Change in crown-to-implant ratio of implants placed in the atrophic posterior maxilla with or without sinus grafting: A 5-year prospective randomized study

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ABSTRACT

Purpose: The aim of the study was to evaluate the 5-year performance of implants placed in extremely atrophic posterior maxilla with versus without grafting material in relation to crown-to-implant ratio (C/I). C/I measurements took in account changes in both crestal and endo-sinus bone levels over 5 years.

Materials and Methods: Patients requiring 1 to 2 implants in at least one sinus with a maxillary residual bone height ≤4 mm were enrolled. Before surgery, individual sinuses were randomly allocated to be grafted or not (control and test groups, respectively). Eight-mm long implants were placed using osteotome sinus floor elevation (OSFE). After 10 weeks of healing, implants were loaded functionally with definitive single crowns. Radiographs were taken immediately after surgery, during the prosthetic steps, and at 5 years. The value 'I' was the distance between the most apical and coronal bone-to-implant contact and 'C' the distance from the most occlusal point of the crown to the crestal bone. Data were analyzed using mixed linear models.

Results: Twenty control and 17 test implants were placed in 12 patients, 35 were restored. One restored implant failed. The mean I was 2.4 ± 0.8 mm (control) and 2.7 ± 0.9 mm (test) immediately after surgery. The difference in I value was not significant between the two implant groups (p=0.351). At loading, the mean C/I ratio was 3.8 ± 0.8 (control) and 4.6 ± 2.0 (test; p=0.033) whereas, at 5 years, it was 2.0 ± 0.8 (control) and 2.1 ± 0.4 (test; p=0.341).

Conclusion: The use of grafting material is not needed to restore posterior maxilla ≤4 mm with the OSFE technique and simultaneous implant placement. Over five years, all restored implants but one were in function. Despite extremely unfavorable initial bone anchorage and height of single crown restoration, a high initial C/I ratio

did not affect the long-term survival of implants placed with and without grafting material in very atrophic posterior maxilla.

KEY WORDS

dental implants, atrophic posterior maxilla, grafting material, osteotome sinus floor elevation, crown-to-implant ratio, proximal bone-to-implant contact.

INTRODUCTION

The crown-to-root ratio is defined as the length of the crown from the most incisal or occlusal position to the crest of the alveolar bone, divided by the length of the root within the bone.[1] When the alveolar bone height decreases, the harmful lateral forces acting on the coronal part of the tooth augment. Although Ante postulated that "the total periodontal surface of the abutment teeth must equal or exceed that of the teeth to be replaced",[2] the optimum crown-to-root ratio for a tooth used as an abutment for a fixed partial denture is 1:2. It is more frequently approximately 2:3, with the minimal acceptable ratio being 1:1.[3] From these principles, it was extrapolated historically that the crown-to-implant ratio (C/I) should not exceed the crown-to-root ratio.

Implants of 10 mm or less in length were frequently associated with lower predictability than the longer ones, particularly in posterior regions of poor bone quality and low bone height. [4] Consequently, it had been recommended that the bone should be augmented sufficiently to accommodate an implant of at least 10 mm in length. However, the evolution of implant designs and surfaces allows now to overcome the limitations of the implant lengths in the augmented posterior maxillae.[5] Osteotome sinus floor elevation (OSFE) procedure involves a crestal approach to elevate the Schneiderian membrane with or without the addition of grafting material and the simultaneous placement of implants.[6-8] At the time of placement, the implants would then protrude into the sinus especially when grafting material was not inserted.

Given the limited bone support in the posterior maxillary region, a tapered shape and reduced thread pitch can improve the primary stability of the implant and maintain the bone crest at the level of the implant machined-threaded junction.[9]

In the present study, 8-mm long tapered implants were placed using OSFE in extremely atrophic posterior maxillae either with grafting material or without grafting

material.[7] The initial maxillary residual bone height was less than 4 mm at time of surgery. Therefore, at least 4 mm of the implants placed were initially not encased in bone. The study aims insight into changes in C/I ratio with endo-sinus bone gain increase along time. The study assessed the performance of the implants and their prosthetic restoration, in relation to the C/I ratio, from the time of implant loading to 5-years after treatment. It was hypothesized that an unfavorable initial C/I and absence of grafting material didn't compromise long-term implant survival in atrophic posterior maxilla.

