In Vitro Assessment of Primary Stability of Straumann® Implant Designs

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ABSTRACT

Background: Primary implant stability (PS) is one of the main factors influencing implant survival rate. Several methods to determine the PS have been used, such as Periotest values (PVs) and resonance frequency analysis (RFA) with implant stability quotient (ISQ) values.

Purpose: The aim of this study was to compare different implant designs in regard to PS assessed by Periotest and RFA in vitro.

Materials and Methods: A total of 90 implants were placed in freshly slaughtered cow ribs. The implants (Straumann®, Institute Straumann AG, Basel, Switzerland; length 10 mm, ø3.3 mm) had the following three designs: Bone Level (BL, 30 implants), Standard Plus (SP, 30 implants), and Tapered Effect (TE, 30 implants). Before implant placement, the investigator was calibrated for every design according to the manufacturer's instructions. An independent observer, blinded to the study, assessed the accuracy of placement. RFA based on the Osstell device and PVs were performed after abutment connection. One-way analysis of variance and Tukey's post hoc test were used for statistical evaluation.

Results: All implants were mechanically stable. The mean PV for BL was −4.67(± 1.18), for SP, −6.07(± 0.94), and for TE, −6.57(± 0.57). The mean ISQ values were 75.02(± 3.65), 75.98(± 3.00), and 79.83(± 1.85), respectively. The one-way ANOVA showed significant difference among three implant designs in PV ($p < .0001$) and for the ISQ between BL/TE or SP/TE implants ($p < .0001$). In addition, the Tukey's (pair-wise comparison) test showed significant differences in PV and RFA between the BL/TE ($p < .0001$).

Conclusion: Within the limitations of this study, higher implant stability was found for tapered designed implants.

KEY WORDS: implant design, Osstell, Periotest, primary stability

INTRODUCTION

The number of dental implants placed today has gradually increased over the last years. The estimated number of implants that are placed in United States itself is over 700,000 implants inserted annually. This number is expected to grow about 9.4% for the next several years.[1] The fact that dental implants are a very accepted treatment modality is important to be able to provide successful implant treatment. The success of dental implant treatment is dependent very largely on the primary stability.[2] Primary stability depends on length, diameter, shape, thread design of the implant and also the surgical technique, and the type of bone.[3] The basic implant design can also significantly affect the stability of the implant. Different authors have discussed either using larger diameter implant, using smaller drill size, etc., which can potentially influence implant stability. As much as implant stability is discussed, there are no

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established measurement standards.[4] The clinical assessment of implant stability is generally experiential and subjective observation.[5] Two different tests that are used occasionally are the Periotest and Osstell methods. The literature discusses the advantages and disadvantages of both of these evaluation methods and both seem not to be the ideal way of assessment.[6]

A few groups have evaluated implant design and its relationship to primary stability (Table 1). A study on beagle dogs was able to show no statistically significant difference on bone formation within the threads between cylindrical and conical implant designs when placed using the nonsubmerged technique.[7] Another group had placed implants in porcine iliac, spongious bone. The investigators attempted to evaluate the primary stability of hybrid self-tapping implants compared with cylindrical non-self-tapping implants. They concluded that the hybrid self-tapping implants could achieve a high primary stability, which predicts them for the use in low-density bone.[8] Scientific groups have also reported that conical and stepped implants may cause higher stresses to the bone than cylindrical and screw-shaped implants.[9] It has been demonstrated that no differences in strain levels on surrounding bone exist for implants with different geometric forms but similar diameters.[10] Another group showed better stability with tapered designed implant systems than cylindrical screw designs.[11]

Evaluation methods for determining primary stability, such as Periotest values (PVs) and resonance frequency analysis (RFA), have been used in different studies. The implant macrodesign in terms of geometrical shape (tapered vs nontapered) was previously critically analyzed and the primary implant stability (PS) was compared by RFA. O'Sullivan and colleagues[5] in a human cadaver study demonstrated higher PS (assessed by implant stability quotient [ISQ] values) for tapered designed implants than nontapered and found similar RFA values for tapered implants irrespective of bone quality. In contrast to this in vitro evaluation by O'Sullivan and colleagues, other investigators found significantly higher RFA values and insertion torque for tapered implants than nontapered in a comparative clinical study.[12]

Although the Nobel Biocare® (Nobel Biocare Nordic AB, Gothenburg, Sweden) macrodesign has been extensively studied in vitro and in vivo, the Straumann® (Institute Straumann AG, Basel, Switzerland) dental implant stability has also to be evaluated, comparing the different implant geometries in terms of primary stability. This implant system is the most common dental implant system worldwide together with the Nobel Biocare dental implant system. This information is of significance for the clinician in cases of weak bone quality and/or in protocols of early/immediate loading.

Therefore, the aim of this study was to determine in vitro the primary stability of Straumann dental implants with different macrodesigns.

