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AINSHAMS DENTAL
JOURNAL

Print ISSN 1110-7642

Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL

Official Publication of Ain Shams Dental School

September 2020 • Vol. XXIII

Clinical and Radiographic Evaluation of two Different Macro Designs Zirconia Root Form Implants

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Abstract

Purpose: Due to advantageous of zirconia root form implant (ZRFI) as low affinity to plaque and favorable biomechanical and esthetic properties, zirconia was a material of choice for replacing remaining root instead of titanium.

Material and methods: This were a randomized controlled clinical trial conducted on twenty patients with twenty anterior maxillary remaining teeth which needed to be replaced with dental implants. The Patients were randomly divided into 2 groups. Group 1 included 10 patients who received zirconia dental implants with oval surface macro retention while group 2 included 10 patients who received zirconia dental implants with round surface macro retention. Each patient received the zirconia root form implant which was fabricated from the remaining root by cone beam computed topography and CAD/CAM machine then immediately placement of implant after extraction.

Result: For the clinical parameters measured, including the propping depth (PD), modified plaque index (mPI) and modified bleeding index (mBI), it was shown that the oval and round group had no effect on the results as no significant. For the radiographically measured there was a stable and non-significance increase in bucco-lingual width. And loss in marginal bone level after 6 months of follow-up. Periotest evaluation showed increase in stability and osseointegration with (ZRFI).

Conclusion: (ZRFI) is a new successful modality for immediate replacement of teeth with no difference regarding oval or round macro-retention features. (ZRFI) is associated with improved stability over time.

KEYWORDS: immediate implant, zirconia root form implant, customized implant.

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Introduction

Since their introduction by Branemark in the 1960s, oral implants have become a reliable treatment option for the replacement of missing teeth (*Branemark, 1977*). Physical and chemical properties of implant materials are well-reported and documented factors that influence of the clinical outcome and the prognosis of implant therapy (*Smith, 1993*).

These properties include microstructure of the implant, its surface composition and characteristics, as well as design factors. The implant design principles should be consistent with the material's physical characteristics. Dental implants can be produced from metals, ceramics or polymers from a chemical view (*Triplett et al., 2003*).

Immediate implant placement is referred to the placement of an implant into a tooth socket concurrently with the extraction. With this procedure the number of surgical procedures a patient would undergo are markedly reduced as well as the overall treatment time as the socket healing and implant osseointegration occur concurrently (*Khzam et al., 2015*).

Material of choice for manufacturing dental implants is commercially pure titanium, because of its excellent biocompatibility and mechanical properties (*Smith, 1993*).

However, titanium's gray color may be disadvantageous and cause esthetic issues, particularly if the condition of soft tissue is not ideal and the dark color shines through the thin peri-implant mucosa (*Kohal et al., 2004*).

In the early 1990s, zirconia was introduced to dentistry and has been made widely available through the computer-aided design/computer-aided manufacturing CAD/CAM) technology (*Guess et al., 2012*).

Zirconia has been proposed as an alternative implant material to titanium owing to its excellent biomechanical characteristics (*Frydman and Simonian, 2014*).

Ceramics have gradually become more popular in the dental industry in a world with increasingly high esthetic demand. Yttria-

stabilized tetragonal zirconia polycrystal ceramics (Y-TZP) are currently the materials of choice for ceramic implant and abutments (*Hashim et al., 2016*).

The first clinical studies of 1-piece (ZI) were presented in 2006 (*Blaschke and Volz, 2006*). Since 2010, several prospective clinical trials evaluating implant survival and marginal bone loss have been performed. Most of these studies were conducted with 1-piece implants, while just a few considered newly developed 2-piece implants (*Becker et al., 2017*).

(*Kohal et al., 2008*) Discussed the high flexural strength of zirconium when used as a dental implant, the hardness and biocompatibility that may be shown to the same extent as titanium implants which was found in several animal studies.

The clinical use of zirconia as dental implant (ZI) material is becoming more popular because of esthetic considerations. Its low elasticity and thermal conductivity modulus, low plaque affinity and elevated biocompatibility make zirconia ceramics a very attractive alternative to titanium in implant dentistry (*Depprich et al., 2014*).

