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Evaluation of marginal bone loss in short implants with different smooth neck length: a retrospective clinical study

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ABSTRACT

Aim The aim of the study was to compare peri-implant bone resorption in two implant systems and to evaluate if there is a correlation between the distance bone-implant-abutment junction (IAJ) and bone loss over time.

Materials and methods A multi-centre retrospective study was carried out to compare 2 implant systems in which the implant body had the same micro- and macro-morphology but with different neck morphologies. The short (Kt) and ultra-short (Kx) implants were 8.3 and 6 mm in length, respectively, with a smooth neck of 1.3 and 0.7 mm, respectively. We investigated the relationship between insertion depth and bone loss. Bone margin level was evaluated at the time of insertion and at follow-up and mean bone loss (MBL) were calculated. Survival and success rates were also evaluated.

Results A total of 52 implants in 40 patients were analysed, with a mean follow-up of about 4 years. Overall survival rate was 100% and success rate was 98.1%. MBL (±SD) was 0.39 mm (±0.40) with Kx implants and 0.43 mm (±0.85) with Kt implants; there was no statistically significant difference in bone resorption between the two implant types. Implant insertion depth was correlated with the MBL at follow-up.

Conclusion Despite the difference in neck morphology, the two implant systems showed comparable results at the 4-year follow-up. The positioning depth of the smooth neck portion of the implant appears to affect medium-term bone resorption.

KEYWORDS Dental implants; Smooth neck; Bone level; Short implants; Ultra-short implants.

INTRODUCTION

Endosseous dental implants are safe and widely used for the restoration of edentulous spaces, with a high long-term success rate (1). Tooth loss leads to progressive osseous resorption, which can reduce the height and width of the residual bone ridge such that it is no longer adequate for the positioning of standard dental implants (≥10 mm).

Grafting and regenerative procedures such as guided bone regeneration, sinus elevation, block grafting, and osteogenic distraction are not exempt from technical difficulties, complications, and high costs of treatment compared to direct implantation techniques (2). Studies comparing the clinical results achieved with bone augmentation/regeneration followed by positioning of standard implants vs direct implantation of short implants into native bone have reported comparable survival rates (3,4). Thus, short implants are a viable option for the rehabilitation of edentulous arches for which standard-length implants cannot be used (5,6).

The definition of a short implant has changed over time, especially with the introduction of ultra-short implants. According to Monje et al., short and ultra-short implants refer to those with a length ≤9 and ≤6 mm, respectively (7). When short and ultra-short implants are placed in atrophic areas, crown space increases in relation to that of implant, but an augmented crown-to-implant ratio seems not to negatively affect peri-implant bone levels over time (8), as long as certain limits are not overcome (9).

The relationship between implant insertion depth and subsequent bone resorption has been previously investigated, with conflicting findings (10–12). Since Brånemark's recommendation (13) of surgically placing the implant countersink below the bone crest in order to prevent implant exposure during physiological bone remodelling, many long-term clinical studies have demonstrated highly predictable outcomes for bone-level implants (14,15). The main advantage of this

technique is that after unavoidable bone loss during the first year of function, the peri-implant bone level remains above the junction of the smooth neck and rough implant body, protecting the latter from bacterial colonization. On the other hand, a longer smooth neck creates vertical distance between the bone level and implant-abutment junction (IAJ), thereby reducing the potentially detrimental effects of bacterial colonization and micro-movements that could occur at the implant-abutment microgap (16,17).

The aim of the present retrospective study was to compare peri-implant bone resorption in two implant systems with the same intraosseous structure but different lengths and smooth collar designs, and in terms of apico-coronal implant insertion depth, with particular attention to the position of the smooth collar component.

MATERIALS AND METHODS

Patient data

This multi-centre retrospective observational study was conducted during routine clinical procedures without any further consequences for the patient, and in accordance with the 1964 Declaration of Helsinki on medical protocols and ethics. As such, and considering the retrospective nature of the study, no approval by the local ethics committee was necessary.

