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RESEARCH ARTICLE

Assessment of Implant Stability of Two-piece Zirconium Dioxide Implants using the Resonance Frequency Analysis: A Pilot Study

[1]Vladimir Kokovic, [2]Muhammed Mustahsen Rahman, [3]Betul Rahman, [4]Mustafa Tattan

ABSTRACT

Objective: The aim of this pilot study is to evaluate to value of primary implant stability for two-piece zirconia implants and longitudinally stability changes of implants during the healing period of 16 weeks.

Materials and methods: Ten patients treated with 12 two-piece non metallic zirconia dioxide root shape implant (⦸4/10 mm, Axis Biodental, Les Bios, Switzerland) for single tooth replacement in the upper premolar area. Resonance frequency analysis (RFA) was used for assessment of longitudinally changes of implant stability during 16-weeks observing period. All patients have been re-evaluated 1 year after loading.

Results: Mean implant stability quotient (ISQ) value of initial implant stability for 12 implants was 60.25 (3.72). Statistically, significant decrease was noted in the first 3 weeks after insertion ($p = 0.000$). Also, statistically significant increasing of implant stability was recorded for observing period for 6th to 16th week.

Conclusion: Increasing of ISQ value during observing period suggests loading of two-piece zirconia dioxide root shape implant for single tooth replacement in the upper premolar area, after healing period of 4 months.

Keywords: Implant stability, Resonance frequency analysis, Zirconia implants.

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[1,3]Associate Professor, [2]Professor, [4]BDS Student

[1]Department of Oral Surgery, College of Dental Sciences, United Arab Emirates

[2]Department of Periodontology, College of Dental Sciences RAK Medical and Health Sciences University, United Arab Emirates

[3]Department of Periodontology, College of Dentistry University Sharjah, United Arab Emirates

[4]Department of Oral Surgery, College of Dental Sciences, RAK Medical and Health Sciences University, United Arab Emirates

Corresponding Author: Vladimir Kokovic, Associate Professor, Department of Oral Surgery, College of Dental Sciences, United Arab Emirates, Phone: +971551536346 e-mail: kokovicv@gmail.com

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INTRODUCTION

The biggest advantage of zirconia to titanium is obviously the biocompatibility and good esthetic result. As opposed to titanium, zirconia does not release ions into the human body.[1] Zirconia shows excellent osteoblastic attachment on its surface and excellent cellular proliferation allowing rapid bone growth along the bone-implant interface.[2,3] Additionally, zirconia implants are capable of establishing close bone-implant contact rates similar to titanium implants.[4,5]

During the healing period, the primary implant stability is replaced by the secondary implant stability, which is a biological phenomenon. Secondary stability is the result of the formation of new woven and lamellar bone onto the implant surface.[6]

Several devices are available to assess implant stability.[7] These devices can be used at various time intervals during the healing and implant loading phases. These procedures can be categorized into invasive and non invasive techniques. Previously, the quantitative measurement of primary stability was limited to only invasive methods, such as pullout and pushout attempts and the assessment of removal torque. Vibration analyses of implants are non invasive methods and allow the assessment of implant stability under clinical settings,[8] where they either use transient or continuous excitation. In 1996, a new method called resonance frequency analysis (RFA) was introduced for the measurement of implant stability. This RFA method is an easily applicable method of measuring quantitative stability and it can be used in a surgical and non-surgical setting. The Hertz waves resulting from the RFA measurement are converted into numeric values on a scale ranging from 1 to 100, called as implant stability quotient (ISQ). Classically, ISQ values have been found to vary between 40 and 80. Higher ISQ values generally represent higher implant stability. It has been reported that ISQ values for successfully integrated implants typically range from 57 to 82 and that ISQ values of less than 50 are associated with higher rates of implant failure.[9]