The custom three-dimensional (3D) printed root form implant as defined by (*Moin et al., 2013; Moin et al., 2014*) is a futuristic treatment option for immediate implantation and immediate loading cases for a soon to be removed tooth.

(*Pirker And Kocher, 2008*) published a novel technique on a case and then followed it with a two-year case report (*Pirker And Kocher, 2009b*) to successfully replace conventional titanium implants with a zirconium custom made replica of an extracted tooth.

The concept of replicating the extracted tooth with customized implant eliminated the need to use bone drills that induce bone necrosis, even the force applied during the use of the handpiece will increase the heat generated on the bone (*Mishra And Chowdhary, 2014*).

In the cases of manufacturing of custom-made zirconia root form implant before tooth extraction, a cone beam computed tomography scan (CBCT) is obtained from the patient dentition. Such information is enough to provide a CAD model of the teeth which are going to be extracted. A 3D surface mesh of the tooth that was obtained from (CBCT) was stored as a standard triangulation language (STL) File (*Patankar et al., 2016; Pirker and Kocher, 2011a; Pirker and Kocher, 2011b*).

The access to STL and CBCT data prior to extraction offers numerous improvements by the digital workflow and enables the option to manufacture the (ZRFI) prior to the surgical phase. The fully digital replication of the tooth root before extraction enables the placement of the implant with minimal modification of the alveolar socket (*Pour et al., 2017*).

Material and Method:

Patient selection

This was a randomized controlled clinical trial study was performed on twenty patients from the outpatient clinic of Oral medicine, department, Faculty of Dentistry, Ain Shams University seeking extraction of a non-restorable maxillary anterior or premolar tooth. The faculty research ethics committee had reviewed and accepted the study proposal.

The patients were randomly divided into 2 groups. Group 1 Included 10 patients who received zirconia dental implants with oval surface macro retention and group 2 Included 10 patients who received zirconia dental implants with round surface macro retention.

Inclusion Criteria

- 20-40 years male or female.
- All patients had non-restorable upper single anterior or premolar tooth which required extraction.

- Absence of periodontal disease or periapical infection.
- All patients should not have any particular medical history (medically free) according to Burkett's health medical history questionnaire.

Preparation of implant

The process of preparation of the implant will be done with the following steps:

- Radiographic process
- 3D design and CAD/CAM process
- Surface Treatment and sterilization

Radiographic process

Radiograph examination using CBCT system¹ was used to obtain three dimensional (3D) of tooth. A 3D surface mesh of the tooth was stored as a standard triangulation language (STL) File

3D design and CAD/CAM process

Through computer 3D designing software² alteration to the surface of implant extracted from STL file were performed by:

- Minimal reduced in buccal and lingual aspect of implant to preserved labial and palatal bone.
- Adding macro retention (oval-round shape) restricted to mesial and distal surface fig (1) (*Mangano et al., 2012*).
- Building abutment as one piece with implant fixture.
- Then a CAD/CAM machine³ was used to mill the tooth using zirconia block (specifically, yttria-stabilized tetragonal zirconia polycrystal)⁴ fig (2).

¹ (scanora3D, soredex Finland)

² (Exocad CAD software Darmstadt, Germany)

³ (Imes-Icore Coritec 250I series Eiterfeld, Germany)

(Nacera Shell 1, Dortmund, Germany) ⁴

Surface treatment and sterilization

The different zirconia implants were treated with concentrated sulphuric acid solution⁵ (*Casucci et al., 2010*), which was heated up to boiling temperature for 20 minutes, then implant was rinsed with deionized water and alcohol in ultrasonic device (*Moon et al., 2011*).