Patients were informed of the nature and aim of the study and signed an informed consent form allowing anonymous processing of their personal data for research purposes. Patient selection was carried out based on predetermined inclusion and exclusion criteria; in the follow-up, subjects were grouped according to their implant system. Patients enrolled in the study were treated with a short or ultra-short implant between 2011 and 2014. Inclusion criteria were as follows: patients with edentulous areas located posteriorly to the remaining natural teeth or between anterior and posterior teeth; a treatment plan that included the positioning of at least one short or ultra-short implant in molar or premolar regions; and patients who participated in the follow-up. Exclusion criteria (checked in medical records) were as follows: subjects with inadequate oral hygiene, smoking (>20 cigarettes per day), alcohol or drug abuse, oral acute infection, previous or ongoing head-and-neck radiotherapy, recent chemotherapy, osseous metabolic bone diseases, oncological diseases with oral involvement, or altered osseous metabolism.

Implant systems

Implants analysed in this study were from the WINSIX "K" line (K implants, WINSIX®; BioSafin, Ancona, Italy). These are tapered implants with a truncated cone body design, self-tapping threads of variable width and depth, and variable apico-coronal geometry. Their surface is sandblasted and acid-etched to achieve microroughness with Ra=1.4 µm (micro-rough surface (MRS®), WINSIX®; BioSafin). The WINSIX "Kx" and "Kt" (Fig. 1) implant systems were included in our analysis. The former is 6 mm long, with 5.3 mm of MRS surface and 0.7 mm of machined smooth collar, a horizontal thread, and two grooves in the coronal

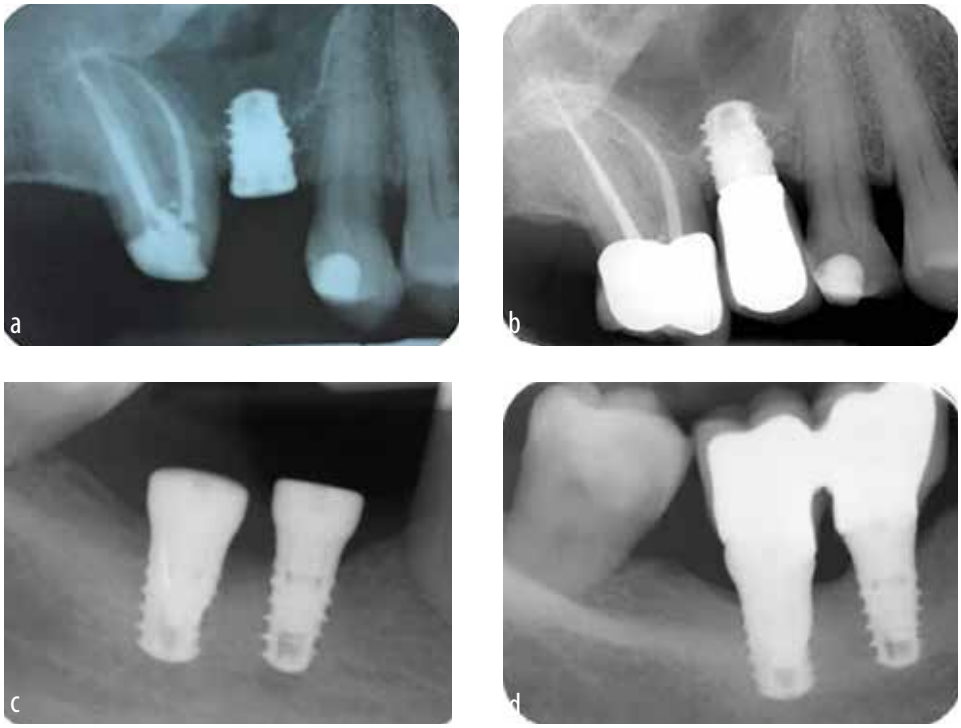

FIG. 1 Radiographic example of Kx and Kt implants: rx of Kx at baseline (a); rx of Kx at 61 months of follow-up (b); rx of Kt at baseline (c); rx of Kt at 57 months of follow-up (d).

part of the MRS apical to the junction with the smooth surface. The implant diameters are 4.5 and 5.2 mm. Kt implants are 8.3 mm long, with 7 mm of MRS surface and 1.3 mm of machined smooth collar; the implant diameters are 3.3, 3.8, and 4.5 mm, but the smooth collar increases the length in the coronal direction, such that the diameters at the implant head are 3.8, 4.5, and 5.2 mm, respectively. According to the Monje classification (2013), the Kx and Kt implant systems are included in the ultra-short and short implant categories, respectively. The clinical indications for the usage of Kx and Kt implant systems are similar, because both of them are usually placed in atrophic jaws in which standard length implants cannot be used without grafting or regenerative procedures.