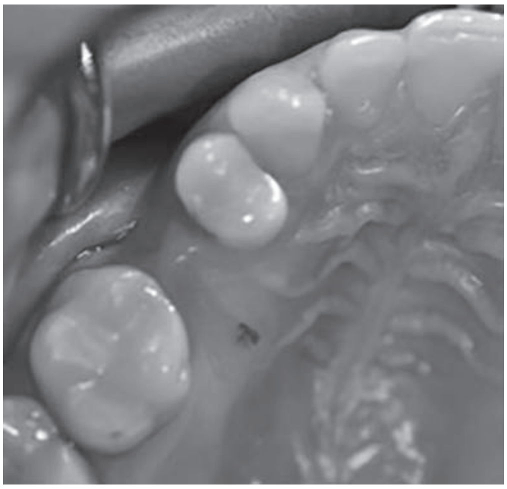


Fig. 1: Edentulous alveolar ridge—upper premolar area (occlusal view)

Fig. 2: Edentulous alveolar ridge—upper premolar area (lateral view)

Modern implantology demands satisfying esthetic results. Titanium dental implants in patients with thin gingival biotype fail to produce such high esthetic demands, due to the visibility of titanium through the partial gingival transparency. Literature recommendation regarding patients with high esthetic requirements is just that, and non metallic zirconium dioxide dental implants present the therapy of choice. Successful further implant therapy includes successful functional and esthetic results during the dental implant rehabilitation.[10]

The purpose of this pilot study was therefore: (1) to evaluate the value of primary implant stability for two-piece non metallic zirconia dioxide root shape implants used for single tooth replacement in the upper premolar area using the resonance frequency analysis; (2) to evaluate longitudinal stability changes of implants during the 16-week healing period.

METHODOLOGY

Subject

The present investigation was comprised of 10 patients treated with 12 two-piece non metallic zirconia dioxide root shape implant for single tooth replacement in the upper premolar area (Figs 1 and 2). All procedures were performed at the Medical Centre, College of Dental Sciences, Medical and Health Sciences University, Ras Al-Khamiah, UAE. Ethical approval was obtained from Ras Al-Khaimah, Medical and Health Sciences University (3-2014-FD) and participants received oral and written information about the study and provided informed consent.

Inclusion Criteria

a. Patient of American Society of Anesthesiologists I or II group;
b. Patients with single tooth space in the upper premolar region with a mesial-distal dimension of 6.5 to 8 mm
c. Patients with single tooth space in the upper premolar region with a bucco-oral dimension ≥ 6 mm
d. Patients with the post-extraction history of edentulous space in upper premolar area lasting at least 4 months.

Exclusion Criteria

a. Presence of systemic disease likely to compromise implant surgery
b. Presence of oral para-functions (bruxism)
c. Heavy smokers
d. Presence of inadequate oral hygiene.

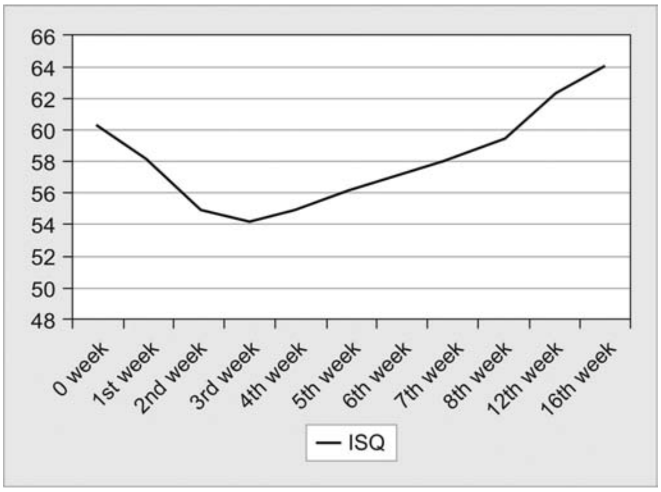
Clinical Procedure

The preoperative planning was based on clinical and radiographic examination. Preoperative radiograph was used.

