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Assessment of patient's centered prosthetic maintenance of two different materials and design of mandibular fixed hybrid prostheses

Lamiaa Farouk zaki[1], Omar Abbas ElSadat[1]

Aim: Compare the prosthetic maintenance between two different framework materials for full arch mandibular fixed prostheses (zirconia over titanium bar and full arch zirconia) during a one-year follow-up.
Materials and Methods: Fourteen completely edentulous participants were selected. For each patient, six implants were installed in the mandible using a surgical guide. Participants were randomly divided into two groups. Group A: Mandibular fixed implant -supported prosthesis was constructed using zirconia over titanium bar framework and Group B: Mandibular fixed implant-supported prosthesis was constructed using full arch zirconia. The prosthetic complications were recorded from the time of prosthesis insertion for one year.
Results: It was found that there was no significant difference between both groups regarding the incidence of different prosthetic complications.
Conclusion: Within the limitation of this study, the type of prosthesis material either full-arch zirconia or zirconia over a titanium bar has relatively similar impact on the frequency of maintenance of prosthetic components.

Keywords: Full arch, zirconia, titanium bar, passivity, screw-retained

1. Lecturer of Prosthodontics, Oral and maxillofacial prosthodontics, Faculty of Dentistry, Ain Shams University, Cairo, Egypt. Corresponding author: Lamiaa Farouk Zaki, email: lamia.farouk@dent.asu.edu.eg

Introduction

The implant-supported fixed prosthesis, introduced in the 1980s to replace missing teeth in the entire lower jaw, is widely acknowledged as a predictable and reliable treatment modality.[1]

The choice of material for the prosthetic framework over implants plays a crucial role in how stress is distributed to the implants and surrounding bone. Therefore, selecting the right material is very important when restoring the arch with endosseous implants. Titanium and cobalt-chromium alloys are often selected for their biocompatibility, lightweight nature, and excellent mechanical properties.[2]

The initial application of computer-aided design/computer-assisted manufacture (CAD/CAM) in dentistry primarily targeted ceramic materials. Nowadays, titanium alloy frameworks for fixed prostheses on implants are often produced using advanced CAD/CAM technologies. These technologies offer numerous advantages including high material quality, precise milling, passive fit, and biological compatibility. Consequently, from a biomechanical perspective, CAM-fabricated frameworks should lead to decreased maintenance and technical complications.[3]

Zirconia, is then introduced as alternative material, in order to fabricate implant frameworks by CAD/CAM technology, with high implant success rate (92.4–100%). Zirconia is a highly durable and biocompatible ceramic material. One of the main advantages of zirconia is its high fracture toughness and strength making it suitable for full arch restorations. Despite the advantages of using zirconia as a full arch restoration, zirconia restorations can still fracture particularly under extreme forces or if there is a problem with framework passivity.[4,5]

While titanium offers numerous advantages, such as its biological and mechanical properties, traditional methods like casting and titanium porcelain firing present challenges.[6] At the close of the 20th century, dental professionals increasingly turned to computer-aided design and manufacturing (CAD/CAM) technology to simplify and expedite procedures.[7,8] Titanium was among the initial metals adopted due to its favorable biological and mechanical characteristics.[9] In contrast to conventional techniques like casting, spark erosion, and laser welding, milling titanium avoids the formation of a reactive surface layer.[10]

The main determinant of framework passivity is trueness, which the International Standards Organization defines as accuracy—the extent to which measured values align with the true value (ISO 5725-1). In this context, accuracy refers to how closely the scanned objects from the milling machine match the original 3D objects. Numerous studies have used reverse engineering and metrology 3D analysis software to accurately evaluate both the quantitative and qualitative 3D deviations between the reference 3D objects and the scanned versions.[11]

When examining technical issues, framework misfit is associated with screw loosening and fractures, which systematic reviews identify as the second and third most frequent complications following veneer fractures. Some definitions of "passive" fit describe it as a condition where any external force applied to achieve a perfect fit has minimal impact on the prosthesis's performance. Another definition suggests that for a framework to achieve passive fit or strain-free integration, it ideally imposes no strain on supporting implant components and adjacent bone under normal conditions, in the absence of external loads.[12]

