Primary Stability in Various Levels of Impacted Implants: An Ex Vivo Study

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The aim of this study was to examine the primary stabilization of different vertically impacted bone implants. Implant stability was measured by resonance frequency analysis. Forty-five dental implants were used and divided into 3 groups. Group 1 was placed 4 mm (1/3 impacted), group 2 was placed 8 mm (2/3 impacted), and group 3 was placed 12 mm (fully impacted). Implant stability quotient values were measured on the longitudinal and transversal axis by 2 independent researchers. The fully impacted group showed the significantly highest value among the groups ($P < .05$). There were statistically varying implant-stability quotient values between researchers. None of the 1/3-impacted implants' value reached a 70 implant-stability quotient value.

Key Words: RFA, primary stability, dental implant, partial impaction

Introduction

Osseointegration of dental implants is associated with obtaining sufficient primary stability.[1] Although primary stability depends on the implant's shape, structure, and surface features, it may also vary according to factors such as bone density, bone-implant contact rate, and osteotomy site preparation protocol.[2] Generally, implants are placed fully impacted into the bone. However, in cases where bone volume is insufficient, the implant's neck region may remain exposed.[3] An exposed implant neck can be covered with various grafts, but grafting cannot be expected to make a positive contribution to implant stability. The main determinant of primary stability is the close relationship between implant threads and residual bone.[4] Measurement of implant stabilization is conducted by means of resonance frequency analysis (RFA) evaluating micromobility. RFA devices provide analytical data on stability using units called the implant stability quotient (ISQ), ranging from 1 to 100. ISQ value enables an objective assessment of the amount of osseointegration.[5] Low ISQ in primary stabilization prolongs the waiting time for osseointegration and delays the prosthetic loading date.[6] In particular, patients with anterior tooth deficiencies wish to complete their prosthetic treatment in a short time due to social and aesthetic considerations. In such cases, temporary prostheses can be made if there is clinical compliance. According to the Sixth ITI Consensus Conference, for a temporary prosthesis with a single crown on a single implant, the implant should ensure adequate primary stabilization.[7] Values of 70 ISQ and above are recommended for the immediate loading of single-crown cases.[8,9]

The aim of this study was to examine the primary stabilization of different vertically impacted bone implants to test the reliability of an RFA device and the mechanical adequacy of partially impacted implants in terms of temporary prosthesis loading.

Materials and Methods

Experiments were carried out under sterile conditions at Trakya University, Faculty of Dentistry Laboratory, by a maxillofacial surgeon and a prosthodontist. No ethical permission was required for our ex vivo study. The methodology was reviewed by an independent statistician. Power analysis showed that 15 samples must be included in the study by taking the probability of 0.05 error and an ICC of 0.90 with 80% power.

Forty-five Straumann sand blasted and acid-etched (SLA) bone level implants (Institute Straumann AG, Basel, Switzerland) having 4.1-mm diameter and 12-mm length were placed into Swiss bovine ribs. Fresh bone tissue was obtained from a butcher shop 2 hours before the study. D1-type bone structure was determined through cut sections of bone and radiography.[10]

Implant Placement Procedure

An oral surgeon completed all surgical procedures using a W&H WI-75 E/KM contra-angle handpiece (W&H Dentalwerk GmbH) and a W&H SI-923 physio dispenser (W&H Dentalwerk GmbH). Implants in each group of 15 were placed on ribs IV, V, and VI of the same animal. A minimum distance of 3 mm was left between the implant cavities. Cavities were prepared using drills of diameters 2.2 mm (800 rpm), 2.8 mm (600 rpm), and 3.8