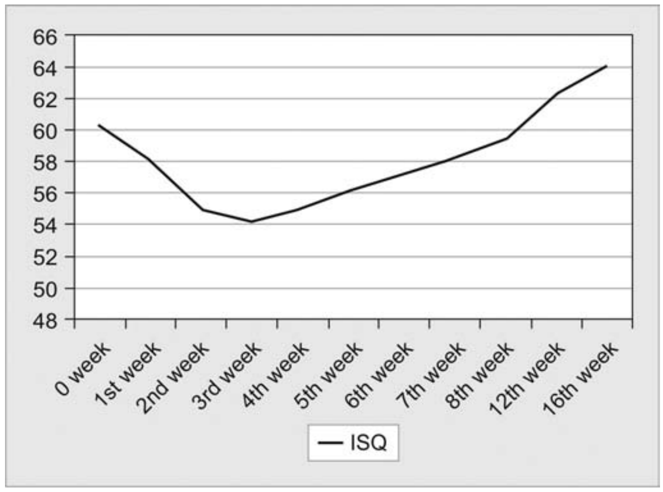
Implant Placement

Antimicrobial prophylaxis (Amoxicillin® 2 g or Clindamycin® 600 mg in penicillin allergic patients) was given orally 1 hour before each implant placement procedure and patients rinsed with a chlorhexidine digluconate solution (0.2%) for 10 minutes before the operation.

The implant placement was carried out under local anesthesia (Xilestesin®; Espe Dental AG, Seefeld, Germany) containing 2% epinephrine. After crestal incision and flap elevation, preparation of the implant socket was preformed following the company's surgical guidelines (Graph 1). Two-piece zirconia dioxide implants (Axis Biodental, Les Bios, Switzerland) of 4 mm diameter and 10 mm length were used in this study. Implant sites were marked using a 1.4 mm round bur with a maximal speed of 800 rpm (Fig. 3). Pilot drill 2.4 mm was used for the



Graph 1: Crestal incision



Graph 2: Connecting the implant holder to the implant

first step of implant site preparation to the final depth (Table 1 and Fig. 4). A direction indicator was used for site depth measurement and implant orientation assessment (Fig. 5). Drill 2.9 mm (yellow ring) and 3.4 mm (red ring) were used for the final preparation of implant site with a maximal speed of 500 rpm (Figs 6 and 7).

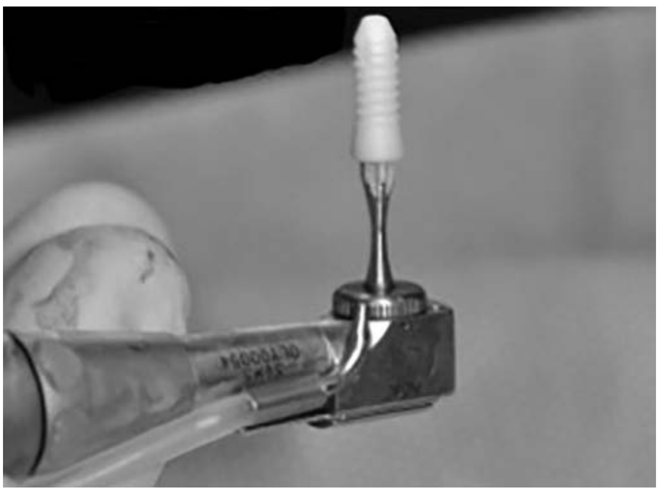


Fig. 3: Round bur for marking the implant site

Definite assessment of site depth and implant angulation was performed using depth gauge M (Fig. 8). Tap 4.0 mm was used for precutting insertions on the site for implant threads (Figs 9 and 10). Implants were removed from blister using implant holder and inserted into the site with maximum torque of 35 Ncm and speed of 15 rpm (Graph 2 and Figs 11 to 13). After implant insertion, primary implant stability was measured using RFA, followed by the screwing of the healing abutment 2.5 mm high into the implant (Figs 14 and 15). The flap was then adapted around the healing abutment with single sutures (Figs 16 and 17).