MATERIALS AND METHODS

Patient entry

The study was approved by the Ethics Committees of the University Hospitals of Geneva and Lausanne (Switzerland) for human research under respective protocol reference numbers 06-089 and 245/06. Patients were eligible for inclusion in this study if:

- they required 1 to 2 implants per sinus in the posterior maxilla;
- tooth extractions at the implant sites were performed at least 4 months before surgery;
- the residual bone height between the alveolar bone crest and the sinus floor, measured on panoramic radiograph, was ≤ 4 mm;
- the osteotome sinus floor elevation procedure was performed with or without grafting material according to the randomization process;
- tapered and chemically-modified hydrophilic surfaced implants, 8-mm in length, was placed;
- they did not wear a removable partial denture during the healing period.

A medical history of acute or chronic sinusitis, an active periodontal disease, diabetes and metabolic bone disease were considered as exclusion criteria.[7]

If one sinus met the enrollment requirements, it was randomized by allocation of a sealed independently prepared envelope containing the procedure characteristics. If both sinuses met the enrollment requirements, the right side was treated according to the procedure attributed by randomization, whereas the left side was treated with the other procedure.

Implant placement and prosthetic rehabilitation

All treatment procedures have been described previously.[7] In brief, surgeries were performed under antibiotic prophylaxis. Full muco-periosteal flaps were elevated following mid-crestal incision without vertical nor periosteal releasing incisions. To obtain access to the sinus floor, the cortical bone was marked using round burs of increasing diameter (diameter 1.4–3.1 mm) and a sinus floor elevation osteotome of 2.8 mm in diameter (Institute Straumann AG, Basel, Switzerland) was used first. The Schneiderian membrane was then elevated by carefully and lightly tapping with a mallet on osteotomes to push the bony sinus floor into the sinus cavity. The osteotomy site was then enlarged with a Ø 3.5 mm osteotome; the integrity of the membrane was controlled with an undersized Ø 2.1 mm depth gauge and by using the Valsalva maneuver. If the sinus was randomized to be grafted (control), Bio-Oss® (Geistlich Pharma AG, Wolhusen, Switzerland) was used to fill the elevated sinus and 1 or 2 implants (TE® SLActive® implants; length: 8 mm, smooth neck length: 1.8 mm; Straumann AG, Basel, Switzerland) were placed. When the sinus belonged to the test group, implants were placed without grafting material. The implants of both groups were seated in the osteotomy site until the limit of the rough

surface was no longer visible on the mesial and distal sides, and the implant neck protruded above the crest. The implants were left to heal transmucosally, and the sites were kept prosthesis-free during the 8 weeks of healing. An impression was then made and single porcelain-fused-to-metals screw-retained crown were fabricated.

Clinical and radiographic controls

The implants were examined at 1, 8 (impression making), 10 (loading of the prosthesis), and 12 weeks and at 1, 3, and 5 years after their placement. Controlled parameters were the followings: pain or subjective sensation, peri-implant infection, mobility, and continuous radiolucency around implants.[10] Implants were considered to have survived if they were still in mouth and in function. Prosthetic complications were recorded including loosening of the crown or abutment, loosening of the screw, and fracture of the abutment and porcelain veneer.

Standardized peri apical radiographs were taken without prostheses in place immediately after surgery, at 8 weeks during the prosthetic and loading step, and at 5 years.[7] Internal calibration was realized on each radiograph by measuring three inter-thread distances (2.4 mm). The change in the crestal bone level as well as the bone anchorage (or the effective implant length in contact with bone, l) were determined on the mesial and distal implant sides (Figure 1).

Non-standardized periapical radiographs of implants with prostheses in place also were taken at the loading step and at 5 years (Figure 2). Prior to radiographic measurements, internal calibration was performed on each radiograph by setting the total implant length to 9.8 mm. The length C was the distance measured from the

most occlusal point to the crestal first bone-to-implant contact. The crown-to-implant ratio (C/I) was obtained by dividing C by I.

Statistical analysis

Descriptive statistics (mean and standard deviation) were used to present the measurements of bone level. The data were analyzed using mixed linear models that included a random effect (random intercept) for each patient and a fixed effect for the treatment group and year. The p-values took into account the random effects factor.