A maintenance appointment for a fixed detachable implant-supported prosthesis typically involves several key

steps. Initially, the patient should be questioned about any discomfort or functional issues with the prosthesis. The occlusion is then assessed with articulating paper to confirm that contact is evenly distributed. Given that many full-arch implant-supported prostheses are challenging for patients to clean thoroughly, the prosthesis needs periodic removal. This process entails removing the restorative material covering the screw access holes to remove the prosthetic screws. It's important to identify which screw corresponds to each implant and examine all screws for signs of bending or wear; any damaged screws should be replaced. After the prosthesis is removed, the clinician can accurately assess the effectiveness of the patient's oral hygiene and evaluate any peri-implant pockets or inflammation.[12] the aim of this study was to assess the prosthetic maintenance between two different framework materials for full arch mandibular fixed prostheses constructed from zirconia over titanium bar versus full arch zirconia along one year follow up.

Materials and Methods

Patient selection and study design

Fourteen patients with edentulous mandible and maxilla were selected. They were selected from outpatient clinic of the Prosthodontic Department, Faculty of Dentistry, Ain shams University.The inclusion criteria were patients aged 45-65 years old with angle's class I maxillomandibular relationship. The mandibular ridge exhibited healthy, firm mucosa with no indications of inflammation or bony undercuts. Patients were free from systemic conditions such as uncontrolled diabetes, cardiovascular diseases, and bone disorders that could impact oral tissues or bone metabolism. All participants had sufficient restorative space, defined as at least 15 mm from the bone level to the occlusal plane. Those with parafunctional habits or heavy smoking were excluded from the study, as were patients with conditions like liver disease that could complicate surgical procedures.

All patients were informed about the surgical and prosthetic steps for this treatment modality and the steps needed for completion of this study. They were also informed about the importance of properly following the instructions. All patients signed written consent.

The study proposal was approved by the ethical committee of the faculty of Dentistry, Ain Shams University (Local ethical committee, No: FDA SU-Rec IR 022329). CONSORT guidelines for clinical trials were followed.

A single operator performed all the surgical and prosthetic steps. Measurements were recorded by another operator who was blinded to the group distribution. The statistical analysis was also performed by a blinded personal to avoid bias.

Surgical procedures:

All selected patients received new complete dentures. Primary and secondary impression was done. Face bow record was taken to mount the upper cast on semi-adjustable articulator. Centric relation was taken to mount the lower cast. Laboratory and clinical remounting were done to eliminate any occlusal interferences.

A radiographic stent was created by duplicating the new mandibular denture and adding gutta-percha radiopaque markers to its polished surface. A cone beam computed tomography (CBCT) scan was then performed while the patient wore the radiographic stent, their upper denture, and was in centric relation, to assess bone quality and quantity and to pinpoint the exact implant positions. An additional scan was taken of the modified lower denture alone.

The two scans were aligned using the radiopaque markers, and the raw CBCT data was processed into 3D images using Blue

Sky software. This software enabled rotation of the 3D images and allowed for selection of implant length and diameter based on available bone. Implants were evenly distributed along the arch, with sizes chosen to match the available bone volume.

A stereolithographic surgical guide was produced using a rapid prototyping machine, incorporating six metallic sleeves that aligned with the precise depth, angulation, mesiodistal, and buccolingual positioning of the planned implants. The guide also featured three labial windows for fixation pins, ensuring they were placed away from the planned drilling sites.

The surgical guide was secured to the mandibular ridge with fixation pins (Fig. 1). Implants were then sequentially drilled using a flapless surgical approach, with all implants inserted at a torque ranging from 35 to 40 N.

Figure 1: Surgical guide fixed with three anchor pins.

Prosthetic procedure:

After the period of osseointegration, implants were uncovered and multiunit abutments were screwed on implants with torque 25 N (Fig. 2).