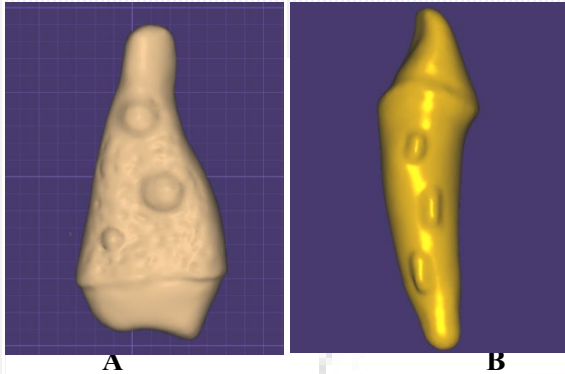


Figure (1): Macro-retention (A: Round shape on mesial surface. B: Oval shape on distal surface).

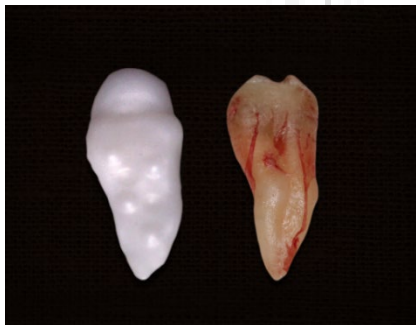


Figure (2): root form zirconia implant after milling.

Surgical Procedure:

Following the administration of local anesthesia, the failing tooth or root was removed atraumatically. To minimize the trauma, the tooth was carefully luxated using periosteal⁶ to preserve bone and soft tissue (*Sharma et al., 2015*).

Implant placement

The implant was removed from its sterile package using tweezers (fig 3), then placed in a fresh extracted socket under finger pressure, followed by a gentle tapping using tip of mirror and mallet⁷.

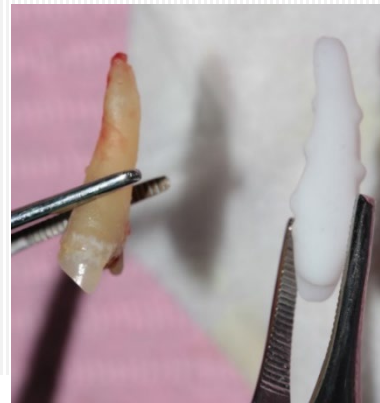


Figure (3): Extracted upper right 2nd Premolar with Root Form Customized Implant.

Prosthetic procedures

After three months of implant placement, professional debridement was done. And final crown with lava ceramic seated (fig 4).

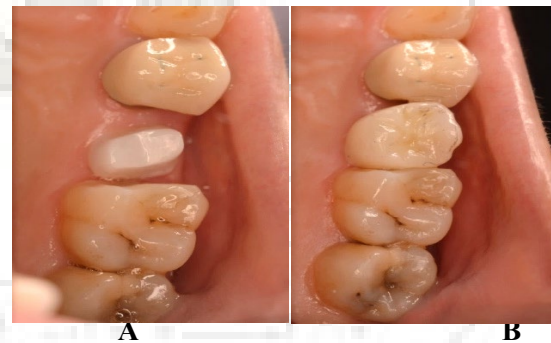


Figure (4): A: 3-months follow-up. B: Final lava ceramic crown.

Stability assessment

stability was achieved and checked by periotest. Seating the patient with a horizontally aligned jaw and the periotest M⁸ at the right angle to the implant, as close as possible to the crestal bone (*Cranin et al., 1998*).

Evaluation of measurement

- Clinical evaluation of peri-implant tissue.
- Clinical Evaluation of retention.
- Radiographic evaluation pre- and post-operative.

- **Clinical evaluation of peri-implant tissue**
various periodontal parameters have been proposed for clinical practice.

Pure reagent of sulphuric acid, having a minimum assay⁵ 98%, molecular weight 98.07 and sp.gr.1.84 by ADWIC, Elnasr Pharmaceutical Chemicals.Co.(Egypt.Batch no. S-0548111). Kohler periosteal (Stockach, Germany).⁶

Premium Instruments (16 Henry Ave, Ronkonkoma⁷ New York, 11779 USA). Periotest M, Medizintechnik Gulden e.k. (Eschenweg,⁸ Germany).

