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

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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 biomechanical stability of the implant immediately after its placement within the bone. If the primary stability of an implant is not sufficient, the healing process will be disrupted due to micro-motions, because a fixture with formal and osseointegration will not take place. 2 A non-invasive and reproducible test for primary stability, which is easy to carry out, is the use of Ostell 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.

A key factor for the implant primary stability is the bone-implant contact and three 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 beds play an important role in the bone-implant contact area.

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.

Reports published on the relationship between the implant primary stability and its shape (parallel or tapered), length and diameter are controversial.5 Oztanm et al7 reported that an increase in implant length causes 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. Billham et al2 carried out a study on the effect of implant shape on the ISQ and reported results similar to those reported by Oltanm et al.7 However, in Billham’s study differences in implant length and diameter did not result in significant differences in implant primary stability. In a clinical trial by Boka et al8 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 Oltanm and Billham, Roll et al9 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 Ostell 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 Ti6Al4V 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 4.5 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 D2 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. Implant stability quotient, ISQ values, resonance stability blocks and primary stability were measured based on resonance frequency analysis using the Ostell Mentor test equipment (Ostell 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 length of 15 mm, and NP Branemark implant with a length of 10 mm, respectively.

Univariate 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. Today’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 Branemark system implants (P ≤ 0.004).

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

In long implants (15mm in Branemark system and 10mm in Replace select system) with RP and NP diameters, Replace select system implants had a significantly higher ISQ values compared to Branemark system implants. The WP diameter implants had higher ISQ values compared to 12 mm implants and 13 mm implants had higher ISQ values compared to 16 mm implants (P ≤ 0.002); however, there were no significant differences in ISQ values between 10 and 13 mm implants (P ≥ 0.60). In the Branemark system in WP implants, 15 mm implants had higher ISQ values compared to 12 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 16 mm implants (P ≤ 0.002). However, there were no significant differences between 12 mm and 15 mm implants (P ≥ 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 ≥ 0.77); however, the ISQ was significantly higher compared to when NP implants were utilised (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 ≥ 0.01). However, there were no significant differences between WP and RP 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 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 12 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 and NP implants and since less bone is removed with WP 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