Surgical protocol

Implant surgery was carried out by two skilled surgeons experienced in implantology at two dental clinics using the same operative protocol. Prophylactic antibiotics were orally administered as a single dose of amoxicillin and clavulanic acid (2 g) 1 h before the procedure, followed by post-surgery therapy (1 g twice daily for 6 days). Patients allergic to penicillin were administered azithromycin for both prophylaxis and post-operative therapy (600 mg once daily for 3 days); anti-inflammatory therapy with NSAIDs (non-steroidal anti-inflammatory drugs) was initiated 1 h before the surgery and then administered as needed to reduce patient pain and discomfort in the following days.

Loco-regional anaesthesia was followed by surgical incision and mucoperiosteal full thickness flap elevation, and the implant site was prepared using the drilling sequence indicated by the implant manufacturer under abundant irrigation with physiologic solution.

Site preparation was carried out based on bone density, with under-preparation of the diameter at low-density sites and preparation to the exact implant diameter at high-density sites. After implant insertion and positioning, the cover screw was tightened and flaps were sutured. Patients were given accurate instructions about immediate post-operative liquid diet and oral hygiene procedures, which included a 0.2% chlorhexidine-based mouthwash to be used twice daily for 10 days. After this early healing phase, patients were instructed to avoid trauma to/loading of implant sites to avoid compromising osseointegration.

Prosthetic protocol

Single crowns and fixed partial dentures (FPD) exclusively supported by implants were used for the prosthetic rehabilitation of the implants. In both cases, the prosthetic protocol allowed for a loading-free healing period of 3 and 4 months from the time of implant insertion into the mandible and maxilla, respectively, to ensure adequate osseointegration of the fixture.

Radiographic follow-up protocol and data collection

Intraoral digital radiographs were obtained immediately after implant placement; 3 months and 1 year later; and then annually for the first 3 years and every 2 years starting from the 4th year. Only radiographs with high sharpness and perpendicular to the X-ray tube were used for analysis. Patients with <1 year of follow-up were excluded at this stage in order not to confuse the results of early physiological marginal remodelling with those caused by mid-term peri-implant bone loss.

Peri-implant bone levels on the mesial and distal sides of the implant were measured with ImageJ software (U.S. National Institutes of Health, Bethesda, MD, USA), using the implant shoulder as a reference when measuring the vertical distance from the most coronal bone-to-implant contact point. To obtain standardized measurements, implant diameter (which was known for certain) was used as a reference scale. Mesial and distal marginal bone levels were measured on postoperative and follow-up radiographs; these values were used to calculate mean bone levels at insertion (baseline) and at the last follow-up, respectively. Two subgroups were established according to the apico-coronal position of the smooth collar portion of the implant. In the apical subgroup, the implant collar was located partly apical to the crestal bone level on the postoperative radiographs; the mean bone level at insertion was ≤0.7 mm for Kx and ≤1.3 mm for Kt implants. In the crestal subgroup, the implant collar was located entirely coronal to the crestal bone level on the postoperative radiograph; the mean bone level at insertion was >0.7 mm for Kx and >1.3 mm for Kt implants.

Implant survival and success

Implant success criteria proposed by Buser et al. (1994) (18) and subsequently modified by Albrektsson and Zarb (1998) (19) were adopted in this study: the success rate was defined as the percentage of implants that met these criteria at the follow-up, while survival rate was defined as the percentage of implants still functioning at the follow-up.

Statistical analysis

Patients' characteristics were summarized either as counts and percentages for categorical variables or as mean±SD for continuous variables, with cross tabulation against implant type (Kx and Kt). Mean bone loss (MBL) has been computed as the within patient difference between the mean of the mesial and distal bone levels at last follow-up visit and the mean of the mesial and distal bone levels at insertion (baseline). MBL rate was calculated as the ratio of MBL at the last follow-up to the length of follow-up. Mesial and distal bone levels and MBL were compared between the two implant types in a pre-implant analysis with the paired t test for normal data and two-sample Wilcoxon test (with t approximation) for non-normal data.