All the data were measured and collected pre-operatively (baseline) 3- and 6-months interval after implant placement. The clinical parameters include the following: Probing depth (PD), modified plaque index (mPI). And modified bleeding index (mBI)

▪ **Clinical Evaluation of retention:**

generally, the Periotest scale ranges from -8.0 to +50.0. The smaller the Periotest value, the higher the stability / damping degree of the implant.

▪ **Radiographic evaluation pre- and post-operative:**

The CBCT was taken before surgery for implant preparation and at 2 occasions later:

- Immediate post-operative
- 6-months (After surgery)

with the assistance of OnDemand3D⁹ software. For bucco-Lingual ridge Width and for marginal bone level.

Bucco-Lingual Ridge width was measured by drawn three lines Bucco-lingually at 3 different apical-coronally levels were taken of 3 different cuts of the area of interest of each case in our study

The marginal bone level (MBLs) were measured from crestal bone level buccally and palatally to the finish line of abutment fig (5)

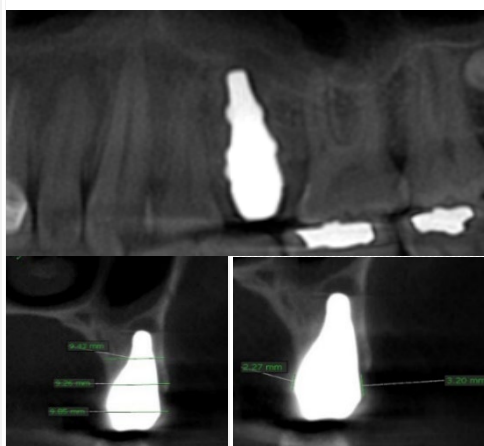


Figure (5): CBCT at base line (immediate post-operative)

Statistical analysis

Statistical analysis was then performed using a chi square test. Numerical data were tested for normality using Shapiro-Wilk test.

The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with IBM¹⁰ SPSS¹¹ Statistics Version 26 for Windows.

RESULTS (Tables 1-3)

I-Clinical findings

1-Bleeding index

Intra group comparison

In the group (1), comparing the baseline and post-treatment median value of bleeding index revealed that increased from (0) to (0.50), with no significant difference ($p=0.122$).

In the group (2), comparing the baseline and post-treatment median value of bleeding index revealed that increased from (0) to (0.50) same value (0), with no significant difference ($p=0.115$).

Inter group comparison

At baseline, comparing the oval and round macro-retention median value of bleeding index revealed both groups had the same median value 0.0(0) ($p=1$).

After 6 months comparing the groups median value of bleeding index revealed that both groups had the same median value [0.50(1)] ($p=1$).

2-Plaque index

Intra group comparison

In the group (1) comparing the baseline and post-treatment median value of plaque. There was no significant difference between

OnDemand software System (by Cypermed, Korea).⁹
IBM Corporation, NY, USA. ¹⁰

SPSS, Inc., an IBM Company. ¹¹

values measured at different follow-up intervals ($p=0.180$).

In the group (2) comparing the baseline and post-treatment median value of plaque index revealed. There was no significant difference between values measured at different follow-up intervals ($p=0.064$).

Inter group comparison

At baseline, comparing the both groups median value of plaque index revealed that group (I) (0.07(0)) had a higher median value than group (II) (0(0)) but the difference was not significant ($P=0.317$).

After 6 months both groups had the same median value 0.50(1) ($p=1$).

3- Probing depth

Intra group comparison

In the group (1) there was no significant difference between values measured at different follow-up intervals ($p=0.314$).

In the group (2) there was no significant difference between values measured at different follow-up intervals ($p=0.106$).

Inter group comparison

At baseline, comparing the both groups median value of probing depth revealed that both groups had the same mean value (3.13 ± 0.83) ($p=1$).

After 6 months of follow-up group (1) (2.63 ± 0.92) had a higher mean value than group (2) (2.25 ± 1.04) yet the difference was not significant ($p=0.456$).

II- Radiographic assessment

1-Bucco-lingual ridge width:

Inter group comparison

- **First assessment baseline (immediate post-operative)**

Group (I) (9.38 ± 0.40) had a higher mean value than group (II) (9.19 ± 0.35) yet the difference was not significant ($p=0.326$).