RESULTS

Among 12 patients (nine women and three men, 57.6 ± 4.7 years), 37 sites (32 molars and five premolars) with residual bone height ≤4 mm met the inclusion criteria. Seven patients needed treatment relative to both sinuses receiving grafting material in one sinus and no grafting material in the other sinus (bilateral sites). In five patients, only one sinus was involved. Twenty control implants and 17 test implants were placed. Antagonists in contact with the planned crowns were natural teeth or restored implants, and the indication for all patients except one was free-end edentulism. The patients did not wear night guards because none suffered from parafunction or muscular hypertrophy at the initial pre-operative clinical examination.

Two implants that were placed in fused cortices showed mobility before the loading step and failed (patient 2, control implant 16; patient 12, control implant 27).[7] Consequently, 35 implants were restored with single crowns after a mean healing time of 2.6 ± 0.9 months. One prosthetic complication, a ceramic fracture, occurred 2.5 years after loading (patient 7, test implant 16). In addition, the failure of that same implant (patient 7, test implant 16) occurred at 2.7 years because of the recurrence of

periodontal disease that had been treated before implant placement.[11] After 5 years, 34 implants out of 35 restored implants survived without prosthetic complications.

Table 1 shows the values of I, crestal bone level, C and C/I ratio for each patient. The mean I(t0) was 2.4 ± 0.8 mm (control) and 2.7 ± 0.9 mm (test), with no significant difference between the test and control groups (p =0.351). At loading, the mean I was 3.7 ± 0.8 mm (control) and 3.4 ± 1.3 mm (test; p =0.405), whereas it was 7.0 ± 1.1 mm (control) and 6.4 ± 0.9 mm (test; p =0.002) at 5 years. The mean value of I increased significantly between the time of loading and 5 years (p < 0.001). At 5 years, 11 control implants and 4 test implants showed at least one side that was embedded completely in newly formed bone. The mean change in crestal bone level showed no significant difference between the test and control groups. It reached -0.5 ± 0.4 mm (control) and -0.7 ± 0.5 mm (test; p =0.134) at loading, and -0.7 ± 1.4 mm (control) and -0.6 ± 0.9 mm (test; p =0.527) at 5 years. It did not change significantly between the time of loading and 5 years (p =0.696).

The mean C was 13.8 ± 1.6 mm (control) and 13.6 ± 0.9 mm (test; p= 0.686) at tload. It was 13.6 ± 1.7 mm (control) and 13.4 ± 1.0 mm (test; p=0.445) at 5 years. The difference in mean C measured at loading and 5 years after placement was not statistically significant (p =0.319). Hence, at loading, the mean C/I ratio was 3.8 ± 0.8 (control) and 4.6 ± 2.0 (test; p=0.033) with a range of 2.0 - 9.3 mm. At 5 years, it was 2.0 ± 0.8 (control) and 2.1 ± 0.4 (test; p=0.341) with a range of 1.4 - 4.8 mm). The difference in mean C/I measured at loading and 5 years after placement was statistically significant (p =0.002). The mean decrease in C/I was 1.7 for the control group and 2.6 for the test group. Seven control implants and 10 test implants presented a 5-year C/I ratio greater than 2. Only two implants (patient 2, implant 15; patient 7, implant 17) showed a large increase in C/I ratio between the time of

loading and 5 years after placement. These two patients showed a worsening of their periodontal condition, although they had been successfully treated prior to implant placement. The mean 5-year crestal bone loss around these implants was high: -4.3 mm for patient 2 (implant 15) and -1.8 mm for patient 7 (implant 17).

DISCUSSION

The aim of the present study was to evaluate C/I ratio along 5 years when implants are placed in atrophic maxillae using OSFE with or without grafting biomaterial. All patients in the present study were recruited using wide inclusion criteria, reflecting the current practice usually encountered in private dental offices. The protocol was tailored to serve the study, particularly by restoring implants with single crowns and by avoiding the placement of provisional restorations. A particularly low range of residual bone height was set at 4 mm or less. No minimal height has been considered. The purpose for this inclusion criterion was to evaluate the feasibility of the OSFE in extreme situations.[7] Although tapered implants were used to improve initial stability, two implants were found to be mobile 1–2 months after placement and failed. These failures were related to the placement of implants in fused cortices, regardless of the presence or absence of grafting material.[7]