A multivariate mixed-effects model with implant type as a fixed effect, patient ID and age as random effects, and mean bone level at baseline as a continuous covariate was generated. However, given the resultant negative estimates of the variance components for the random effects, age could not be included in the mixed model even if implants were significantly different in the univariate analysis; therefore, a fixed effects-only model was also generated. The normality assumption was verified with the Shapiro–Wilk test. Categorical variables were compared with Fisher's exact test. A subgroup analysis was performed for patients whose implants were located partly apical (apical group) or entirely coronal (crestal group) to the crestal bone. The correlation between bone loss and mean bone level at baseline was evaluated with Pearson's correlation coefficient (r2). All tests were two-tailed and differences were considered significant at the 5% level. All analyses were performed using SAS v9.4 (SAS Institute, Cary, NC, USA).

RESULTS

A total of 40 patients with 52 positioned implants (26 Kx and 26 Kt types) were included in the analysis. Patient characteristics are summarized in Table 1. Among Kt implants, 18 were inserted in the mandible and 8 in the maxilla; and among Kx implants, 8 were positioned in the mandible and 18 in the maxilla, for 26 implants for both the posterior regions of the upper and the lower arches. Three Kx and 6 Kt implants supported single crowns, while 23 and 20, respectively, supported FPDs. The frequency distributions of implant site and prosthesis type were not significantly associated with the implant type (Fisher's exact test: p=0.09 and p=0.47 respectively). The distribution of diameters was as follows: 3.3 mm, n=2 (Kt); 3.8 mm, n=14 (Kt); 4.5 mm, n=20 (10 Kt and 10 Kx); and 5.2 mm, n=16 (Kx). The 4-year survival rate was 100%. Excessive bone loss (3.35 mm at 59 months) occurred with one Kt implant; therefore, the success rate was 98.1% overall (100% for Kx and 96.1% for Kt implants). Mesial and distal bone levels and mean bone level differed significantly between Kx and Kt implants at baseline; however, there were no significant differences at the last follow-up. MBL (±SD) at the last follow-up was 0.43 (±0.85) mm for Kt and 0.39 (±0.40) mm for Kx implants (p=0.87) (Table 2, Fig. 2). The average bone loss rate was 0.12 mm/year. A subgroup analysis comparing the apical vs crestal groups (Table 3) showed a significant difference at the last follow-up, with a MBL (±SD) of 0.54 (±0.62) mm for the apical group and 0.03 (±0.64) mm for the crestal group (p=0.04) (Fig. 3). The correlation between mean bone level at baseline and MBL at the last follow-up was r2=0.20 (p=0.02) for Kt and r2=0.08 (p=0.17) for Kx implants (Fig. 4). The multivariate fixed-effects model showed no significant difference in MBL by implant type (p=0.26); the effect of age was non-significant (p=0.11) whereas mean bone level at baseline had a significant effect (p=0.002). Subgroup univariate analysis showed that Kt vs Kx implants were not significantly different also for the 'apical' and 'crestal' groups separately.

DISCUSSION

A total of 52 implants in 40 patients were included in our analysis. No implant was lost or removed during 4 years of follow-up, so the survival rate was 100%. However, the success rate according to Albrektsson and Zarb criteria (1998) (19) was 98.1% because one Kt implant inserted in the lower molar region of a female patient

	Implant type			
Characteristic	All patients N=40	Kt N=24	Kx N=16	*p* value[b]
Sex				
Female	25 (62.5)	12 (50.0)	13 (81.3)	
Male	15 (37.5)	12 (50.0)	3 (18.7)	0.06
No. of implants/patient				
1	31 (77.5)	22 (91.7)	9 (56.3)	
2	6 (15.0)	2 (8.3)	4 (25.0)	
3	3 (7.5)	0	3 (18.7)	0.02
Age, years	57.7 (10.4)	54.5 (10.9)	62.5 (7.5)	0.02
Follow-up, months	47.9 (21.4)	46.6 (26.2)	49.9 (11.3)	0.58

[a] *Data are presented as N (%) for categorical variables and mean (SD) for continuous variables.*
[b] *p values in bold type are statistically significant at p<0.05.*

TABLE 1 Summary statistics of patient characteristics.