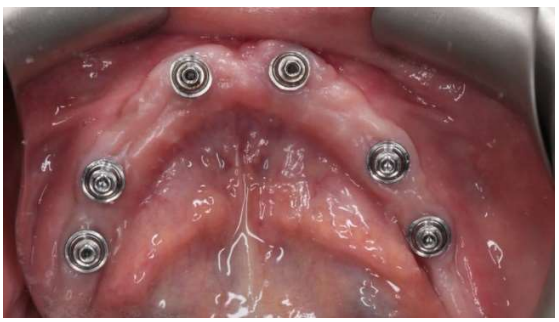

Figure 2: Multiunit abutments torqued on all implants.

After two weeks, Open tray multi-unit impression copings screwed onto the multiunit abutments and splinted with flowable composite (Fig. 3). An open tray impression technique was taken with elastomeric impression material to capture the position of the implants and surrounding soft tissues. Then verification jig was done on the master cast and tried in patient's mouth to confirm accuracy of the impression.

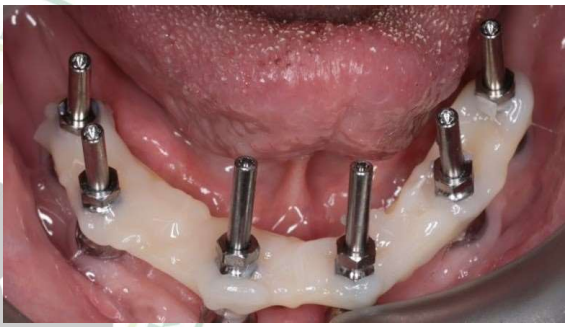

Figure 3: Splinting of impression copings.

Cold cured acrylic resin mandibular trial denture base was constructed on the final stone cast and connected to two of the implants. This screw retained lower acrylic record base provides stability for the record bases during taking jaw relation. Then wax rim was added to the trial denture base. A face bow record was taken to mount the maxillary cast on a semi-adjustable articulator. The mandibular cast was mounted using a centric occlusion relationship recorded with the interocclusal wax wafer technique, and a protrusive record was made to adjust the horizontal condylar guidance of the articulator.

The master cast was then scanned using desktop scanner and by using 3 shape software, the framework design was made creating STL file. The file was transferred to the CNC milling machine to produce the final prosthesis.

The patients were divided randomly into two groups using a numbered excel sheet and closed envelope method to allocate them

into the perspective group according to the material of the final prosthesis:
Group A: Mandibular fixed implant - supported prosthesis was constructed using zirconia over titanium bar framework (Fig. 4). Group B: Mandibular fixed implant-supported prosthesis was constructed using full arch zirconia (Fig. 5).


Figure 4: Zirconia over titanium bar.


Figure 5: Full arch zirconia.

The final prostheses for both groups were placed in the patient's mouth. Occlusion adjustments were made, and the screws were tightened according to the manufacturer's instructions. Screw access holes were then sealed with flowable composite.

Sample Size Calculation:
A power analysis was designed to ensure sufficient power for testing the null hypothesis that there would be no difference between tested groups . using an alpha (α) level of 0.05 , a beta (β) level of 0.2 (i.e. power=80%) and an effect size (ω) of (0.455) calculated from previous study results. the required total sample size (n) was determined to be (40) cases) i.e. 20 cases per group). Sample size calculation was performed using R statistical analysis software version 4.4.1 for windows.

Method of evaluation:
Prosthetic complications for both groups were recorded and calculated at 12 months follow up period. The following aspects were inspected regarding screw loosening, screw fracture, superstructure fracture, wear on opposing dentition, soft tissue response and aesthetics.

Statistical analysis:
Categorical data were reported as frequencies and percentages and analyzed using Fisher's exact test. The significance threshold for all tests was set at $p<0.05$. Statistical analyses were conducted using R statistical analysis software version 4.4.1 for Windows.

Results
Results of intergroup comparisons presented in Table (1) showed that there was no significant difference between both groups regarding the incidence of different prosthetic complications ($p>0.05$). The distribution of different complications in both groups is presented in (Fig. 7).

