The Influence of Implant Design on Bone Remodeling around Surface-Modified Southern Implants®

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ABSTRACT

Background: Implant survival and success have shown to be related to a number of factors.

Aim: To evaluate the impact of implant design on implant survival and success, focusing on thread pitch and implant shape.

Materials and Methods: Non-smoking patients treated by two experienced periodontists with standard diameter externally-hexed Southern® implant(s) inserted in healed bone were retrospectively selected. A one-stage surgical approach was used in all cases and implants had been installed for at least 6 months. Information pertaining to patient-related variables, time of loading, implant design and radiographical outcome was retrieved from patients' records. Implant success was defined according to the criteria by Albrektsson and Isidor, taking into consideration bone level, defined as the distance from the implant–abutment interface to the first bone-to-implant contact.

Results: In total, 59 patients treated with one hundred eleven externally-hexed Southern Implants® met the inclusion criteria. Fifty-six straight implants with a thread pitch of 0.6 mm and 55 tapered implants with a thread pitch of 1.0 mm were placed. The total implant survival rate was 98.2% after a mean follow-up period of 14 months (range 6–28). The mean bone level was 1.35 mm (SD 0.46, range 0.59–3.70) and the overall implant success rate was 75.7%. Age, gender, length, and time of loading were not decisive for implant neither failure nor bone loss in contradiction to implant design and thread pitch ($p < .01$). Tapered implants with a 1.0 mm thread pitch were less successful than parallel-walled implants with a 0.6 mm thread pitch.

Conclusion: The Southern Implants® system shows good short-term survival rates and bone preservation. However, bone remodeling seems affected by the implant design. Whether this is due to the tapered shape of the implant or the thread pitch is unclear and needs to be elucidated in future research.

KEYWORDS: bone remodeling, dental implant, implant design, Southern Implants, thread pitch

INTRODUCTION

Although various attempts had been made throughout the history of dentistry to replace missing teeth,[1–3] it was not until the 1960s that P.I. Branemark reported the first successful results with dental implants.[4] Today, good long-term results are available for the first generation of predominantly machined-surface dental implants;[5–7] however, these surfaces have been replaced by surface-enhanced implants and no longer commercially promoted. At present, an estimated 1,300 types of dental implants are available with variations in shape, thread

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design, material composition, surface and prosthetic connection.[8,9] Sometimes, implant companies are launching altered implant designs and surfaces, without scientifically sound testing that may result in disappointing treatment outcomes.[10–12] Studies by Eckert and colleagues[13] and Esposito and colleagues,[9] questioning the level of scientific evidence of various implant systems, revealed that only a few implant designs are supported by high level scientific research. The Southern Implants® system (Irene, South Africa) was established in 1987. Since then, scientific studies have been published reporting results comparable with other implant systems.[14–19] Still, the available literature on the various implant shapes of the Southern Implants® system remains scarce.

According to the internationally accepted criteria, successful implant treatment relies not only on implant survival, but requires stable marginal bone levels after the first year of implant placement and loading.[20] This can be affected by patient dependant factors, surgical protocol and implant design. The aim of the present study was to examine retrospectively the clinical outcome of externally hexed Southern Implants®, and to analyze the influence of surgical protocol and different implant design parameters on peri-implant bone remodeling and, more specifically, on implant success.

MATERIALS AND METHODS

Selection

In order to limit the number of variables, a careful case selection was done. Inclusion criteria were: patients treated with standard diameter externally hexed Southern implant(s)®, non-smokers, one-stage surgery, delayed placement, and at least 6 months of follow-up. All patients were treated during a 2 year period in two private clinics in Belgium, by two experienced periodontists (ET and JT).

Data collection was based on anonymized patient's files, as approved by the ethical committee of the University Hospital in Ghent (Ref. 2007/194) and according to the guidelines described by the Helsinki statement. The following parameters were extracted from the files: date of birth, gender, implant position, implant type, length and diameter, time of loading, and implant survival. For each implant, the last available radiograph was digitized to evaluate the bone level and determine implant success. Radiographs were made using a radiographic film holder to have the X-ray beam perpendicular to the film in order to visualize the implant threads and bone-to-implant contact level.