			Implant type		
Site of implant	Time	All implants N=52	Kt N=26	Kx N=26	*p* value[e]
Mesial	Baseline	0.48 (0.61)	0.25 (0.41)	0.72 (0.69)	0.01
	Last follow-up	0.85 (0.76)	1.13 (0.88)	0.58 (0.50)	0.02
	Difference	0.37 (0.75)	0.41 (0.97)	0.33 (0.43)	0.98
	Loss rate	0.11 (0.23)	0.13 (0.30)	0.09 (0.13)	0.60
Distal	Baseline	0.71 (0.80)	1.10 (0.85)	0.32 (0.52)	<0.001
	Last follow-up	1.16 (0.87)	1.55 (0.90)	0.77 (0.64)	0.002
	Difference	0.45 (0.80)	0.45 (1.03)	0.45 (0.51)	0.69
	Loss rate	0.14 (0.28)	0.16 (0.38)	0.12 (0.15)	0.93
Mean bone level[b]	Baseline	0.60 (0.59)	0.91 (0.58)	0.28 (0.40)	<0.001
	Last follow-up	1.01 (0.73)	1.34 (0.78)	0.67 (0.48)	0.002
	Difference[c]	0.41 (0.66)	0.43 (0.85)	0.39 (0.40)	0.87
	Loss rate[d]	0.12 (0.22)	0.15 (0.29)	0.10 (0.12)	0.43

[a] *Data are presented as mean (SD).*
[b] *Mean values for medial and distal bone levels.*
[c] *Mean bone loss.*
[d] *Mean bone loss rate, mm/year.*
[e] *p values in bold face are statistically significant at p<0.05.*

TABLE 2 Univariate analysis of mesial and distal bone levels and mean bone level over time and according to site of implantation.

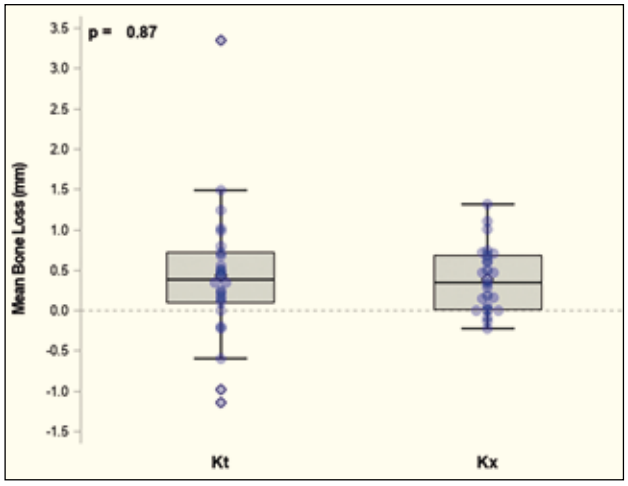

FIG. 2 Mean bone loss at the last follow-up by implant type.

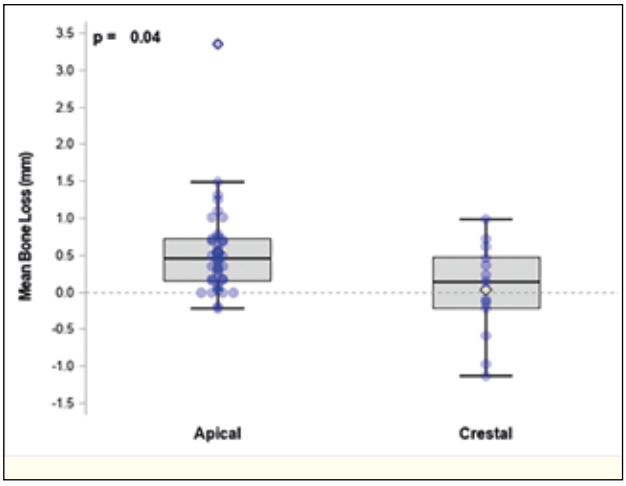

FIG. 3 Subgroup analysis of mean bone loss at the last follow-up.