Table 1: Pilot drill-first drill for preparation implant site to the final depth (max 800 rpm)

Week	*Mean ISQ (SD)*	*Range*	*p-value*
3	54.92 (3.28)	50–59	0.008
5	56.25 (1.96)	55–60	0.005
6	57.17 (1.89)	54–61	0.002
7	58.17 (1.69)	55–61	0.000
8	59.42 (1.31)	56–61	0.000
12	62.25 (1.86)	59–64	0.000
16	64 (2)	60–67	0.000

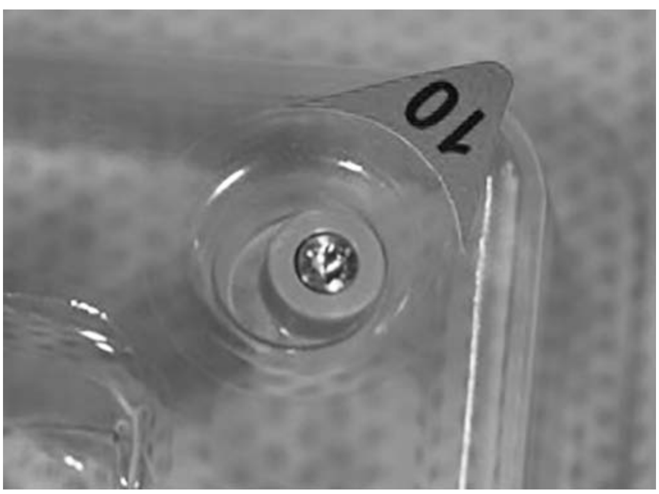


Fig. 4: Preparation of implant site with pilot drill

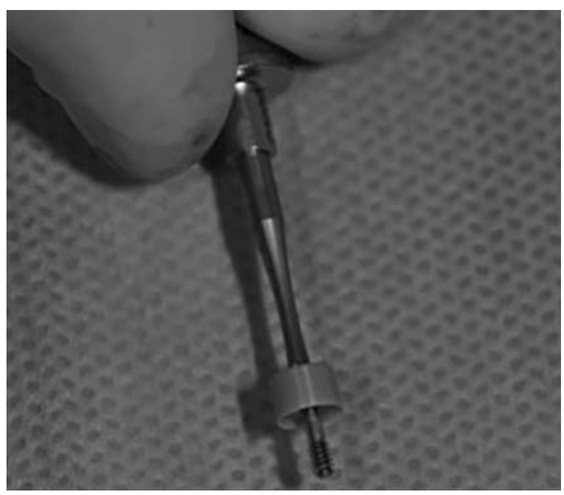


Fig. 5: Measurement of implant site depth and assessment of its orientation with direction indicator

Fig. 6: Drill S (⌀ 2.9 mm; maximum speed 550 rpm)

Fig. 7: Drill M (⌀ 3.4 mm; maximum speed 500 rpm)

Fig. 8: Assessments of implant site orientation by depth M

Fig. 9: Tap M (⌀ 4.0 mm)

Fig. 10: Taping the implant site

Postplacement Procedure

Antibiotics and nonsteroidal analgesics were continued for 3 days. Postoperative edema was controlled with corticosteroids (Dexason® 4 mg im 1 hour before and 8 hour after the procedure).

Patients were asked to limit their consumption to a soft diet for 2 weeks after the surgery, in addition to the use of 0.2% chlorhexidine digluconate mouth rinses for 1 week after surgery. The avoiding of brushing, and flossing of the tooth of interest and adjacent tissue were reccommeded for a week after the insertion.