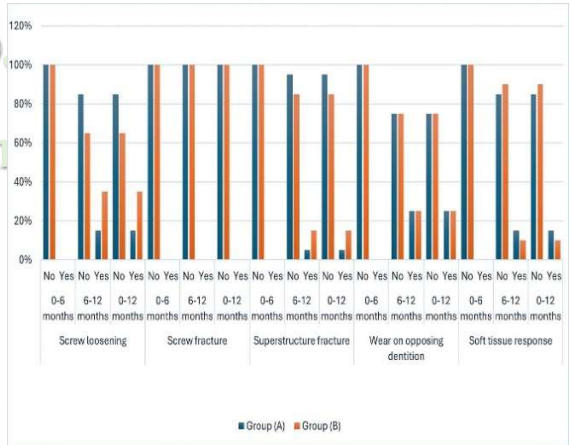

Figure 7: Bar chart showing the incidence of different prosthetic complication

Table 1: Intergroup comparisons for prosthetic complications.

Parameter	Interval	Incidence	n (%)		p-value
			Group (A)	Group (B)	
Screw loosening	0-6 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	6-12 months	No	17 (85.00%)	13 (65.00%)	0.273
		Yes	3 (15.00%)	7 (35.00%)	
	0-12 months	No	15 (75.00%)	9 (45.00%)	0.105
		Yes	5 (25.00%)	11 (55.00%)	
Screw fracture	0-6 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	6-12 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	0-12 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
Superstructure fracture	0-6 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	6-12 months	No	19 (95.00%)	17 (85.00%)	0.605
		Yes	1 (5.00%)	3 (15.00%)	
	0-12 months	No	16 (80.00%)	11 (55.00%)	0.176
		Yes	4 (20.00%)	9 (45.00%)	
Wear on opposing dentition	0-6 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	6-12 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	0-12 months	No	15 (75.00%)	15 (75.00%)	1
		Yes	5 (25.00%)	5 (25.00%)	
Soft tissue response	0-6 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	6-12 months	No	20 (100.00%)	20 (100.00%)	NA
		Yes	0 (0.00%)	0 (0.00%)	
	0-12 months	No	17 (85.00%)	18 (90.00%)	1
		Yes	3 (15.00%)	2 (10.00%)	

NA: Not Applicable.

Prosthetic maintenance assessment:

I. Screw Loosening:

During (0-6 months), there were no occurrences of screw loosening in either group A or group B: No instances of screw loosening were observed in either Group A or Group B. At (6-12 months),In Group A, 85% of participants had no screw loosening while 15% experienced it. In Group B, 65% had no screw loosening and 35% did experience it. The p-value of 0.273 indicates that the difference between the groups is not statistically significant. At (0-12 months), Through the follow up period, the screw looseness revealed a non-statistically significant difference between (Group A) and (Group B), where (p= 0.105).

II. Screw Fracture:

During (0-6 months), there were no occurrences of screw fractures in either group A or group B. At (6-12 months), Also no screw fractures were reported in either two groups. At (0-12 months), no screw fractures were observed in either group A or group B throughout the year.

III. Superstructure Fracture:

During (0-6 months), No superstructure fractures occurred in either group A or group B. At (6-12 months),In Group A, 95% had no superstructure fracture, and 5% had one. In Group B, 85% had no superstructure fracture and 15% had one. The p-value of 0.605 indicates that the difference between the groups is not statistically significant. At (0-12 months), through the whole follow up period, 80% of Group A and 55% of Group B had no superstructure fracture, while 20% of Group A and 45% of Group B experienced fractures. The p-value of 0.176 suggests that this difference is not statistically significant.

I.V. Wear on Opposing Dentition:

During (0-6 months), no wear on opposing dentition was observed in either group A or group B. At (6-12 months), No wear was observed in either group during this period. At (0-12 months), Throughout the year, 75% of participants in both groups had no wear on opposing dentition, and 25% experienced wear. The p-value of 1 indicates no significant difference between the groups.

V. Soft Tissue Response:

During (0-6 months), no adverse soft tissue responses were recorded in either two groups. At (6-12 months), no adverse soft tissue responses were observed in either group. At (0-12 months), Over the year, 85% of Group

A and 90% of Group B had no adverse soft tissue responses, while 15% of Group A and 10% of Group B experienced such responses. The p-value of 1 indicates that there is no significant difference between the groups.
In summary, across all parameters and time intervals, there were no statistically significant differences between Group A and Group B.

