

The Effect of Implant Length and Diameter on the Primary Stability in Different Bone Types

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Abstract

Objective: The focus of this paper is to evaluate the influence of mechanical characteristics of the implant on primary stability in different bone types, based on resonance frequency analysis (RFA).

Materials and Methods: A number of 60 Nobel Biocare Replace Select TiUnit Tapered implants of two different lengths (10 mm and 13 mm) and three different widths as 3.4 mm (narrow platform (NP)), 4.3 mm (regular platform (RP)) and 5 mm (wide platform (WP)) were placed into two different groups of bone blocks. Bone blocks were different in bone quality, but similar to bone types D1 and D3. Immediately, after implant placement, implant stability quotient (ISQ) was measured using the Osstell mentor device.

Results: ISQ values for implant placements in D1 bone were significantly higher than those for implants placed in D3 bone. In D1 bone, the implant length did not make any significant difference in primary stability; however, in D3 bone, the primary stability of the implant increased when longer implants were utilized. NP implants presented significantly lower ISQ values compared to the two wider implants.

Conclusion: In cases of low bone quality, the optimum increase in the implant length and diameter should be taken into account to achieve higher primary stability.

Key Words: Dental Implants; Osseointegration; Primary stability; Implant Geometry; Bone Type

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INTRODUCTION

Primary stability of implants is commonly considered as a key factor for achieving successful osseointegration [1]. Micro-motions higher than the threshold of 50 to 100 μm can lead to formation of fibrous tissue at the bone-to-implant interface.

Therefore, osseointegration may be vitiated due to insufficient primary stability [2,3]. Hence, when immediate loading of the dental implant is preferred as the treatment strategy, primary stability of the implant must be taken into account as a determining criterion [4-6].

Numerous techniques have been introduced to evaluate implant stability, among which the technique developed by Meredith in 19987 is a straightforward and noninvasive method. Meredith technique can reproducibly assess the bone-to-implant contact through direct attachment of a transducer to the abutment or the implant body with the application of Osstell mentor device. This technique expresses the implant stability by reading the implant stability quotient (ISQ), obtained through the resonance frequency analysis (RFA). The ISQ values range from 1 to 100 with higher values of the ISQ indicating higher implant stability [8, 9]. It has been discussed by several researchers that some factors, such as bone quantity and quality, the surgical technique of implant placement and geometrical factors of the implant including shape, length and diameter may influence the primary stability of the implant [3, 10, 11]. As bone density affects the amount of bone-to-implant contact, high bone density on the implant side can positively influence the primary implant stability [3]. However; there is no unanimous agreement on the impacts of the implant type or geometry as to how effectively they improve the primary stability in different bone types.

Bischof et al. [12] argued that length and diameter of the implants have no significant effects on the ISQ.

It should be noted, however, that in the clinical study conducted by Bischof et al. [12] patients with bone type IV were excluded. According to a study performed by Ostman et al. [13] placement of wide platform implants in the posterior regions can lead to achieving higher ISQ values. On the other hand, lower ISQ values were reported when the length of the implants increased. A finite element analysis by Winter et al. [14] demonstrated that in a higher level of bone stiffness, the implant length did not have any significant effect on ISQ values. However, in simulation of the lower level of bone stiffness a positive correlation was observed between the implant length and stability. Bilhan et al. [3] compared the effect of different implant diameters of 3.8 mm and 4.6 mm on the primary stability in cancellous bone and found no statistically significant differences in ISQ values. Carcia et al. [15] studied the effect of implant diameter on implant primary stability in D1 and D2 bone types and postulated that the implant diameter did not have any significant effects on primary implant stability.

Table 1. Group Classification of Bone Blocks and Implants Utilized in This Study

Group No.	Bone Type	Implant Length (mm)	Implant diameter (mm)	N
1-1	D1	10	3.4 NP	5
1-2	D1	10	4.3 RP	5
1-3	D1	10	5 WP	5
1-4	D1	13	3.4 NP	5
1-5	D1	13	4.3 RP	5
1-6	D1	13	5 WP	5
2-1	D3	10	3.4 NP	5
2-2	D3	10	4.3 RP	5
2-3	D3	10	5 WP	5
2-4	D3	13	3.4 NP	5
2-5	D3	13	4.3 RP	5
2-6	D3	13	5 WP	5

WP: Wide Platform, RP: Regular Platform, NP: Narrow Platform

The aim of this study was to evaluate the influence of implant length and diameter on primary implant stability in different bone types, based on resonance frequency analysis through in vitro conditions to avoid the effects of other intermediary factors.