The low residual bone height confers an unfavorable initial C/I at the time of loading (mean value: 4.2 ± 1.5). However, the OSFE technique permits the formation of endo-sinus bone even when grafting material is not used. The mean gain in endo-sinus bone was 3.8 ± 1.0 mm (test) and 4.8 ± 1.2 mm (control, p=0.004) after 5 years.[11] Hence, the mean osseointegrated implant height I was sufficient to allow implants to perform successfully over 5 years of functional loading. The mean C/I was 4.2 at time of loading but reached 2.1 after 5 years with the increase of the

endo-sinus bone along the implants. Seventeen implants showed a C/I value ≤ 2 and 14 implants between 2 and 2.5. Two cases of extensive crestal bone loss were recorded around two implants in patients who didn't strictly adhere to appointments for dental hygiene and maintenance care. This led to one late implant failure. This further illustrates that implant placement in atrophic bone should be performed only in patients maintaining a high standard of oral hygiene.[12]

It should be pointed out that most studies describing in the literature about C/I ratio are usually retrospective. They report only one C/I value taken at a particular time, mainly at the time of prosthesis placement or at an occasional control. More, there are no report in the literature that analyzes the way in which the C/I ratio evolves over time. A specific feature of the present study is the reporting of two C/I measurements, one obtained at the time of loading and the second at the 5-year follow-up examination. Most studies use the so-called 'anatomical' C/I ratio and/or 'clinical' C/I ratio. In both types of ratio, the measurement of I starts from the apex of the implant because, in standard placement, the implant is generally totally endosseous. In the current study, the reported C/I ratios considered both crestal and endo-sinus changes in bone level. The value of C took into account the change in crestal bone level.[13, 14] The length I was regarded as only the part of the implant that had integrated into bone. It corresponded to the bone anchorage height measured between the crestal and endo-sinus bone levels. The protruding part of the implant within the sinus was not considered to be osseointegrated.

Some authors reported that the crown-to-root ratio of natural teeth (i.e. 1:2 to 1:1) should not be applied to all implant-supported restorations.[15, 16] Blanes et al reported an overall clinical C/I ratio of 1.77 ± 0.56 for implants placed in posterior regions.[13] Rokni et al reported an anatomical C/I ratio of 1.5 ± 0.4 (range 0.82–3.24)

for 199 implants, with 78.9% of the implants between 1.1 and 2.0.[16] Birdi et al[17] and Anitua et al[18], respectively, measured mean C/I ratios of 2.0 ± 0.4 (range 0.9–3.2) and 1.82 ± 0.42 (range 1.04–3.31), respectively, for ≤8.5 mm long implants. The mean C/I reported by Malchiodi et al[19] was 2.08 ± 0.80 (range 0.95–4.80). It should be noted that no author has reported an average value as high as that obtained at the time of loading in the present study. However, at 5 years, the values of C/I were consistent with those found in the literature and could be considered promising to maintain appropriate biomechanical conditions and implant function.

Implants placed in the posterior maxilla may be at higher risk of complications because of increased occlusal forces. For this reason, implants of less than 10 mm have been recommended only when two or more implants were placed and rigidly splinted by the restoration.[20] Implants with internal conical interface through a more rigid connection were reported to improve marginal tissue response and resistance to micro-movement under bending moments. Therefore, these implants, with such a design and a rough surface, could be suited for unsplinted restorations in posterior regions.[21] The present study used implant-supported single crown restorations. In this situation, stress was exerted individually on each implant without distribution on the adjacent implants when compared to splinted restoration. The main reason for single crown restoration was to measure the C/I ratio versus bone levels around each implant without any influence on adjacent implants. Complication risk may have increased but improve the validity of the findings. The adjacent pre-existing dentition may influence force distribution and be beneficial for the implant.[22] In the present study, no implant had pre-existing adjacent dentition bilaterally. All were multiple single implants.[7] The regenerated bone within the sinus, in the presence or absence of grafting material, was able to withstand masticatory strains exerted on the

implant/single crown system. Among the 35 restored implants, only one prosthetic complication occurred in the current study. The relationship between the C/I ratio and technical complications of implant-supported restorations has not yet been clarified.[23, 24]

A limitation of the present study is the number of studied implants. Furthermore, study specifics were tailored to serve data analysis and to validate the objectives. They can serve as model, to be used in conjunction with the technique of sinus elevation with osteotomes but caution must be exercised before such protocol can be generalized.