MATERIALS AND METHODS

Freshly slaughtered bovine ribs were cut into 30-cm-long pieces and a total of 20 bovine rib blocks were prepared after complete removal of the soft tissues in room temperature.

Surgical Protocol

The distance between the implants was about 10 mm. Two types of straight-screw type implants and one tapered-screw type implant were used (Figure 1). A total of 90 implants were placed in freshly slaughtered cow ribs using a surgical guide. All implants placed in similar areas of the rib as the medial part has less density than the distal part of the rib in order to have comparison of the bone density in the osteotomy sites. The implants (Straumann, length 10 mm; ø3.3 mm) had following three designs: Bone Level (BL, 30 implants), Standard Plus (SP, 30 implants), and Tapered Effect (TE, 30 implants). Before implant placement, the investigator was calibrated by placing 50 additional implants for every design according to the manufacturer's instructions. An independent observer (G.E.R.), blinded to the study, assessed the accuracy of placement. The implants were placed according to the manufacturer guidelines using the complete sequence of drills for each individual implant design. The quality of bone of ribs was assessed by three different clinicians (G.E.R., G.C., and A.J.), after performing osteotomies, close to the experimental areas in a blinded mode (Figure 2). All evaluators considered the bone density as type 3, bone quality.

Evaluation of the Primary Stability

After implant placement, the ISQ was measured by using RFA with the Osstell device (Osstell AB, Göteborg, Sweden). For each implant design, a suitable-transducer was inserted into the implant body (Smart peg type 41 for BL/type 4 for SP and TE implants, Osstell mentor,

TABLE 1 Different Studies Focused on the Primary Stability According to the Implant Macrodesign

Study	Type of Study	Type of Implant	Implant Designs Tested	Testing Method RFA/Periotest	Sample Size	Results
(O'Sullivan and colleagues, 2000)[5]	Human cadaver	Nobel Biocare	Standard threaded	RFA	52 total	Type 2,3 bone, all implants did well
			Self-tapping implant	RFA		The Standard, Mark II, Osseotite, and TiOblast were less stable when placed into bone type 4. The Mark IV implants appeared to maintain a high primary stability even in type 4 bone
			Tapered self-tapping implant	RFA		
		Astra TiOblast		RFA		
		3i Osseotite		RFA		
(O'Sullivan and colleagues, 2004)[13]	In vivo (animal)	Nobel Biocare	Titanium implants with one degree (EXP 1)	RFA and insertion torque	10	RFA more for EXP 1
			Titanium implants with two degrees (EXP 2)	RFA and insertion torque	10	EXP 2 failed to insert, RFA was very low
			Standard Brånemark design	RFA and insertion torque	10	
(Markovic and colleagues, 2011)[23]	In vivo (human)	Blue Sky (Bredent)	Self-tapping	RFA	56	Immediate RFA showed same numbers
		Standard Plus® (Straumann)	Non-self-tapping	RFA	56	2–12 weeks showed significantly high by self-tapping
(Chong and colleagues, 2009)[26]	In vitro		Self-tapping	RFA		Non-self-tapping showed initial higher stability than self-tapping
			Non-self-tapping	RFA		
(Kim and colleagues, 2011)[22]	In vitro	Osstem Implant Co.	Self-cutting blades	RFA		Non-self-cutting blades showed higher primary stability than with self-cutting blades
			Without self-cutting blades	RFA		
(Toyoshima and colleagues, 2011)[8]	In vitro	Straumann	Tapered Effect implant	RFA and Periotest	10	Periotest lower for Tapered Effect implants
			Hybrid, self-tapping implants	RFA and Periotest	10	RFA showed no significant differences
			Cylindrical, non-self-tapping implant	RFA and Periotest	10	
(Moon and colleagues, 2010)[24]	In vitro	Shinhung Co.	Straight, screw type	RFA		ISQ values of the straight-screw type and tapered-screw type implants were not significantly different
			Tapered, screw type			

ISQ = implant stability quotient; RFA = resonance frequency analysis.

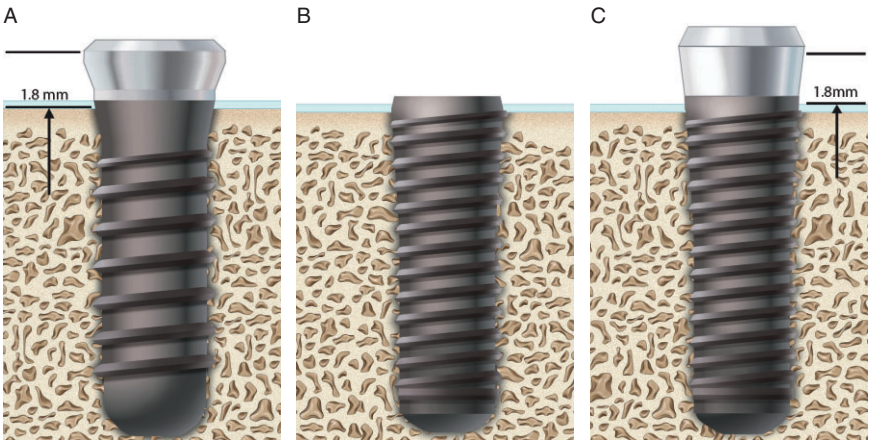

Figure 1 Different implant designs (Straumann®) used in this study (A: SP Straumann; B: Bone Level; C: Tapered Effect implant).