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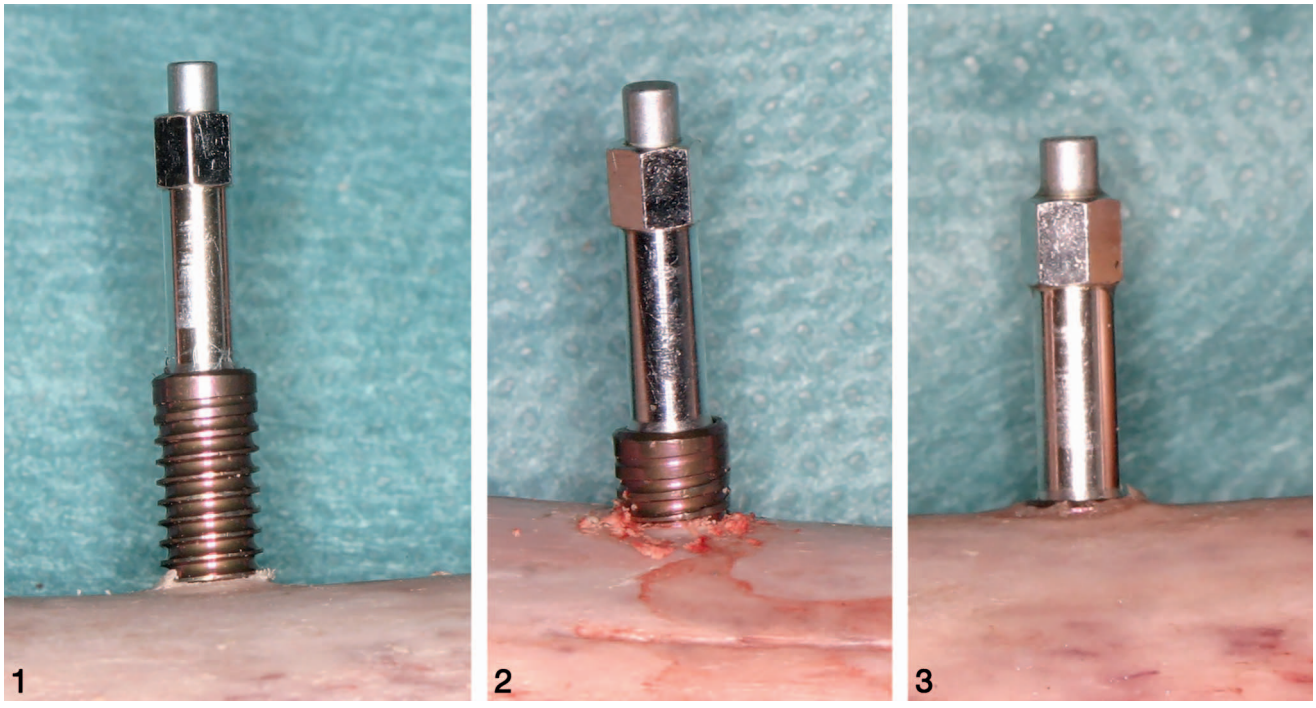


Figures 1–3. Figure 1. 1/3-impacted implant (group A) with SmartPeg. **Figure 2.** 2/3-impacted implant (group B) with SmartPeg. **Figure 3.** Fully impacted implant (group C) with SmartPeg.

mm (500 rpm) (Straumann Surgical Cassette, Institute Straumann) under external cooling with saline solution in accordance with the manufacturer's instructions. Profile and tap drills were used as well. A precalibrated parallelometer (Bego) assisted in the pilot drill to obtain a vertical angle on the bone. After bone cavities were prepared according to the groups, implants were placed with a constant torque force of 35 N-cm.

Study Design and Measurement of Primary Stabilization

Implants were assigned to the 3 groups according to the amount of impaction: group 1 (Figure 1), 4 mm (1/3 vertical impaction); group 2 (Figure 2), 8 mm (2/3 vertical impaction); and group 3 (Figure 3), 12 mm (fully impacted). An Osstell ISQ device (Osstell) was used for stabilization measurements of implants. SmartPegs Type 54 (Osstell) were screwed to the implants for detecting RFA values. Measurements were performed from transversal (^{T}) and longitudinal (^{L}) directions with different bone thicknesses to simulate labiolingual and mesiodistal axes. To enhance the study's reliability and mimic clinical functioning, the oral surgeon (A) and the prosthodontist (C) inserted the SmartPegs and measured and recorded all values separately after repeating the procedure 5 times consecutively.

Statistical Analysis

ISQ data obtained were analyzed using IBM SPSS Statistics for Windows version 21.0 (IBM Corp), Turcosa (Turcosa Analytics Ltd Co), and MedCalc version 14.12.0 (MedCalc Software) programs. Shapiro-Wilks test showed that the parameters were not normally distributed. Bonferroni correction, Kruskal-Wallis, and Mann-Whitney *U* tests were conducted. As descriptive statistics, mean ± SD and median (min-max) values were used (Table 1). The level of compatibility between the researchers' values for the same implants was examined using Bland-Altman analysis and ICC (Table 2).