Discussion

When assessing implant treatment, it is essential to consider both clinician and patient perspectives. For clinicians, key factors include implant survival, durability, and the frequency of prosthesis complications. To assess the survival of an implant prosthesis, "time to retreatment" is a useful reference.[13] Complications with implant prostheses fall into two categories: biological and technical. Biological complications involve issues affecting the supporting peri-implant tissues, such as early and late implant failures or adverse reactions in the peri-implant hard and soft tissues. Technical complications, on the other hand, pertain to mechanical damage to the implant, its components, and superstructures.[14]Additionally, while prosthetic complications after the final prosthesis insertion may not necessarily lead to implant loss, they can increase the need for repair and maintenance.[15]

Full arch, screw-retained, implant-supported prostheses can significantly improve the quality of life for individuals who are fully edentulous. However, they require ongoing maintenance by a dental professional to ensure their longevity. Full arch, implant-supported fixed prostheses are effective for rehabilitating edentulous arches and generally boast high success rates. However, biological complications like peri-implant mucositis and peri-implantitis can threaten the survival of one or more implants and potentially lead to prosthesis failure, with significant consequences for the patient. To reduce the risk of failure, regular maintenance by both patients and dental professionals is essential. This paper explores several important aspects of maintaining full arch, screw-retained implant-supported prostheses.[16]

The most frequent problems with screw-retained prostheses are the loosening or fracturing of prosthetic screws. Other issues may include wear, separation, or fracturing of resin teeth from the metal or acrylic base, chipping or breaking of porcelain on metal/ceramic or zirconia/ceramic prostheses, and framework fractures in some free-end prostheses.
A passive fit of the substructure is necessary for preventing the crestal bone loss around the implants, prevents overloading of the screw-implant abutments and ensures long term reliability of implant-retained rehabilitation.[17] This explains why fractures might occur in full arch zirconia frameworks or cracks may develop in zirconia overlaying a titanium bar. Since zirconia is a brittle material, an unpassive fit can lead to uneven force distribution, which can create microcracks and ultimately result in fractures within the zirconia framework.

The more passive the framework, the less complication as screw loosening , screw fracture, the less stresses will be encountered around implant and the more the survival rate.[17]

Chipping or fracturing of the veneering material is reported as the most frequent complication associated with prostheses.[18] Therefore, exploring alternative materials that offer greater durability and overcome problems commonly found with traditional hybrid and ceramo-metal prostheses is very important . Potential alternatives include CAD/CAM-fabricated titanium frameworks with cemented individual crowns and CAD/CAM-fabricated cross-arch zirconia frameworks. However,

these alternatives can also present complications, such as crown fractures, framework fractures, and high rates of chipping. Recent advancements in prosthetic rehabilitation for endosseous implants involve using CAD/CAM technology for the design and production of monolithic zirconia prostheses.[19]

Conclusion

Within the limitation of this study, the type of prosthesis material either full-arch zirconia or zirconia over a titanium bar has relatively similar impact on the frequency of maintenance of prosthetic components.

-Funding: This work did not get special grants from any funding organizations.

-Data Availability: The analyzed data of this experiment is available upon reasonable request.

-Declarations:

- **Ethics approval and consent to participate:** The study proposal was approved by the ethical committee of the faculty of Dentistry, Ain Shams University (Local ethical committee, No: FDA SU-Rec IR 022329). CONSORT guidelines for clinical trials were followed. All patients signed written consent.

Competing interest: The authors declare no competing interests.

Author Contributions

Conceptualization: Omar Abbas ElSadat and Lamiaa Farouk Zaki, **Methodology and data curation:** Lamiaa Farouk Zaki, **Resources**: Omar Abbas ElSadat and Lamiaa Farouk Zaki, **Formal analysis**: Lamiaa Farouk Zaki, **Writing – original draft**: Omar Abbas ElSadat and Lamiaa Farouk Zaki, **Writing – review and editing**: Lamiaa Farouk Zaki, **Visualization and supervision:** Lamiaa Farouk Zaki.

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