Integration Diagnostics AB, Göteborg, Sweden). Measurements were done in two different directions of the implant, perpendicular to the Smart peg according to the manufacturer guidelines. The mean values of the two measurements were selected for each implant determining the final ISQ of this implant.

After evaluation of the PS with the ISQ values, abutments were torqued-down and PVs evaluated the PS of the implants. The PV was determined three times repetitively and the average value was used as a final PV of each implant (Figures 3–5).

Statistical Analysis

Statistical software SPSS (Statistical Package for the Social Sciences, New York, USA) was used for statistical analysis. One-way analysis of variance (ANOVA) and Tukey's post hoc test were used for statistical evaluation. The level of probability (p) of 5% with $p < .05$ was considered statistically significant.

RESULTS

All implants were mechanically stable. No mobility was observed. The mean PV for group BL was −4.67(± 1.18), for group SP, −6.07(± 0.94), and for group TE, −6.57(± 0.57). The mean ISQ values were 75.02(± 3.65), 75.98(± 3.00), and 79.83(± 1.85), respectively. The one-way ANOVA showed significant difference among three implant designs in PV ($p < .0001$) and between BL/TE and SP/TE implants for the ISQ ($p < .0001$). In addition, the Tukey's (pair-wise comparison) test showed significant differences in PV and RFA between the BL/TE ($p < .0001$).

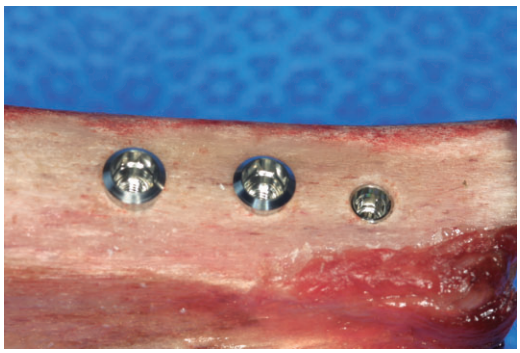

Figure 2 Implants placed in fresh bovine ribs.

DISCUSSION

In the present study, straight-screw type implants and tapered-screw type Straumann implants were used. The calibrated surgeon placed implants using standardized drilling protocols. The PS was measured using the Periotest and Osstell devices. There was a statistically significant difference between the PVs for the TE implants presenting higher stability for this design compared with the conventional SP design. There are not many studies that have tested the primary stability of Straumann implants and especially with respect to the macrodesign of the implant. The present study aimed to evaluate the specific implant geometry and if there is a relationship between the design and the primary stability values.

The results of the present study are synonymous with the study by Sakoh and colleagues,[11] who investigated the primary stability of hybrid implants and conical implants and concluded that tapered implants had a superior PS. They used Periotest as one of the assessment tools. Some of the differences in this investigation were that fresh porcine bone was used, while in the present study, bovine bone was used.

The results of another study by Toyoshima and colleagues,[8] which also tested PS of two types of hybrid