CONCLUSION

This present study resulted in a high implant survival rate after 5 years for restored implants placed with and without grafting in a maxillary bone height of ≤4 mm. Within the limitations of the study, the influence of the C/I ratio was not observed, despite the low initial bone-to-implant contact height, the location -posterior maxilla-, and the non-splinted restorations. The mean C/I ratio was extremely high, 4.2 ± 1.5 at loading. After 5 years, with or without grafting material, it evolved to 2.1 ± 0.6. The use of grafting material doesn't seem to be necessary to restore extremely atrophic posterior maxilla with OSFE technique and simultaneous implant placement.

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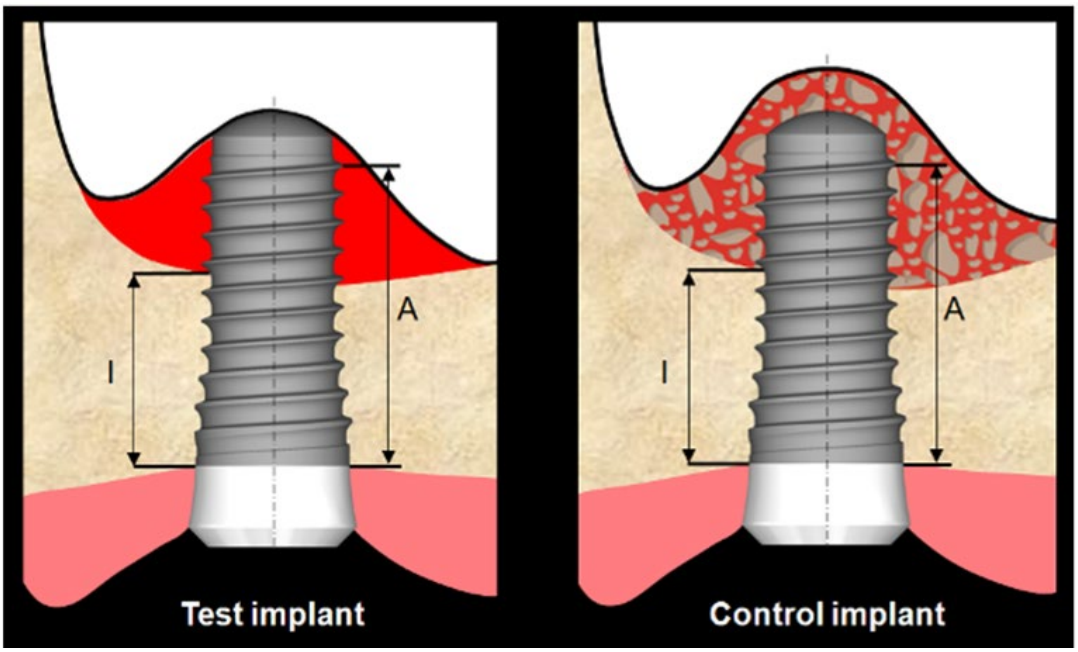
Figure Legends

Fig 1 Radiographic measurements of crestal bone level and bone anchorage (I) on standardized peri-apical radiographs.

Crestal bone level: The distance A, parallel to the implant axis and between the most coronal bone-implant contact and the most apical thread of the implant, was measured on both sides of each implant and averaged. A decrease in this mean value between tload and t5y radiographs was indicative of crestal bone loss (negative value). Conversely, an increase indicated crestal bone gain (positive value).

Fig 2 Patient #3. Radiographic evolution of C and I on non-standardized peri-apical radiographs taken at the time of loading (a) and at 5 years after placement (b).



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Bone anchorage: The distance I, between the most coronal bone-implant contact and the most apical bone-implant contact, was measured on both sides of each implant and averaged.

