. KG, Langeheide Essen, Germany) using ROLAND DWX-50 ® 5-axis milling machine, Roland DG Corporation, Hamamatsu-shi, Shizuoka-ken Japan). The milled frameworks were then tried to check for passivity on the actual master casts in the laboratory and clinically as shown in Figure 4A and B.

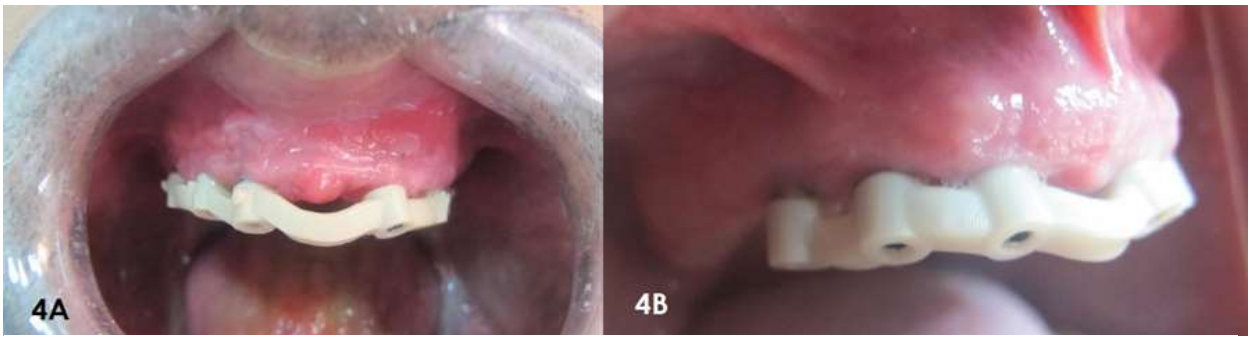

Figure 4: The screw-retained Zirconia Framework tried in the patient's mouth. A: Front View. B: Buccal View.

Final Prostheses Delivery

After passivity was verified carefully, bite registration was performed followed by the mounting of upper and lower casts on semi-adjustable articulators. Following Misch's IPO [14] instructions, acrylic teeth were set, and then the gingiva was built by hand utilizing the Visiolign Veneering (Visiolign, Bredent GmbH & Co.KG, WeissenhornerSenden, Germany) light-cured technology.

The final screw-retained implant-supported prostheses were screwed and delivered intra-orally as shown in Figure 5. Using a torque wrench, the prosthesis screws were tightened to 30Ncm then sealing of the access holes, and light-cured composite resin restorative material was used to establish adequate occlusion with the opposing mandibular teeth. Patients received information on the value of adhering to instructions, attending follow-up appointments, and maintaining good dental hygiene.

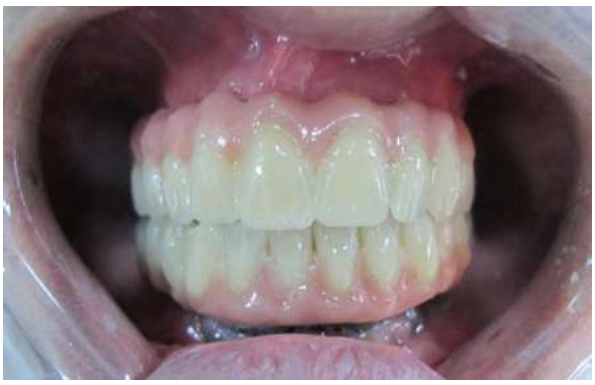

Figure 5: Final Screw Retained restorations delivered

In this randomized trial, framework passivity at the time of definitive prosthesis delivery was the first outcome to be reported for each group. Prosthetic and biological complications were also assessed at three and six months after prostheses delivery in both groups. Outcomes in this study were reported as binary data, and evaluation of the prosthesis was performed in each visit. The primary investigator of this study dealt with any prosthetic or biological difficulties by taking the following appropriate action for all encountered complications such as screw re-tightening (caused by loosened screws), Screw replacement in case of screw breakage, replacing failed implants, fractured teeth and/or acrylic resin as well as managing peri-implantitis as appropriately needed. Additionally, the number of visits, duration of the procedure, and the number of resources used for healthcare were recorded and statistically analyzed in each group.

RESULTS

Data revealed were reported as counts and percentages for each output of various complications during six months follow-up period. A comparison between Group I and Group II was performed using the Chi-square test for significance evaluation.