- **Second assessment (6 months)**

Group (I) (10.30 ± 0.19) had a higher mean value than group (II) (10.28 ± 0.23) yet the difference was not significant ($p=0.868$).

Intragroup comparison:

Group (I) value measured at 6 months (10.30 ± 0.19) was significantly higher than that measured at baseline (9.38 ± 0.40) ($p=0.001$).

Group (II) value measured at 6 months (10.28 ± 0.23) was significantly higher than that measured at baseline (9.19 ± 0.35) ($p<0.001$).

Intergroup comparison of percentage change:

Group (II) (11.93 ± 4.81) had a higher mean value than group (I) (9.89 ± 5.35) yet the difference was not significant ($p=0.436$).

2- Marginal bone level:

Inter group comparison

- **First assessment baseline (immediate post-operative)**

Group (II) (4.02 ± 0.81) had a higher mean value than group (I) (3.66 ± 1.00) yet the difference was not significant ($p=0.442$).

- **Second assessment (6 months)**

Group (II) (4.24 ± 0.80) had a higher mean value than group (I) (3.88 ± 1.00) yet the difference was not significant ($p=0.446$).

Intragroup comparison:

Group (I) value measured at 6 months (3.88 ± 1.00) was significantly higher than that measured at baseline (3.66 ± 1.00) ($p<0.001$).

Group (II) value measured at 6 months (4.24 ± 0.80) was significantly higher than that measured at baseline (4.02 ± 0.81) ($p<0.001$).

Intergroup comparison of percentage change:

Group (I) (6.44 ± 2.30) had a higher mean value than group (II) (5.65 ± 2.11) yet the difference was not significant ($p=0.486$).

III-Implant stability

Intergroup comparison:

Baseline group (II) (3.68 ± 1.44) had a higher mean value than group (I) (3.58 ± 1.08) yet the difference was not significant ($p=0.877$).

6 Months group (II) (-2.36 ± 1.64) had a higher mean value than group (I) (-2.51 ± 1.28) yet the difference was not significant ($p=0.841$).

Intragroup comparison:

Group (I) value measured at baseline (3.58 ± 1.08) was significantly higher than that measured at 6 months (-2.51 ± 1.28) ($p=0.004$).

Group (II) value measured at baseline (3.68 ± 1.44) was significantly higher than that measured at 6 months (-2.36 ± 1.64) ($p=0.001$).

Intergroup comparison of percentage change:

Group (II) (186.04 ± 67.44) had a higher mean value than group (I) (183.81 ± 58.48) yet the difference was not significant ($p=0.944$).

DISCUSSION

The esthetic zone is any dental-alveolar area that is obvious subjectively upon full smile. In the last decades, implant dentistry has been dealing with different types and techniques of implants and restorative material to preserve this esthetic zone.

Patients demand an esthetic result that satisfies them. Titanium implants can be of very poor aesthetics particularly in the esthetic area due to a thin labial bone that may present a gray shadow of titanium implants which may be shown through the gingiva. Also, the effect of toxic titanium particles releasing which may causes gingival recession in the esthetic zone should be considered; therefore, the use of zirconium dental implants to solve these problems (*Sailer et al., 2007*).

Apratim et al., (2015) concluded that zirconia is osteoconductive and has also shown a favorable interaction with soft tissue. Zirconia has been found to reduce plaque formation on the surface of the implant, resulting in an excellent healing and effective implant treatment.

In the past according to *Pirker and Kocher in 2008*, the tooth root after extraction was laser and macro- retentions were designed, then on day 4 after extraction the alveolar socket was curetted and flushed with a sterile physiologic saline solution and implant placed. In our study cone beam computed tomography (CBCT) was taken before surgery to obtain the

remaining root three-dimensional (3D) then saved as standard triangulation language (STL) file. Preparation of implant before extraction was performed for placing it on the day of extraction instead of leaving the socket 4 days after extraction which may cause formation of granulation tissue and change in dimensions of socket.

During patient selection, strict inclusion and exclusion criteria were used to minimize the variables that could influence outcomes.

