The Effect of Shape, Length and Diameter of Implants on Primary Stability Based on Resonance Frequency Analysis

Hamidreza Barikani- Shadab Rashtak- Soolmaz Akbari
Mohammadjavad KharraziFard Amirreza Rokn

Dental Implant Research Center, Tehran
University of Medical Sciences Tehran, IRAN

Tehran University of Medical Sciences

Introduction

One of the factors involved in the success of osseointegration and the long-term success of implants is the implant primary stability, which is defined as the biometric stability of the implant immediately after its placement within the bone.1 If the primary stability of an implant is not sufficient, the healing process will be disrupted due to micro-motions, because a fibrous tissue will form and osseointegration will not take place.2 A non-invasive and reproducible test for primary stabilities, which is easy to carry out, is the use of Osstell Mentor test equipment based on resonance frequency analysis (RFA). In this system the primary stability of the implant is defined in the range of 1-100 based on implant stability quotient (ISQ), i.e. higher ISQ values indicate a higher primary stability.3

A key factor for the implant primary stability is the bone-implant contact4 and thus, factors such as implant shape, length and diameter that cause an increase in the contact area between the implant and bone may increase the implant primary stability. Also, the quality of bone bed plays an important role in shaping the bone-implant contact area.5

Based on the data available, an increase in bone quality causes the primary stability of the implant to increase.4, 6-8 Therefore, it is essential in soft bones to achieve sufficient primary stability through other determining factors.2

Reports published on the relationship between the implant primary stability and its shape (parallel or tapered), length and diameter are controversial.5 Ostman et al7 reported that an increase in implant length caused the ISQ to decrease; however, the ISQ increased with an increase in implant diameter. They also found that tapered implants exhibited lower ISQ values compared to parallel implants. Billhan et al2 carried out a study on the effect of implant shape on the ISQ and reported results similar to those reported by Ostman et al.7 However, in Bilhan's study2 differences in implant length and diameter did not result in significant differences in implant primary stability. In a clinical trial by Rokn et al9 implant length was found to have no significant effect on the ISQ; however, an increase in implant diameter improved the primary stability of the implant. Contrary to the results reported by Ostman7 and Bilhan2, Rokn9 reported higher ISQ values in tapered implants in comparison with parallel implants.

In clinical trial studies there is a tendency to apply short, wide and tapered implants in the cases of insufficient bone height or low bone quality. This tendency may cause errors to the results of studies on the effect of geometrical factors on the implant primary stability.7, 10 Therefore, it is essential to carry out in vitro studies to avoid the effect of bone condition on the choice of the implant to be applied for treatment.

The aim of this in vitro study was to evaluate the effect of implant shape (conical or cylindrical), length and platform diameter on implant primary stability based on RFA by using Osstell Mentor test equipment.

Materials and Methods

In order to determine the primary stability of implants and to evaluate the effect of implant length, diameter and shape on its primary stability, two implant groups were selected:
Group 1: Replace Select Tapered implants from the Nobel Biocare System (n = 45). In this group implants were of tapered screw type.
Group 2: MK III Branemark implants from the Nobel Biocare System (n = 45). In this group implants were of cylindrical screw type.
The surfaces of both implants were similar to each other and were of Tiunit type. Each group was divided into three subgroups based on the implant length of short (10 mm), medium (13 mm) and long (16 mm in Replace Select, and 15 mm in Branemark). Each subgroup was also divided into 3 subgroups as narrow platform (NP), regular platform (RP) and wide platform (WP) of 3.4 mm, 4.3 mm and 5 mm in diameter, respectively. Therefore, each group consisted of 9 subgroups and 5 implants were tested in each subgroup.

Implants were placed in artificial bone blocks (Dentium Implant Institute, Korea) with an osseous quality similar to D3 bone. In each case the entire implants length was placed in the bony block. The surgical protocol was followed exactly as had been recommended by the manufacturer. Immediately after the implants were placed in the bony blocks, their primary stabilities were measured based on resonance frequency analysis using the Osstell Mentor test equipment (Osstell TM mentor; Integration Diagnostics AB, Sweden) and the ISQ index was also recorded.

Results

The highest and lowest mean values were 69.8 ± 1.48 and 39.2 ± 2.77, exhibited by the WP Branemark implant with a length of 15 mm and NP Branemark implant with a length of 10 mm, respectively.
Univariant analysis of variance (ANOVA) was performed to examine if there existed any significant interaction between variables. Since the interaction tests were statistically significant, T-test and turkey's HSD Post Hoc were performed for further data analysis. T-test was used to evaluate the effect of implant shape on ISQ. Tukey's HSD Post Hoc was used to compare the effects of the implant length and diameter.

Comparison of the effect of implant system on ISQ

For short implants (10 mm) and for all the three different implant diameters (WP, RP and NP) Replace select system implants exhibited a significantly higher ISQ values compared to Branmark system implants ($P \leq 0.004$).