The Evaluation of the passive fit was done using the one screw test during framework construction for both groups at 0 Months. In the Conventional Casting group, a total of two frameworks (33.33%) were not passive and required sectioning and re-soldering at three sites; 2 sites (one anterior and one posterior site) in the first framework and one site (one posterior site) in the second framework. While in the CAD/CAM zirconia group, all frameworks (0%) were passive according to the one screw test performed and none required re-makes. Comparison between Groups I and II revealed that there was a higher percentage of lack of passivity at zero months in Group I (33.33%) than in Group II (0%), however, Statistical analysis showed an insignificant difference as P-value > 0.05.

Regarding Prosthetic complications, three different complications were reported in this

study; Screw looseness, Screw fracture, and Teeth/ Acrylic Fracture/Separation. Results of this study revealed a total of 8/36 screws were loose in Group I (22.22%) while a total of 2/36 screws in Group II (5.56%) were reported as loose at the 3-month follow-up period. Statistical analysis to compare Groups I and II revealed a higher statistically significant percentage of screw looseness in Group I (22.22%) in comparison with Group II (5.56%), as P-value < 0.05. At the 6-month follow-up, a total of 5/36 screws were loose in Group I (13.89%) while a total of 1/36 screws in Group II (2.78%) were reported as loose screws. Statistical analysis of screw looseness at 6 months revealed a higher percentage of screw looseness in Group I (13.89%) than in Group II (2.78%), without any statistically significant difference as P-value > 0.05, and as listed in the table (1) and showed in Figure 6.

While for teeth/acrylic fracture and separation, zero out of six frameworks in Group I (0%) had one or more teeth/acrylic fracture and/or separation while a total of 2/6 frameworks in Group II had one or more teeth/acrylic fracture and/or separation at the 3 months follow-up period. Statistical analysis showed that there was a higher percentage in Group II (5.56%) higher than in Group I (0%), but with a statistically insignificant difference (P-value > 0.05). At the 6-month follow-up, both groups showed equal (1/6) frameworks with one or more teeth/acrylic fracture and/or separation.

Regarding biological complications, three different complications were reported; Implant failure, Implant fracture, and Peri-implantitis. Results were recorded and tabulated as shown in Table 2 and Figure 7. There were no implant fractures reported in both group after 3 and 6 months of follow-up in the current study. Statistical Analysis at three months of implant failure/looseness revealed a higher percentage in Group I (5.56%) than in Group II (2.78%), also with a statistically insignificant difference (P-value > 0.05). At the six months follow-up, implant failure/looseness revealed an insignificant percentage difference between Group I (2.78%) and Group II (0%), as P-value > 0.05.

Whereas for peri-implantitis, results revealed that in Group I there was (13.89%) higher number of implants with peri-implantitis than in Group II (5.56%), but without a statistically significant difference as P-value > 0.05 in the three months follow-up and insignificant increase in Group (I) (11.11%) higher than Group II (2.78%), as P-value > 0.05 in the six months follow-up as listed in the table (2) and shown in figure 7.

Regarding the Evaluation of needed visits, Group I (7.83 ± 0.75) was significantly higher than Group II (3.76 ±0.41) as P <0.05. In the duration of needed visits, Group I (469 ± 11.9) was also significantly higher than Group II (187 ±9.2) as P <0.05. (Table 3)