MATERIALS AND METHODS

To evaluate the effects of the quality of the bone bed on the primary stability of the implant, two different artificial bone blocks similar to D1 and D3 bone types were prepared. A number of 60 Nobel Biocare Replace Select TiUnit Tapered implants with two different lengths (10 mm and 13 mm) and three different widths of 3.4 mm (narrow platform (NP)), 4.3 mm (regular platform (RP)) and 5 mm (wide platform (WP)) were utilized for primary stability evaluation. Two main groups, based on the bone type, and 6 subgroups, based on the geometrical features of the implants, were formed, as presented in Table 1. In each case the entire implant length was inserted into the prepared bone blocks. The surgical protocol was performed based on the instruction provided by the manufacturer. Immediately after implant placement, primary implant stability was measured based on the RFA using the Osstell mentor device (Osstell TM mentor; Integration Diagnostics AB, Sweden) and the ISQ values were recorded.

The mean ISQ values of each of the twelve groups studied in the current research were statistically compared using T-test and Tukey's HSD Post-hoc test.

The level of statistical significance was defined as $P < 0.05$.

RESULTS

Mean values and standard deviations of the ISQ values for each of the twelve groups, studied in this paper, are presented in Table 2. Univariate Analysis of Variance was performed to assess if the variables, i.e. bone type and implant length and diameter, had any interactions.

Since the tests indicated that significant interactions existed between the variables, T-test with P value adjustment, using Bonferroni correction method, was performed to evaluate the effect of bone type together with implant length on the ISQ values.

Tukey's HSD Post-hoc test was also conducted to evaluate the effect of the implant diameter on the ISQ values.

The influence of bone type on ISQ values:

The ISQ values measured for implants placed in D1 bone type were significantly higher than those measured for implants with the same length and diameter, but placed in D3 bone type ($p \leq 0.001$).

Table 2. Mean Values and Standard Deviations of the ISQ Values

Bone type	IL	ID	WP	RP	NP
D1	10		74.6±0.54	75.2±2.58	70.8±0.83
	13		77.2±0.44	75.6±1.81	69.0±1.58
D2	10		49.6±3.91	51.4±4.66	37.6±4.77
	13		59.2±4.02	60.4±0.89	49.8±1.09

ID: Implant Diameter, IL: Implant Length (mm)

WP: Wide Platform, RP: Regular Platform, NP: Narrow Platform

The influence of implant length on ISQ values:

When utilizing WP implants of 13 mm and 10 mm length, the comparison of ISQ values for implant placements in D1 bone type indicated that the ISQ values were significantly higher for longer implants, with the mean difference of 2.60 ($p = 0.000$). More importantly, for implants of 13 mm in length, the ISQ values were even higher when placing the implant in D3 bone type, with the mean difference of 9.60 ($p = 0.005$). RP implants of 13 mm in length presented significantly higher ISQ values compared to their 10 mm counterparts when placed in D3 bone type ($p = 0.011$). However, different lengths of RP implants did not make any significant differences in ISQ values measured for implants placed in D1 bone type ($p = 0.785$). In NP implants, there was a positive correlation between the implant length and the ISQ values in D3 bone type ($p = 0.001$), while in D1 bone type no statistically significant difference was observed in the ISQ values when NP implants of different lengths were applied ($p = 0.065$).

The influence of implant diameter on ISQ values:

Analysis of the experimental data revealed that narrow platform implants presented significantly lower ISQs in comparison with regular and wide platform implants ($p \leq 0.007$). However, no significant differences were observed when comparing the ISQ values for regular and wide platform implants ($p \geq 0.215$).

DISCUSSION

Primary stability of the implant can be defined as the absence of implant movement, including micro-motions, immediately after insertion of the implant into the bone bed [2, 3]. Primary stability of the implant mainly depends on bone-to-implant contact. The bone quality and implant length and diameter have been assumed to be influential on the bone-to-implant

contact and consequently on implant primary stability [3]. In this paper, primary stability was significantly higher in high bone quality compared to low bone quality. Ostman et al. [13] pointed out that the presence of cortical bone, which is 10 to 20 times more rigid than cancellous bone, can be the cause of high primary stability in high bone quality. Based on the results of this study, which is in accordance with the result of numerous clinical studies [8, 13, 16, 17], the authors recommend avoiding the immediate loading protocol after implant placement in low quality bones. The same approach was also proposed by Trisi et al.[4] who measured primary stability based on insertion torque in different bone densities. Moreover, Neugebauer et al.[16] concluded, from their animal study, that implant immediate loading can be applicable only when a high primary stability is achieved. According to a study carried out by Javed et al.[2], immediate loading in the anterior region of the mandible showed a high success rate due to good bone quality in this region. However, recently Degidi et al.[17] found that only a weak correlation exists between bone density and the ISQ values. Degidi et al.[17] noted that the different implant geometry, used in their study may be one of the reasons of inconsistency between their results and results from other studies [6, 11].