Measurement of Implant Stability with Resonance Frequency Analysis

Resonance frequency analysis measurements were performed immediately following implant placement and during follow-up period using (Osstell™ mentor, integration diagnostics AB, Göteberg, Sweden) according to the manufacturer's recommendations. The measuring devices (Smartpeg™) were attached to the implant using 10 Ncm of torque (Fig. 18). All measurements were performed with the probe (Osstell™ mentor probe II) aiming from the buccal direction. The probe was held at a distance of 2 to 3 mm until the instrument displayed the ISQ value (Figs 19 and 20). Two ISQ values were recorded and used as a mean value for statistical analysis. Follow-up

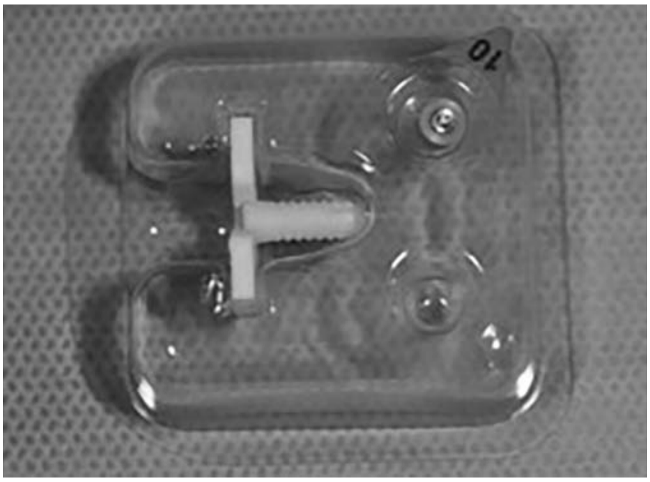


Fig. 11: Implant in the blister

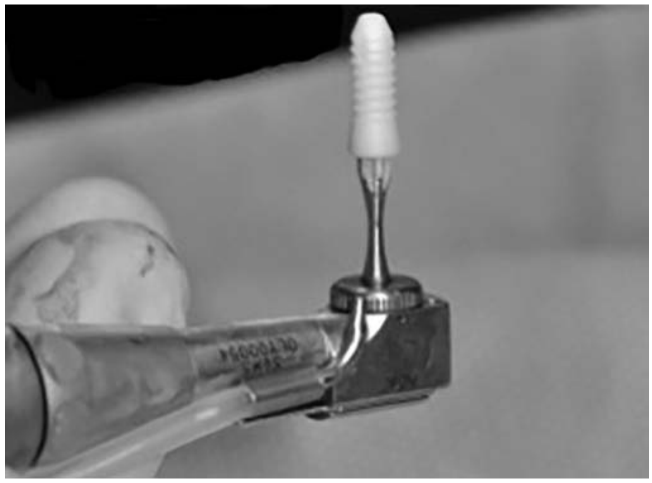


Fig. 12: Implant and implant holder

Fig. 13: Machine insertion of implant

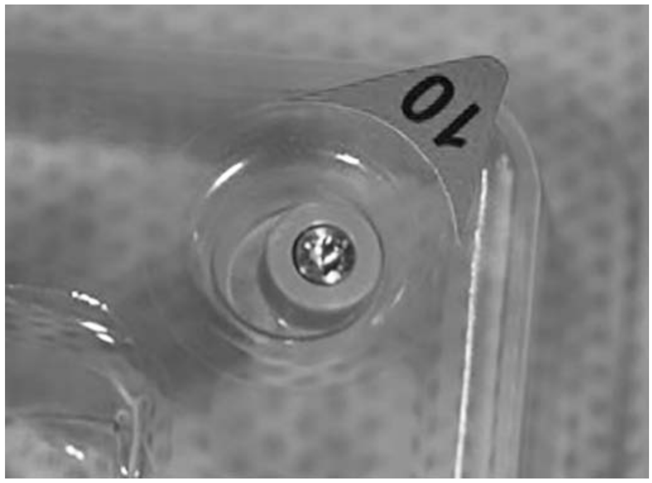


Fig. 14: Cover cap in blister

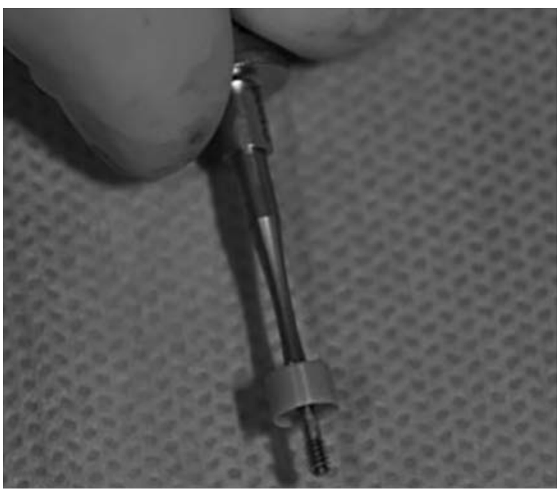


Fig. 15: Screwing of cover cap

periods were the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 12th and 16th weeks after implant placement.

Prosthetic Procedure

Sixteen weeks after implant placement, an impression was taken using open tray transfer (Graph 3). A full zirconia crown was fabricated in the dental lab on PEKK straight abutment.