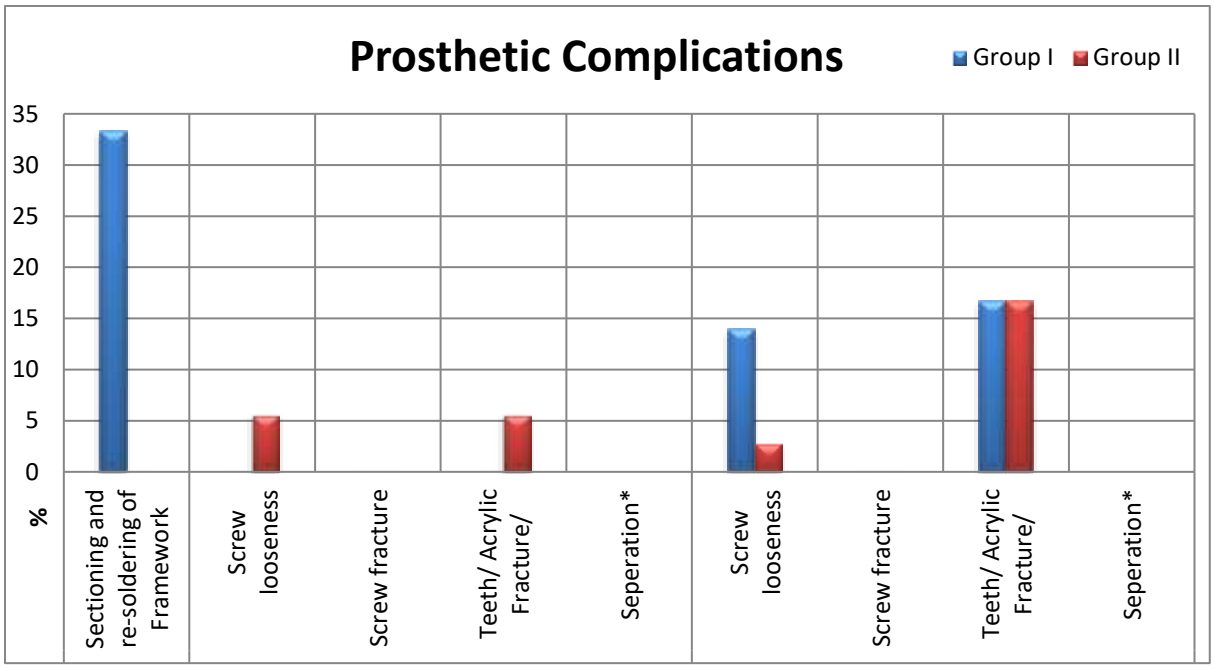

Figure 6: Bar chart representing percentage of different Prosthetic Complications in both groups.

Table 1: Frequency and Percentage of different Prosthetic Complications

		Group I (Conventional Casted Framework)		Group II (CAD/CAM Framework)		P value (Chi square test)
		N	%	N	%	
At 0 months	Sectioning and re-soldering of Framework	2/6	33.33	0/6	0	**0.1380 (NS)**
At 3 months	Screw looseness	8/36	22.22	2/36	5.56	**0.0424 ***
	Screw fracture	0/36	0	0/36	0	----------
	Teeth/ Acrylic Fracture/ Separation*	0/6	0	2/6	5.56	**0.5749 (NS)**
At 6 months	Screw looseness	5/36	13.89	1/36	2.78	**0.0904 (NS)**
	Screw fracture	0/36	0	0/36	0	----------
	Teeth/ Acrylic Fracture/ Separation*	1/6	16.67	1/6	16.67	----------

N; Count, %; Percentage, P; Probability Level
Ns; Insignificant Difference using Ch square test.
**Significant Difference using Chi square test*

Table 2: Frequency and Percentage of different Biological Complications

		Group I (Conventional Casted Framework)		Group II (CAD/CAM Framework)		P value (Chi square test)
		N	%	N	%	
At 3 months	Implant looseness (Failed)	2/36	5.56	1/36	2.78	**0.5579 (NS)**
	Implant fracture	0/36	0	0/36	0	----------
	Peri-implantitis	5/36	13.89	2/36	5.56	**0.2362 (NS)**
At 6 months	Implant looseness	1/36	2.78	0/36	0	**0.3171 (NS)**
	Implant fracture	0/36	0	0/36	0	----------
	Peri-implantitis	4/36	11.11	1/36	2.78	**0.1674 (NS)**

N; Count, %; Percentage, P; Probability Level
Ns; Insignificant Difference using Ch square test.