The implant used by Degidi et al. [17] was XiVE implant, which has a cylindrical core with an increasing thread depth from the crestal to apical region in a way that the thread pitch remains equal. Degidi et al. [17] also denied the importance of implant length and diameter on the ISQ values, since they only found a weak correlation between RFA and implant length and diameter. It should be mentioned that Degidi et al. [17] did not analyze the interaction between the effects of implant geometrical factors (length and diameter) and different bone qualities on RFA. On the contrary, the current study showed that there is an interaction between the effects of implant ge-

ometrical variables and the quality of bone bed on RFA.

Based on the results of the current study, implant length did not have any significant influence on primary stability when there was a high bone quality on the implant side. However, in cases of insufficient bone quality, an increase in implant length resulted in an increase in implant primary stability. In addition, in accordance with the results of the current study, a finite element analysis by Winter et al.[14] reported a positive correlation between implant stability and implant length in low levels of bone stiffness. Moreover, Lachman et al.[18] conducted an in vitro study to compare implants with different lengths of 11 mm, 13 mm, 15 mm and 18 mm. They concluded that only 11 mm-long implants, which were placed in soft bone blocks, presented significantly lower ISQ values. On the contrary, Ostman et al.[13] reported that the use of longer implants resulted in lower primary stability. They compared primary stability of implants with the lengths of 7 mm, 8.5 mm, 10 mm, 11.5 mm, 13 mm, 15 mm and 18 mm and found that by increasing the implant length from 8.5 mm to 10 mm, primary stability increases and for a range of implant lengths from 10 mm to 13 mm, primary stability is almost constant. They also found that implants 15 mm and 18 mm in length resulted in lower primary stability compared to implants 13 mm in length, mainly because they were more heat generated due to the longer bone drilling. Therefore, in low quality bone types with an inadequate bone height, and bone augmentation should be performed instead of applying short implants. Moreover, implant site preparation with osteotome technique is preferred since it can improve the bone density [19, 20]. Furthermore, application of implants that are specially designed to achieve more primary stability should be given consideration [21]. It is also believed by some researchers that the cortical bone is more rigid than cancellous bone and the highest load concentrates in the

cortical zone and thus, the role of implant width is more important than the role of implant length to achieve high primary stability [3, 15]. In the current study, NP implants presented a significantly lower ISQ when compared with RP and WP implants, especially in D3 bone type. Furthermore, Rokn et al. [8] conducted a study on Nobel Biocare Replace Select TiUnit Tapered implants and found that RP (4.3 mm) implants presented a significantly higher primary stability compared to NP (3.5mm) implants. On the other hand, Ostman et al.[13] compared implants of 3.75 mm, 4 mm and 5 mm diameters and found that WP (5 mm) implants had significantly higher primary stability; however, he did not observe any difference between RP and NP implants.

The reason for this similarity in primary stability of RP and NP implants can be ascribed to the slight difference between implant diameter in RP and NP implants in Ostman's study [13]. Accordingly, in cases of low bone quality, it is recommended to avoid using NP implants and it is preferred to perform bone reconstruction methods such as Guided Bone Regeneration. Basically, application of NP implants must be limited to the anterior region of the mandible and premolar sides in the maxilla where implants are imposed to mild occlusal loads [22]. Since ISQ values in RP and WP implants did not show any significant differences, the authors suggest using RP implants to preserve further thickness of bony walls. In general, in order to achieve high primary stability of implants placed in low bone quality, optimum increase in length and diameter of implants should be seriously considered.

CONCLUSION

Within the limitation of the current in vitro study it can be concluded that Implant primary stability was higher in high bone quality. Implant length was a determining factor to achieve more primary stability in low bone quality. NP implants demonstrated the least

implant primary stability. The difference in primary stability, which was affected by application of narrow platform implants, was more prominent in low bone quality RP and WP implants did not have any significant influence in terms of implant primary stability.

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