		Time		
Subgroup	Implant type	Baseline	Last follow-up	Difference
Apical	Kt, N=19	0.65 (0.43)	1.27 (0.81)	0.62 (0.80)
	Kx, N=20	0.09 (0.16)	0.54 (0.41)	0.45 (0.40)
	p value b	<0.001	0.003	0.70
Crestal	Kt, N=7	1.62 (0.24)	1.53 (0.74)	−0.09 (0.83)
	Kx, N=6	0.94 (0.18)	1.11 (0.49)	0.17 (0.36)
	p value [b]	0.01	0.26	0.73

[a] *Data are presented as mean (SD).*
[b] *p values in bold face are statistically significant at p<0.05*

TABLE 3 Subgroup analysis of mean bone loss (mm) by implant type.

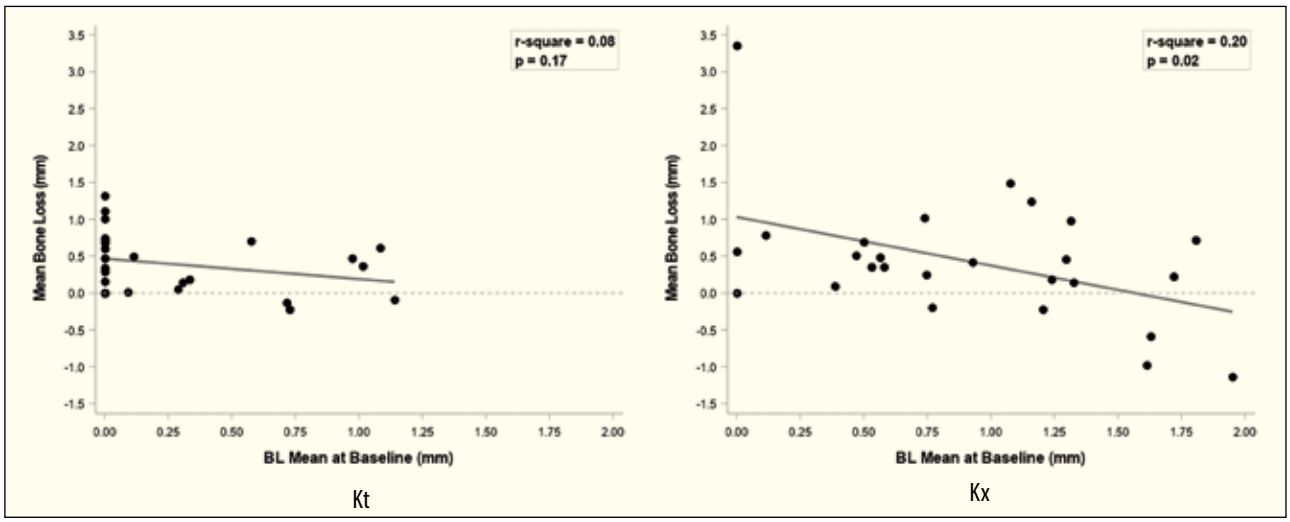

FIG. 4 Correlation between mean bone loss at baseline and at the last follow-up for Kt and Kx implants; BL=bone level.

had lost 3.35 mm of marginal bone after 59 months of follow-up. Nonetheless, this implant is still functioning and therefore contributed to the survival rate. All other implants had <1.5 mm of bone loss. The survival and success rates of short and ultra-short implants in our study are comparable to those reported in earlier studies with short- and medium/long-term follow-ups (20–22). Peri-implant MBL in our study (0.41±0.66 mm) was also consistent with previous work (20,23–25). There was no difference in MBL after 4 years between Kt (0.43±0.85 mm) and Kx (0.39±0.40 mm) implants (p=0.87). Thus, the two implant systems showed the same 4-year performance in terms of bone loss and survival/success rates.