STATISTICAL ANALYSIS

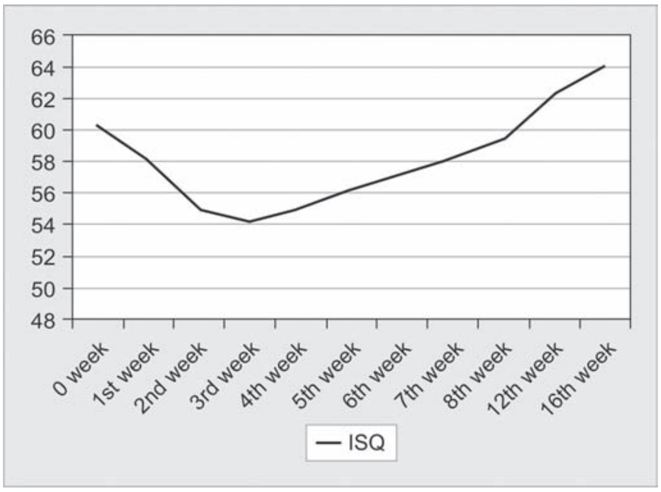
All data were first analyzed by descriptive methods (QQ plots, box plots) (SPSS 18.0; SPSS, Austin, TX, USA). The implant was chosen as the unit for statistical analysis. The Wilcoxon signed rank test was used as well as Pearson's coefficient of correlation. The level of significance chosen in all statistical tests was at $p < 0.05$.

RESULTS

A total of 10 adult patients (seven women and three men; average age at the time of surgery: 28 years; range: 19–42) received 12 two-piece ⦸ 4 mm zirconia dioxide implants (Axis Biodental, Les Bios, Switzerland) with 10 mm length. Equal numbers of implants (6) were inserted in the position of upper 1st and 2nd premolar. During the study, the results of all patients were analyzed.

Resonance Frequency Analyses

At implant placement, all implants had to be clinically stable before the ISQ was measured. At baseline, the average ISQ value was 60.25 (minimum 55 and maximum 63).



Graph 3: Significant changing in mean implant stability quotient value during observing period of 16 weeks

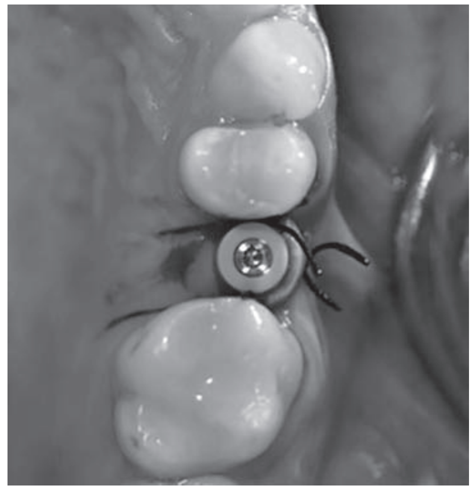


Fig. 16: Adaptation of flap around cover cap (occlusal view)