Patients were advised to follow the plaque control guidelines for reducing peri-implant tissue disruption including brushing and interdental cleaning techniques. The chlorhexidine was used in our study as an antibacterial agent before extraction, after extraction and curettage of the socket (*Woodcock, 1988; Kuyyakamond & Quesnel, 1992*).

In present study, we used periotest for evaluation of implant stability after implant placement as it one of the first instruments to provide a reasonably quantifiable measure of the bone-implant complex. It has been shown that the periotest provides accurate information about initial implant reliability. The Periotest instrument appears to be highly reproducible and capable of detecting minor changes in the bone-implant complex within a specific range of rigidity. (*Jun et al., 2010; Khalaila et al., 2019*).

One of the key factors for the long-term success of oral implants is the maintenance of healthy tissues around them. During the study period, the modified plaque index (mPI) and modified bleeding index (mBI) scores reported in the first 6 months of this study was either 0 or 1, indicating that patients had been able to maintain a good oral hygiene condition. There were no statistically significant differences between different time periods in both groups in most (mPI) and (mBI) scores, and this excludes any plaque effect on the final result.

Probing depth (PD) measurements are commonly used to compare changes over time. In the intragroup comparison for both groups there was no significant difference between values measured at different follow-up intervals 0, 3 and 6 months. Mean and Standard deviation values for intergroup comparison of percentage change from Baseline to 6 months in group (I)

was a higher mean value than group (II) yet the difference was not significant.

Regarding radiographic alveolar ridge bucco-lingual width changes, within group (I) value measured at 6 months was significantly higher than that measured at baseline and in group (II) value measured at 6 months was significantly higher than that measured at baseline. Non-significant increase was noticed in both groups after 6 months. The increase in bone width over the time after placement of zirconia implant is in agreement with previous reports by (*Imai and Hiromoto, 2014*) that showed osteoid formation and high levels of bone remodeling during osteotomy healing around zirconia. Another study by (*Ida et al., 2018*) concluded that zirconia implants showed an increase in new bone formation and osseointegration compared with titanium implants. Since no accumulation of metal ions, with superior mechanical properties, biocompatibility, stability and biosafety compared to titanium implants. Moreover, tapping technique that was used also aid to preserve the bucco-lingual alveolar ridge. Also, flapless implant surgery results in decreased loss of bone (*Divakar et al., 2019*).

Regarding percentage change of radiographic alveolar ridge width group (II) had a higher mean value than group (I) yet the difference was not significant. This non-significant difference may be related to (ZRFI) macro-retentions which is limited to the proximal surface and diameter reduction next to the thin labial cortical bone in both groups (*Pirker et al., 2011a*).

Regarding the change in marginal bone level (MBL) in our study. By monitoring the (MBL) at baseline (Day of surgery) and 6 months after surgery in each of buccal and lingual side and then collecting overall. In intragroup comparison, group (I) value measured at 6 months was significantly higher than that measured at baseline. Group (II) value measured at 6 months was significantly higher than that measured at baseline. Thus, was in accordance with previous study showed that immediate implant is associated with crestal bone loss (*Browaeys et al., 2015; Albrektsson et al., 2017*). Regarding the Intergroup comparison of percentage change mean and standard deviation values for marginal bone level percentage change

showed that group (I) had a higher mean value than group (II) yet the difference was not significant. Thus, different macro-retention features on proximal surface has no effect on the marginal bone change.

Regarding implant stability measurement periotest value is marked from -8 (low mobility) to +50 (high mobility) (*Kuo-Ning et al., 2017*). Group (I) value measured at baseline was significantly higher than that measured at 6-months. Group (II) value measured at baseline was significantly higher than that measured at 6-months. This is in agreement with what is obtained in other reports (*Van and Wilson, 1991; Negm, 2016*).

CONCLUSION

According to the limitation of the study we concluded the following:

- Zirconia root form Implant is a new successful modality for immediate replacement of teeth with no difference regarding oval or round macro-retention features.
- Zirconia root form implant is associated with stable bucco-lingual alveolar ridge dimensions.

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