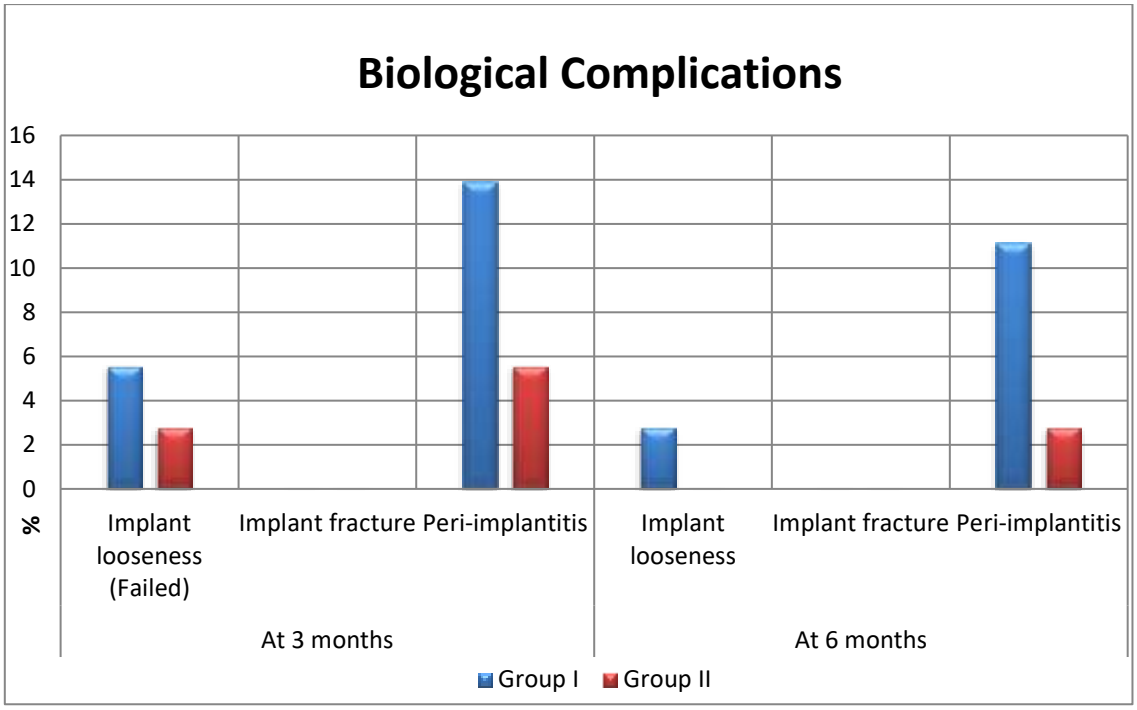

Figure 7: Bar chart representing percentages of biological complications in both groups.

Discussion

Due to the restoration being transformed from a removable complete denture to a fixed screw-retained implant-supported restoration, the majority of the research participants was able to adjust and was generally satisfied with the implant-supported restorations they received. This increased masticatory performance, increased comfort, and removed the need for flanges as agreed upon with Misch [14] As described by Di Francesco et al. [15], six implants were also inserted into the maxilla to support a fixed detachable prosthesis, which is thought to be the ideal amount of implants to allow for better stress distribution and more predictable prosthetic survival. [15]

Theoretically, the framework should generate zero strain on the supporting bone and implant structures in the absence of any external load. [14] Lack of passivity induces internal stresses in the framework, which results in mechanical complications such as screw loosening, fracture of screw, framework, or prosthesis [16]. Evaluation of the passive fit was done in this study using the one screw test at the time of prosthesis delivery which is a technique proposed by Sahin and Cehreli [16] where they screwed the framework from the most distal abutment and checked for the possible lifting of the frame at any point, followed by the middle screw and so forth. The detection of any gap is an indication that sectioning and soldering (or welding) was required as advised by Hellden and Derand [17]

In the current study, a Comparison between Groups I and II revealed that there was a higher percentage of lack of passivity in the Cast framework Group than in the CAD/CAM zirconia Group, however with a statistically insignificant difference. This indicates that the CAD/CAM Zirconia frameworks had superior passivity and better precision when compared with the conventional casting frameworks which can be explained by the fact that the CAD/CAM technologies have eliminated the inaccuracies, porosities, and distortions associated with conventional waxing, casting, and finishing procedures of casting. This was in accordance with multiple studies [18, 19] that reported that the CAD/CAM frameworks achieve implant/framework fit superior to those obtained with cast metal framework.

Furthermore, a higher statistically significant percentage of screw looseness at the 3-month follow-up in Group I but an insignificant difference at 6 months was revealed in this study. Lack of Passivity of the conventional casting frameworks 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 in multiple studies [20-22]. This was shown in the current study where Statistical Analysis at all-time intervals of implant failure/looseness revealed a higher percentage in Group I than Group II but with a statistically insignificant difference. Whereas for peri-implantitis, results revealed a statistically significant difference in the three months follow-up and insignificant increase in group I than Group II. If the marginal gaps between the screw-retained frameworks and abutments are excessive, large external preloads are introduced on the implant abutments and fixation screws which in turn create a lever arm that overloads the entire system. [23, 24] Accordingly, these built-in stresses from the casted frameworks transmit continuous, non-intermittent lateral forces to the bone-implant interface that may thus compromise its integrity and lead to biological complications such as implant peri-implantitis and failure if the load exceeded a certain limit [25].

Regarding the analysis of the number and duration of needed visits, Group I was significantly higher than Group II which can be attributed to the need of numerous steps required in the conventional cast group, lack of passivity of the cast frameworks which required, sectioning, soldering, and reassembly of the framework [26]. Additionally, the adjustment of the frameworks needed long duration compared to the CAD/CAM Group.

CONCLUSION

CAD/CAM restorations yielded fewer prosthetic and biological complications, time, and the number of clinical visits generally than the Conventional Casting group. CAD/CAM restorations should thus be considered a viable alternative to cast restorations for implant frameworks.

DISCLOSURE

The authors claim to have no financial interest in any company or any of the products mentioned in this article.

Conflict of Interest: The authors declare no conflict of interest.

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Ethics:

This study protocol was approved by the Research ethical committee in the Faculty of Dentistry- Cairo University on 11/2022.

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