Implant

The implants scrutinized in this study were a 4 mm tapered implant (IBT) and a 3.75 mm straight implant (IBI) (Southern Implants®) (Figure 1). Both types have the same enhanced abraded surface of grade 4 rutile titanium obtained through sand-blasting, described as moderately rough ($S_a = 1.43\ \mu$), an external hexagon and a turned collar of 0.8 mm. While the IBT implant has a tapered form and a thread pitch of 1.0 mm, the IBI implant is straight and has a thread pitch of 0.6 mm.

Outcome Variables

Survival Rate. Implant survival was only related to the presence of the implant irrespective of bone levels. Implants lost or removed because of non-osseointegration or infection were registered as failures.

Peri-Implant Bone Level. The peri-implant bone level was defined as the distance from the implant-abutment interface to the first bone-to-implant contact. Periapical radiographs were measured using DBSWIN software (Dürr Dental AG, Bietigheim-Bissingen, Germany) with an accuracy of 0.1 mm and using the known thread pitch as a reference for calibration. Analyses were done by one independent examiner (SV), who had not been involved in the patient's treatment. The time in function for purposes of bone level calculation was the time between surgery and the date of the last available radiograph. In order to determine intra-examiner repeatability and inter-examiner reproducibility, 20 radiographs were analyzed twice by one blinded clinician who analyzed all the radiographs of the study (SV) and once by another clinician (JC).

Implant Success. Implants up to 1 year in function were called a success when the bone level during the first year was located ≤1.5 mm below the reference point; implants longer than 1 year in function were successful when the bone level was $\leq 1.5 + [0.2 \times (\text{time in months} - 12)/12]$ mm. This formula was based on accepted criteria stipulating maximal 1.5 mm bone loss during the first year and 0.2 mm yearly thereafter.[20]

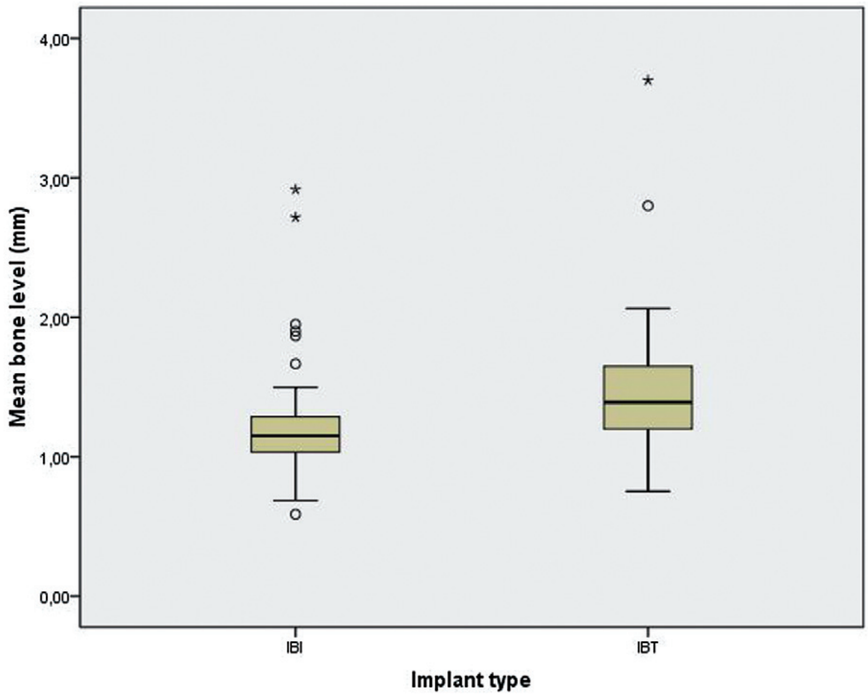

Figure 1 Overview of the two externally-hexed Southern Implants® evaluated in the study, with their respective thread pitch (mm).