In medium length implants (13 mm) with equal diameters there were no significant differences between the two implant systems under study ($P \geq 0.31$).

In long implants (15mm in Branemark system and 16mm in Replace select system) with RP and NP diameters, Replace select system implants had a significantly higher ISQ values compared to Branemark system implants ($P = 0.000$). However, with the WP diameters there were no significant differences between the two implant systems ($P = 0.54$).

Comparison of the effect of implant length on ISQ

In the Replace Select system, 16 mm implants had significantly higher ISQ values compared to 10 and 13 mm implants ($P \leq 0.003$); however, there were no significant differences in ISQ values between 10 and 13 mm implants ($P \geq 0.68$). In the Branemark system in WP implants, 15 mm implants had higher ISQ values compared to 13 mm implants and 13 mm implants had higher ISQ values compared to 10 mm implants ($P = 0.000$). In cases of RP and NP implants, 15 mm implants had higher ISQ values compared to 10 mm implants ($P = 0.000$). This difference was also observed between 13 mm and 10 mm implants ($P \leq 0.002$). However, there were no significant differences between 13 mm and 15 mm implants ($P \geq 0.51$).

Comparison of the effect of implant diameter on ISQ

For the Replace Select system, when implants with equal lengths were applied no significant difference was observed between WP and RP implants ($P \geq 0.77$); however, the ISQ was significantly higher compared to when NP implants were utilized ($P = 0.000$).

In the Branemark system, with 10 mm and 13 mm implants there were no significant differences in ISQ values between WP and RP implants ($P \geq 0.11$). However, there were significant differences between NP and two other wider implants ($P = 0.000$).With 15 mm implants, WP implants had significantly higher ISQ values compared to RP and NP implants ($P = 0.000$), but RP implants had significantly higher ISQ values compared to NP implants ($P = 0.000$).

Conclusion

Within the limitation of the current study which is the difference between the required in vitro environment and the clinical conditions, such as the lack of blood supply to the bone under study it can be concluded that:

1. In cases in which bone height is not adequate and short implants should be used, use of tapered implants is recommended.
2. The primary stability of tapered implants is higher than that of parallel implants regardless to the implant length and diameter.
3. An increase in implant length from medium to long in tapered implants results in a higher primary stability. However, in parallel implants this change does not increase primary stability except for WP implants.
4. Implants of 13 mm long with three different diameters can provide an appropriate primary stability regardless of implant shape.
5. Primary stability of WP implants was not different from that of RP implants and since less bone is removed with RP implants during the drilling for implant placement, thicker bone will be left in place and therefore, the use of RP implants may have a positive effect on implant longevity.

References

1. Javed F, Romanos GE. The role of primary stability for successful immediate loading of dental implants. A literature review. Journal of Dentistry. 2010;38(8):612-20.
2. Bilhan H, Geckili O, Mumcu E, Bozdag E, Sunbuloglu E, Kutay O. Influence of surgical technique, implant shape and diameter on the primary stability in cancellous bone. Journal of Oral Rehabilitation. 2010;37(12):900-7.
3. Sencimen M, Gulses A, Ozen J, Dergin C, Okcu KM, Ayyildiz S, et al. Early detection of alterations in the resonance frequency assessment of oral implant stability on various bone types: a clinical study. J Oral Implantol. 2011;37(4):411-9.
4. Winter W, Mohrle S, Holst S, Karl M. Parameters of implant stability measurements based on resonance frequency and damping capacity: a comparative finite element analysis. Int J Oral Maxillofac Implants. 2010;25(3):532-9.
5. Lachmann S, Laval JY, Axmann D, Weber H. Influence of implant geometry on primary insertion stability and simulated peri-implant bone loss: an in vitro study using resonance frequency analysis and damping capacity assessment. Int J Oral Maxillofac Implants. 2011;26(2):347-55.
6. Bischof M, Nedir R, Szmukler-Moncler S, Bernard J-P, Samson J. Implant stability measurement of delayed and immediately loaded implants during healing. Clinical Oral Implants Research. 2004;15(5):529-39.
7. Ostman PO, Hellman M, Wendelhag I, Sennerby L. Resonance frequency analysis measurements of implants at placement surgery. Int J Prosthodont. 2006;19(1):77-83.
8. Garcia-Vives N, Andres-Garcia R, Rios-Santos V, Fernandez-Palacin A, Bullon-Fernandez P, Herrero-Climent M, et al. In vitro evaluation of the type of implant bed preparation with osteotomes in bone type IV and its influence on the stability of two implant systems. Med Oral Patol Oral Cir Bucal. 2009;14(9):e455-60.
9. Rokn A, Ghahroudi AARR, Mesgarzadeh A, Miremadi A, Yaghoobi S. Evaluation of Stability Changes in Tapered and Parallel Wall Implants: A Human Clinical Trial. Journal of Dentistry of Tehran University of Medical Sciences. 2011;8(4):186-200