A retrospective study showed a positive association between MBL and implant insertion depth: implants that were more deeply inserted registered more bone loss than those positioned superficially (26). In a histological study in dogs, peri-implant bone loss after a 6-month submerged healing period was found to depend on both the distance between implant shoulder and bone level and the presence/absence of a machined neck (27). In the present study, there was less bone resorption for implants with a larger extraosseous portion at insertion: there was a moderate inverse correlation between MBL and implant insertion depth for Kt implants (r2=0.20, p=0.02) but not for Kx implants (r2=0.08, p=0.17). These results can be explained by the larger smooth portion in the former implant, which created a longer distance between the implant-abutment junction and marginal bone, as evidenced by the decrease in bone resorption with increasing bone–IAJ distance. In contrast, Kx implants with a smooth neck of just 0.7 mm did not show the same inverse linear relationship and maintained a stable bone level over time. Moreover, while Kt implants had variable insertion depth due to their positioning under intra-operative bone conditions, a large number of Kx implants were placed in a juxta-osseous position; thus, the ability to detect a statistically significant linear relationship was significantly reduced by the sample's features. The observed inverse linear relationship of Kt implants is supported by a retrospective analysis demonstrating that implants placed more apically showed greater bone resorption (11).

Mean bone level at follow-up was similar to the height of the smooth collar for both implant systems: 1.34 vs 1.3 mm for Kt and 0.67 vs 0.7 mm for Kx. These results suggest that bone remodelling led to the placement of the bony crest at the transition between smooth and rough surfaces in both systems, despite differences in the distance between the bony crest and implant shoulder at the time of insertion (p<0.001 for mean bone level at baseline with Kx vs Kt). This issue has been previously addressed in a study using 8.7 mm-long implants with a sintered porous surface and 2-mm smooth collar; the results showed that at 3 years from loading, the bone level was at the junction between the rough and smooth surfaces of the implants and remained stable after 10 years of follow-up (28). Additional support for our results comes from a 10-year prospective study of 40 implants with a 6-mm rough surface body and 2.8-mm transmucosal smooth collar; the mean bone level of 2.8 mm was identical to the length of the implants' smooth component (29).

Inserting the smooth portion of the implant apically to the bone level can lead to peri-implant bone resorption until smooth–rough surface junction, allowing the formation of an adequate biological width around the implant (30). To evaluate this possibility, we compared bone loss in two subgroups, namely, implants with a smaller vs larger mean bone level at baseline than the length of the smooth component (0.7 mm for Kx and 1.3 mm for Kt). MBL was greater for the first subgroup than for the second one (0.54 vs 0.03 mm, p=0,04),

confirming the inverse correlation between MBL and insertion depth. Thus, implants with fully extraosseous smooth portion appear to maintain a stable bone level over time regardless of the length of the smooth neck.
A clinical trial found that implants with a machine-roughened surface junction placed 1 mm deeper showed more bone resorption than other implants at the 1-year follow-up; this difference was due to the more apical placement of the transition between the two surfaces (31), as observed in our study. This was further supported by a split-mouth comparison study in which supracrestal placement of implants with a machined neck resulted in only minor bone loss 1 year after insertion (32).
The initial placement of the rough portion of the implant at the bone crestal level—or slightly extraosseous in some parts—did not increase the risk of developing peri-implantitis in the mid-term, despite the fact that rough surfaces are more likely to promote bacterial colonization (33,34). On the other hand, deeper placement of the machine-roughened implant junction does not confer any advantage and is therefore not recommended from a biological standpoint (31), in line with our conclusions.
Despite some limitations including the lack of analyses of potential confounders such as smoking and diabetes, it is interesting to note that the two implant groups in our study showed almost the same behaviour after 4 years of function: the apico-coronal placement level rather than implant type appeared to be the main factor affecting bone stability, as demonstrated by the multivariate fixed-effects model, which revealed a significant difference in mean bone level at baseline ($p=0.002$). Long-term follow-up is needed to evaluate the stability of bone level over time; additionally, data from a prospective study with a larger sample can strengthen our findings.

CONCLUSIONS

The two implant systems analysed in this work (Kt and Kx) showed no difference in MBL over the medium term and are therefore attractive treatment options for restoring edentulous spaces. Analysis of bone resorption relative to apico-coronal implant positioning revealed that implant insertion depth (especially sub-crestal placement of the implant's smooth collar) influences bone loss over time. Moreover, for the implant with a longer smooth collar (Kt), there was an inverse relationship between MBL and implant insertion depth, indicating that distancing the bone from the IAJ can reduce bone loss.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
Informed consent: Informed consent was obtained from all individual participants included in the study.

Declaration of competing interest

None.

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