Data and Statistical Findings

When interobserver compatibility was examined for the transversal direction, only group 3^{T} was compatible, while groups 2^{T} and 1^{T} were not. Although compatibility between all researchers could not be achieved, significant differences between the 2 researchers' groups were similar. In assessing these results, it was found that those of Group 3^{T} were significantly higher than Groups 2^{T} and 1^{T} ($P < .05$), and group 2^{T} data were significantly higher than Group 1^{T} ($P < .05$) (Figures 4 through 6).

When intergroup compatibility was examined for the longitudinal direction, all groups (groups 1^{L}, 2^{L}, 3^{L}) were statistically compatible (Table 2). In both researchers' measurements, group 3^{L} was found to be significantly higher than groups 2^{L} and 1^{L} ($P < .05$). Group 2^{L} were significantly higher for both researchers compared to group 1^{L} ($P < .05$) (Figures 7 through 9).

There were statistically significant differences between groups 1 through 3 in transversal and longitudinal directions both researchers (A; $P = .000$, C; $P = .000$, respectively). Groups 1 and 2, groups 1 and 3, and groups 2 and 3 showed significant differences for both researchers (Figures 10 and 11).

Results

Results and conclusions were reviewed by an independent statistician. High ISQ values indicate good stability, and a stable

Table 1

ISQ measurement values

	Oral Surgeon (A)							
	Transversal			Longitudinal				
Variable	Mean ± SD	Median	(Min-Max)	Mean ± SD	Median	(Min-Max)	P_T	P_L
Impacted 1/3	59.80 ± 0.41	60	(59–60)	59.40 ± 1.18	60	(58–61)	.002*	.002*
Impacted 2/3	73.67 ± 2.16	74	(70–76)	75.13 ± 0.64	75	(74–76)	<.001**	<.001**
Impacted 3/3	87.27 ± 1.16	87	(86–90)	88.73 ± 0.46	89	(88–89)	.002***	.002***
P	.001			.001				

*Compared with groups 1 and 2; **compared with groups 1 and 3; ***compared with groups 2 and 3.

implant has a better prognosis for recovery in terms of osseointegration. In this study's results, ISQ values increased in direct proportion with the vertical impaction rate of the implant in a D1 bone type. Fully impacted implants were found to be more stable than 2/3-impacted implants, and 2/3-impacted implants were more stable than 1/3-impacted implants. RFA was conducted to verify the estimated success according to laws of mechanics, and the results also suggested that the RFA device's measurements of implants with partial impaction were reliable.

Interobserver consistency was achieved in all longitudinal direction measurements mimicking mesiodistal from different directions. However, consistency was not achieved in all transversal measurements mimicking buccal–lingual/palatine.

According to Sixth ITI Consensus criteria, adequate primary stability is required for immediate prosthetic loading. Our study's results showed that measurements of both fully impacted implants and 2/3-impacted implants were all found to be above 70 ISQ, while none of the 1/3-impacted implants were. However, only implants without bone augmentation can be loaded with an immediate prosthesis.

Discussion

To ensure good stability of implants placed in the bone, the implant's entire surface should be in direct contact with the bone, but bone density, geometric structure, and implant surface properties affect stability. In our study, a D1-type bovine rib was used to minimize the variable results from variations in bone density. In clinical relevance, only basal mandibula can be available as D1-type.

Romanos et al[1] tested the primary stability of different implant designs using RFA measurements by placing implants in fresh bovine ribs and obtained statistically significant differences. The anterior tooth regions especially are aesthetically more critical. Bone level type implants used in these regions offer advantages for prosthetic attachment that may not be reflected from the gingiva. Den Hartog et al[11] emphasized the importance of bone level implants in the aesthetic region. The shape, size, and thread design of the implant are also important for providing primary stabilization. In our study, we ensured that implant threads that remained in the bone were balanced and evenly distributed. The structure of Straumann bone level 12-mm-long cylindrical implants was available to divide the implant groups into 3 balanced groups. A 12-mm-long implant is desirable for the anterior region. Chang et al[12] examined the distribution of stress on the implant and pointed out that there was a more balanced stress transmission to the bone in threads with homogeneous distribution. Mazzo et al[13] reported a statistically significant difference for primary stabilization in their study comparing groups of 8 implants. Lachmann et al[14] showed significant results in a study in which 8 samples were tested for the reliability of the RFA method. In a study in which Xiao et al[15] explored the influence of repetitive occlusal forces on the implant's stability, they determined the adequate number of samples in each group to be 12. In our study, a power analysis was carried out to calculate the number of samples. However, ICC tests may be repeated with more implants to ensure reliability between researchers. Implant stability measurements can be made with mobility tests, such as RFA and Periotest®. Many studies single out RFA as a reliable test method for implant stabilization measurements. In this study, Osstell ISQ was used as the RFA device.