Statistical Analysis

Data analysis was performed using the implant as the experimental unit. Mesial and distal bone levels were averaged to obtain a single bone level per implant. Intra-examiner repeatability and inter-examiner reproducibility on bone level were assessed using percent agreement within 0.2 mm deviation, Pearson correlation coefficients, and the Wilcoxon signed ranks test. The possible impact of age on implant failure was evaluated using the Mann-Whitney test. The influence of gender, implant type, implant length, time of loading, and jaw on implant failure was evaluated using Fisher's exact test.

The association of age with bone level was evaluated using the Pearson correlation coefficient. The Mann-Whitney test was engaged to evaluate the impact of age on implant success.

The influence of gender, implant type, implant length, time of loading, and jaw on bone level was also evaluated using the Mann-Whitney test. Fisher's exact test was used to evaluate the impact of these variables on implant success.

The level of significance was set at 0.05.

RESULTS

The intra-examiner repeatability on bone levels was high (90% agreement within 0.2 mm deviation; Pearson correlation coefficient: 0.988 $p < .001$; Wilcoxon signed ranks test: $p = .834$), as was the inter-examiner reproducibility (85% agreement within 0.2 mm deviation; Pearson correlation coefficient: 0.985 $p < .001$; Wilcoxon signed ranks test: $p = .322$).

In total, one hundred eleven implants were placed in 59 patients (21 male, 38 female) with a mean age of 56 years (SD 13, range 18–75). The frequency of implant length and type can be seen in Table 1. The mean follow-up period was 14 months (SD 5, range 6–28). Two patients experienced one early failure each, resulting in a survival rate of 98.2%. For the remaining one hundred nine implants, the mean overall bone level was 1.35 mm (SD 0.46, range 0.59–3.70). The overall implant success rate was 75.7%.

No significant association was found between implant failure and age ($p = .834$), gender ($p = 1.000$), implant type ($p = 1.000$), implant length ($p = .928$), jaw ($p = .482$), and time of loading ($p = 1.000$) (Table 2).

A significant difference in bone level was observed between both types of implant, with the tapered implant losing more bone ($p < .001$) (Figure 2). Age ($p = .665$), gender ($p = .180$), implant length ($p = .092$), jaw ($p = .179$), and time of loading ($p = .471$) did not affect bone remodeling (Table 2).

The straight implant demonstrated a significantly higher success rate compared to the tapered implant

TABLE 1 Overview of all implants according to their respective diameter and length. Lost implants are given between brackets

		Implant Length						
		8,50	10,00	11,50	13,00	15,00	18,00	Total
Implant type	IBI (ø 3.75)	4	6	14	12 (1)	18	2	56 (1)
	IBT (ø 4.0)	0	1	12	14	28 (1)	0	55 (1)
Total		4	7	26	26 (1)	46 (1)	2	111 (2)

($p = .004$). Success rate was not affected by age ($p = .995$), gender ($p = .112$), implant length ($p = .309$), jaw ($p = .810$), and time of loading ($p = .757$). (Table 2)

DISCUSSION

Although the Southern Implant® system lacks long-term survival studies, several clinical studies are available showing implant survival up to 100%.[14–16,18,19] With a 98.2% survival rate, the present study confirms this good clinical outcome albeit limited to a 14-month follow-up period. Additionally, the present study reflects the everyday clinical situation and reports a good clinical outcome that is comparable to other studies using different implant systems and protocols, reporting survival rates of 95.2 to 100% up to 3 to 5 years.[21–32]