Fig. 17: Adaptation of flap around cover cap (lateral view)

Fig. 18: Fixing of Smartpeg^{TM} using 10 Ncm torque

Fig. 19: Measurement of implant stability using Osstell^{TM} mentor

Fig. 20: Implant stability quotient value recording on Osstell^{TM} mentor monitor

In the first week, the average ISQ values decreased from 60.25 (SD 3.72) at implant placement to 58.17 (SD 3.61). This increase was statistically significant. A decrease in implant stability was noted in the 2nd and 3rd weeks after implant placement comparing to value recorded on baseline. This decrease was, also, statistically significant (Table 2).

An increase in ISQ value was noted in the 5th week compared to the 3rd week, as the period with the lowest recorded value. Statistically, significant differences were observed (Table 3 and Fig. 1).

At the 1 year loading control, implant survival rate of all implants was 100%.

Table 2: Mean implant stability quotient values (standard deviation) for observation points of 3 weeks. Statistically significant differences were presented as p-value for ISQ values noted at observing points compered with baseline value

Week	*Mean ISQ (SD)*	*Range*	*p-value*
0	60.25 (3.72)	55–64	
1	58.17 (3.61)	52–63	0.045
2	54.25 (3.51)	50–60	0.000
3	54.92 (3.28)	50–59	0.000

Table 3: Mean implant stability quotient values (standard deviation) for observation points from 5th to 16th week. Statistically significant differences were presented as p-value for ISQ values noted at observing points compared with mean value on 3rd week

Week	*Mean ISQ (SD)*	*Range*	*p-value*
3	54.92 (3.28)	50–59	0.008
5	56.25 (1.96)	55–60	0.005
6	57.17 (1.89)	54–61	0.002
7	58.17 (1.69)	55–61	0.000
8	59.42 (1.31)	56–61	0.000
12	62.25 (1.86)	59–64	0.000
16	64 (2)	60–67	0.000

DISCUSSION

The results of the present pilot study show significant change in value of implant stability along the observation time.

Using RFA to assess initial implant stability and its fluctuation during the healing period has been mentioned in many papers.[11-13] Recent dates indicate that initial implant stability between 60 and 65 ISQ-a is a prerequisite for the immediate loading protocol, and loading after healing period is requested for less values.[12-14] The lowest measured value of initial implant stability in the group of 12 non metallic zirconia dioxide root shape implants was 55 ISQ (average 60.25). Consequently, biological implant stability was successfully obtained in all situations and no implants were lost.

The purpose of this pilot study was to longitudinally evaluate stability changes in non metallic zirconia dioxide root shape implant. During an initial period of 16 weeks, the value of implant stability significantly increased in the analyzed group. In a clinical study with titanium dental implants, decreasing values of implant stability were reported during just the first 3 weeks.[15] This is kind of an increase has been noted in the present pilot study (60.25 ± 3.72 *vs* 54.92 ± 3.28 ISQ) (Table 2).

Significant increasing of implant stability value was noted from the 5th week and up to the observation period. This is in agreement with recent titanium implant studies which also showed increase in RFA value over time.[11,16,17]

There is insufficient data regarding implant stability changing of the values during the healing phases of nonmetallic zirconia dental implants.

The cumulative survival rate after 1 year of loading for 49 two-piece zirconia implants carrying single crowns was 87.3%.[18] The rate was lower as compared to the 100% survival rate of the implants noted in our pilot study during the same observation period. Higher values can be explained with a smaller sample group presented in our previous study.

CONCLUSION

Replacement of single teeth in the upper premolar area with two-piece zirconium dioxide implants is a successful procedure. The study demonstrated that increasing implant stability during the observing period suggests loading of two-piece zirconia dioxide implants with single crowns after a healing period of 4 months. In order to confirm the present results, further researches including larger sample sizes should be performed. Dentistry is varying with induction of modern science to practice dentistry.[19]

ACKNOWLEDGMENT

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