As a result of a primary stabilization study on a cadaver, Brouwers et al[17] reported that the RFA method is reliable. In a study comparing Periotest and RFA methods by Oh and Kim,[18] both methods were reported to be consistent and reliable in terms of determining stability. Gonzalez-Serrano et al[19] compared primary stabilization of 60 equal-size implants with double- and single-thread designs using RFA and Periotest devices. While the implants with the double-thread design showed significant differences in the statistical results of the RFA measurements, there were no significant differences in the Periotest results. Also, RFA shows a stabilization difference more detailed compared to the Periotest device.[19] The Osstell device returns different measurements among researchers, which may depend on various factors, the most likely being the tightening of SmartPegs with a different finger torque force of each individual. When the results of our study were examined, interobserver compatibility was

Table 2

ICC values for interobserver reliability

Researchers A–C	ICC	95% Confidence Interval	*P*
Group 1^T	−0,12	−1.3825–0.5690	.600
Group 2^T	0.857	0.5734–0.9520	.001
Group 3^T	0.4181	−0.4220–0.7892	.127
Group 1^L	0.9723	0.9182–0.9907	.000
Group 2^L	1.000		
Group 3^L	−0.047	−2.117–0.649	.533

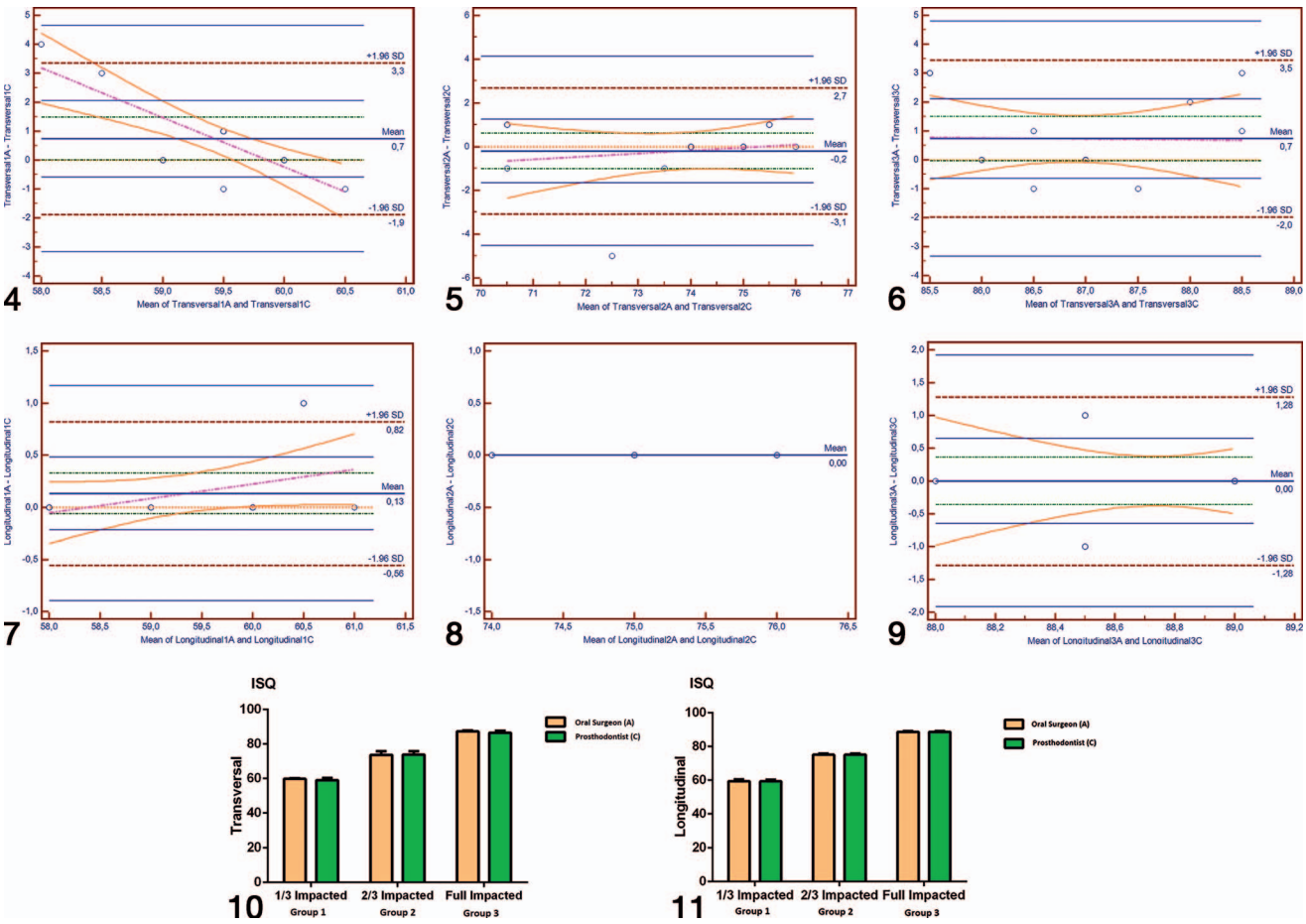
TABLE 1

Extended

Prosthodontist (C)							
Transversal			Longitudinal				
Mean ± SD	Median	(Min-Max)	Mean ± SD	Median	(Min-Max)	P_T	P_L
59.07 ± 1.22	59	(56–61)	59.27 ± 1.03	60	(58–61)	.002*	.002*
73.87 ± 1.92	75	(70–76)	75.13 ± 0.64	75	(74–76)	<.001**	<.001**
86.53 ± 1.18	87	(84–88)	88.73 ± 0.45	89	(88–89)	.002***	.002***
.001			.001				

found statistically variable. Geckili et al[20] stated that there might be significant measurement differences among researchers in the inserting of SmartPegs.

There are many studies in the literature about the primary stabilization of various-length implants. Degidi et al[21] in a study of 4135 implants, reported a directly proportional relationship between implant length and stabilization. However, current knowledge is limited about the stabilization of implants in cases of bone deficiency. Tözüm et al[22] established in vitro peri-implantitis models on 12 implants of 12 mm length. They concluded that the ISQ value decreases directly with the increase in the amount of defect in RFA measurements made on implants with vertical defects of 0, 1, 2, 3, 4, and 5 mm.