Apart from survival, maintaining peri-implant bone level is indicative of long-term stability and peri-implant health. In the present report, a mean bone level value of 1.35 mm after an average function time of more than 1 year is within the limits of the internationally accepted success criteria.[20] Success rate in this study was calculated on an individual implant basis and not on a patient basis. As suggested by De Bruyn and Collaert,[33] the calculation based on the latter can hide critical clinical information when multiple implants are present. Indeed, one implant with more pronounced bone loss can be masked when the other implants have a normal bone adaptation. Calculating success per implant is a more appropriate way to evaluate biologically related problems such as bone loss, but may result in lower implant success rates. The level for success was arbitrarily chosen as 1.5 mm, because currently, there are no success criteria dealing with early bone remodeling between fixture insertion and connection of the prosthesis as described by Åstrand and co-workers.[22]

The same methodology was recently used to compare turned titanium implants (Brånemark System, Nobel Biocare, Zurich, Switzerland) with moderately rough TiOblast implants (Astra Tech Dental, Mölndal, Sweden).[34] The success was 57.1% and 78.4%, respectively, after 1 year. In the present report using moderately rough Southern Implants®, the overall implant success was 75.7% after 14 months.

Although some studies report different bone loss patterns between the upper and lower jaw, this was not the case in the present study.[35,36]

The same conclusion also pertained for immediate loading. Although some studies showed that immediate loading may increase the risk for implant failure,[37,38] recent studies with immediately loaded Southern Implants® describe good survival and success rates.[14,15] The fact that no difference was seen between the immediately and delayed loaded implants regarding bone level, implant survival, and success corresponds with findings from other studies comparing the treatment outcome of both protocols.[39–44]

Although the implants used in this study were very similar, they had two major differences. The first difference lies in the thread pitch. Few studies have examined the effect of the implant thread pitch on the surrounding bone. The implant threads play a role in enlarging the contact surface, improving initial stability and in distributing the stress on the surrounding bone.[45–49] A wider thread pitch leads to a decrease in the number of threads and, consequently, in a decrease of the contact surface. In addition, a decrease of the pitch from 1.0 mm to 0.9 mm leads to a decrease of 15.4% in stress concentration.[45] A further decrease to 0.7 mm only lowers stress concentration with 5%. Therefore, it seems that a thread pitch of 0.9 mm or smaller is indicated for dental implants.[45,50] In their study, Hansson and co-workers[51] mentioned that the use of a straight part between two threads is a disadvantage in most of the cases and should be avoided. In a dog model study, Orsini and colleagues[52] reported a higher primary stability for the

TABLE 2 Overview of All Variables with Corresponding Data on Implant Survival, Bone Levels, and Implant Success

		N	Follow-Up (months)	*p* Value	Survival %	*p* Value	Bone Level (mm)	*p* Value	Success %	*p* Value
Type	IBI	56	14.99 (Range 6–28)	0.210	98.2	1.000	1.23 (SD 0.42; Range 0.59–2.92)	<0.001	87.5	0.004
	IBT	55	13.29 (Range 10–24)		98.2		1.47 (SD 0.48; Range 0.75–3.70)		63.6	
Gender	Male	39	13.81 (Range 7–21)	0.926	97.4	1.000	1.49 (SD 0.64; Range 0.59–3.70)	0.180	66.7	0.112
	Female	72	14.33 (Range 6–28)		98.6		1.27 (SD 0.30; Range 0,69–2.06)		80.6	
Time of loading	Immediate	96	13.22 (Range 11–18)	0.452	100	1.000	1.35 (SD 0.36; Range 0.69–1.88)	0.471	73.3	0.757
	Delayed	15	14.30 (Range 6–28)		97.9		1.35 (SD 0.48; Range 0.59–3.70)		76.0	
Jaw	Maxilla	31	14.72 (Range 6–25)	0.352	96.8	0.482	1.25 (SD 0.40; Range 0.59–2.06)	0.179	74.2	0.810
	Mandible	80	13.93 (Range 6–28)		98.8		1.39 (SD 0.48; Range 0.80–3.70)		76.3	