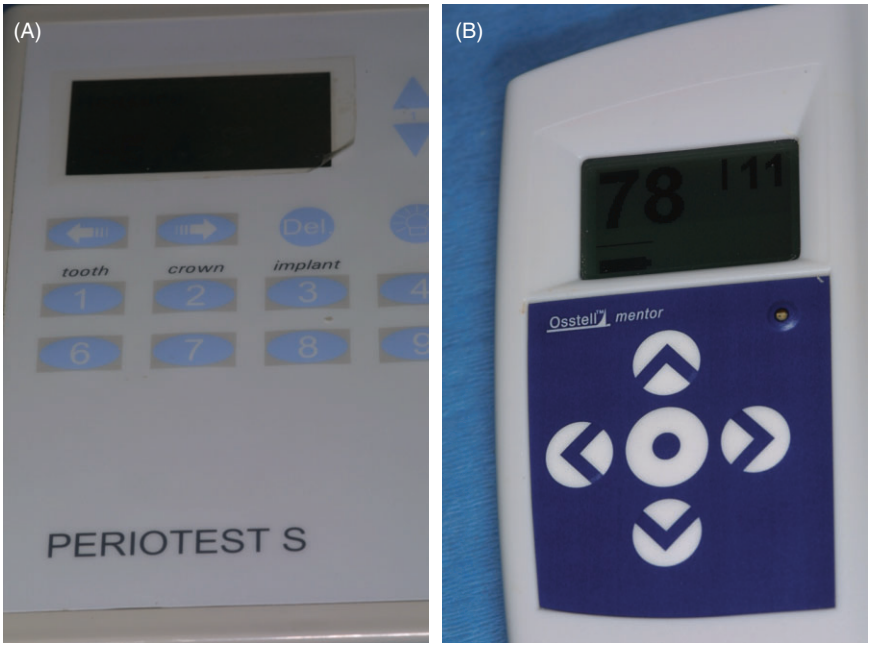

Figure 3 Periotest (A) and Osstell (B) devices for evaluation of the implant stability.

self-tapping implants, showed that tapered implants had significantly lower values when measured by Periotest, but Osstell showed no differences. The study of Toyoshima and colleagues[8] is also resonant of the results of the present study.

In a human cadaver study, O'Sullivan and colleagues[5] demonstrated higher PS (assessed by ISQ values) for tapered designed implants than nontapered and found similar values for implants placed in type 2 and type 3 bone. In contrast to this in vitro evaluation by O'Sullivan and colleagues,[13] it was found in a comparative clinical study significantly higher RFA values and insertion torque for one degree taper than two degree taper implants with standard Brånemark design.

Other studies have also shown that tapered implants can be used in sites of fresh extraction sites, where immediate loading was attempted and they did have an acceptable PS. The theory behind the use of tapered implants is to provide for a degree of compression of the cortical bone in a poor bone-implant site.[13] In a study with 16 individuals, who received tapered designed titanium implants, the overall implant survival rate was reported to be 95.8% after a mean follow-up of 40 months.[14]

The present study reiterates the idea that tapered implants may have a better implant PS than cylindrical implants. The important part also to understand is if there is any literature discussing the reliability of the

Figure 4 Evaluation of the primary stability using the Periotest device.

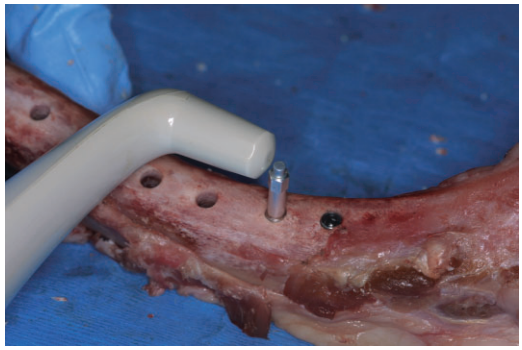

Figure 5 Evaluation of the primary stability using the Osstell device.

Periotest and Osstell devices. Periotest has been used as a measuring gauge in many studies and it has been shown that it is a reliable indicator in conventional as well as immediate loading situations.[15–17]

The Osstell and RFA have also been reported in the literature as a useful measuring gauge for implant PS. These devices have been tested in both clinical trials as well as experimental studies.[9,18,19] The results of the RFA have to be evaluated carefully especially in clinical studies due to the boundary height, width, and density factors.[20] The use of RFA may provide an objective approach to measuring initial PS by being able to detect changes in micromotion that could be associated with increase or decrease in degree of osseointegration. For that reason, the RFA has been used extensively in different studies to evaluate the PS.

Table 1 shows a brief literature review of the studies that were performed and tested the macrodesign and its correlation with implant PS. Some aspects that were different in the studies evaluated were the use of different kinds of bone, such as bovine, porcine, freshly slaughtered, or frozen. The condition, under which the experiment was conducted, can possibly contribute to its outcome and therefore some differences in the results of the studies are expected. It has been demonstrated and also becomes more apparent on reviewing literature that tapered implant designs may provide improved PS.

Today there are more than 220 implant brands, which are being manufactured under 80 different companies, as shown by Jokstad and colleagues.[21] There are many clinical trials performed, which have discussed implant characteristics and clinical outcomes.[22–26] Among the many implant types available in United States that are US Food and Drug Administration (FDA) approved, Straumann and Nobel Biocare have a very large usage and acceptability.

For that reason, we have tried in the present study to assess with different methods the PS of Straumann dental implants in order to make more successful different treatment protocols and therapeutic strategies, such as immediate loading in conjunction with simultaneous augmentations or for implants placed in fresh extraction sockets, as well as for implants placed in poor bone qualities. Further studies evaluating the PS of various implant designs placed in different bone qualities with various implant placement protocols are in preparation in our laboratory and provide more information in order to improve the final clinical outcome in implant dentistry. Further studies may also evaluate how the implant design can influence the soft tissue adaptation in order to improve the esthetic result.

CONCLUSION

Within the limitations of this in vitro study using cow ribs as an experimental model, higher implant primary stability was found for the tapered designed Straumann implants.

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