[22] Akca et al[23] placed 32 implants with 12-mm lengths into the iliac bone of a cadaver and formed vertical defects up to half of the implant neck. They reported that, according to comparisons with a control group, the implants with defects demonstrated significantly lower RFA and Periotest values. According to our study results, the transversal direction consistency between researchers was found to be weaker than that for the longitudinal direction, even if the order of stability among the groups was the same. Bone present in the direction of measurement might improve the RFA consistency among researchers. However, it is unclear why only 2/3-impacted



FIGURES 4–11. FIGURE 4. Mean of transversal 1A and 1C. FIGURE 5. Mean of transversal 2A and 2C. FIGURE 6. Mean of transversal 3A and 3C. FIGURE 7. Mean of longitudinal 1A and 1C. FIGURE 8. Mean of longitudinal 2A and 2C. FIGURE 9. Mean of longitudinal 3A and 3C. FIGURE 10. Column graph for transversal values of all groups. FIGURE 11. Column graph for longitudinal values of all groups.

implants provided interobserver consistency in the direction of transversal measurements. The Osstell ISQ manual[24] states that value differences may occur with the change in the direction measured on the same implant. Thus, the measurements were repeated for each researchers at least 5 times in the same axis.

The Sixth ITI Consensus recommends that if immediate implant placement and immediate restoration are made in the anterior region, insertion torque should be 25 to 40 N-cm with adequate implant stability. Although all clinical conditions affecting implant success were eliminated, none of the 1/3-impacted implants reached 70 ISQ in our study.[23] Our study controlled and limited mechanical tests only for type 1A implant clinical cases. However, we state that an ex vivo study with limitations may not entirely mimicking any clinical status. Likewise, the only mechanical situation was simulated with fresh bone tissue in a limited manner. Therefore, future studies should focus mechanically on studies under standard conditions; further clinical studies should obtain immediate implantations and immediate restorations in the anterior region. Our ex vivo results may guide clinical studies for assessing the primary stabilization of implants.

Conclusions

1) It was observed that there is a linear relationship between the amount of implant-bone contact and primary stabilization.
2) Resonance frequency analyzer can be used to evaluate the primary stability of partially placed implants.
3) ISQ values can be affected by applied finger torque force while tightening of SmartPegs.

Abbreviations

ICC: interclass correlation coefficient
ISQ: implant stability quotient
ITI: International Team for Implantology
RFA: resonance frequency analysis
SLA: sandblasted and acid-etched

Note

The authors declare no conflicts of interest

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