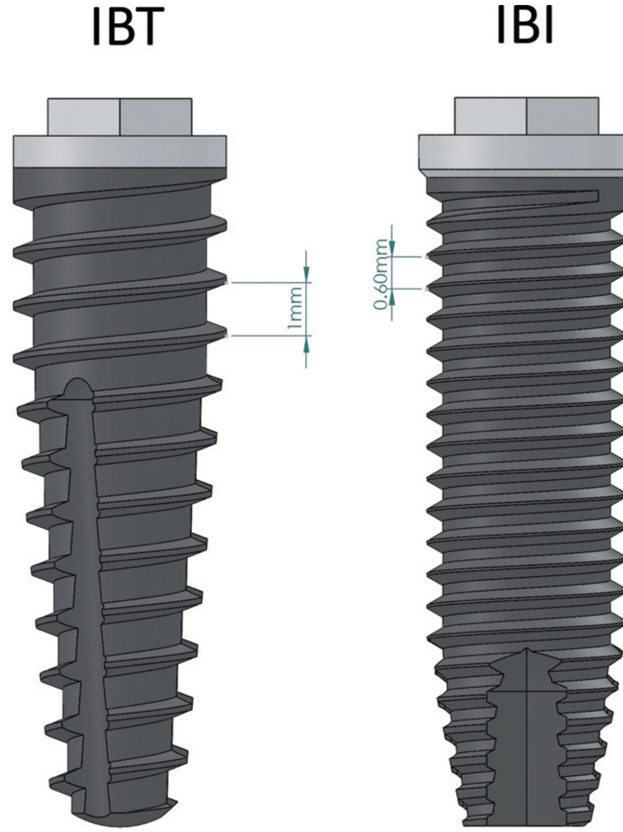

Figure 2 Bone level according to implant thread pitch.

narrow (0.5 mm) pitch implant compared to the wide pitch implants (1.5 mm). Shorter pitch distances also had a better stress distribution when using orthodontic mini screws.[53] These literature findings may offer an explanation for the findings in the current study, whereby the implant with the 1.0 mm thread pitch showed more bone loss and a lower success rate compared with the 0.6 mm pitch implants.

The second difference is the form of the implants. The higher insertion and removal torque forces reported with tapered implants[54–56] have the advantage of achieving primary stability more easily,[57,58] but also increase the stress in the surrounding bone, which is highest in the cortical area around the implant neck and induces more bone loss.[59–61] Although the tapered implants in the present report did not show increased risk for failure,[62] more bone loss was indeed observed. The fact that all tapered implants examined in the current study also had a 1.0 mm thread pitch might confound the true reason for the changes in bone level and implant success. Although the literature is not suggesting more bone loss for tapered implants, the current study cannot fully elucidate whether the implant thread pitch or the implant shape is the predominant factor associated with the increased bone loss. Since there are no such findings on tapered versus straight implants, it is tempting to suggest that the thread pitch is the most likely causative factor. A recent review concluded that a smaller thread pitch was favorable, although this was mainly based on finite element analyses.[63] This would also be in line with recent findings showing more bone preservation around implants with a microthread at the collar level.[64,65] Clearly, a controlled comparative clinical study would be ideal to elucidate this issue.

No impact of implant diameter or length on peri-implant bone level could be observed in this study, which confirms the conclusions of two reviews[66,67] that neither the implant length nor the diameter are responsible for inferior results, but rather the indications they were used for. Wide and short implants are often used in the posterior area, where poor bone quality and limited bone height, combined with higher occlusal forces, may influence the outcome. However, the use of a moderately rough surface increases the bone anchorage and may compensate for an unfavorable implant dimension or bone quality.[68–71]

CONCLUSION

The present comparative study shows that age, gender, implant length, and time of loading were not decisive in bone loss. The implant design, especially pitch thread, influence the treatment outcome related to bone preservation. A small thread pitch is recommended to enlarge the total contact surface with the bone in order to allow a positive stress distribution and limit the amount of bone loss.

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