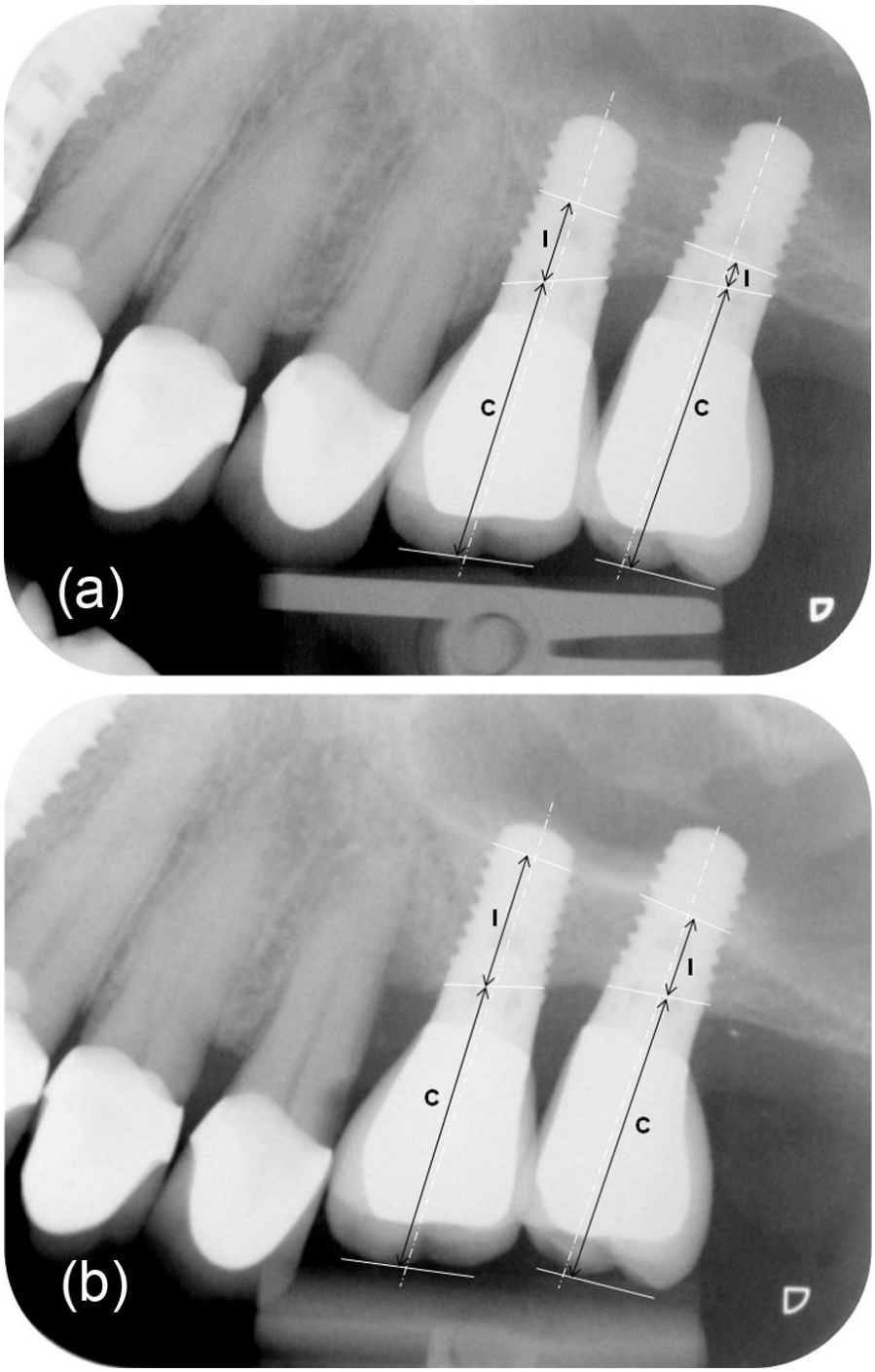

Fig 2 Patient #3. Radiographic evolution of C and I on non-standardized peri-apical radiographs taken at the time of loading (a) and at 5 years after placement (b).

Patient N°	Implant site	Implant group	I (mm)			Crestal bone level (mm)		C (mm)		C/I	
			t0	loading	5 years	loading	5 years	loading	5 years	loading	5 years
1	16	Test	3.1	3.3	5.1	-0.1	-1.0	14.8	15.1	4.5	3.0
	17	Test	2.6	3.0	7.1	-0.6	-0.9	14.9	15.1	5.0	2.1
2	15	Control	4.0	4.0	3.5	-0.1	-4.3	12.7	16.9	3.2	4.8
	16	Control	0.6	–	–	–	–	-	-	-	-
3	16	Test	2.4	2.1	6.8	-0.6	-0.1	13.6	13.0	6.6	1.9
	17	Test	1.9	2.1	6.2	-0.3	0.6	14.3	13.2	6.9	2.1
	26	Control	2.2	4.5	6.8	-0.3	-1.3	11.3	12.5	2.5	1.8
	27	Control	2.4	3.9	8.0	0.1	0.3	12.1	11.5	3.1	1.4
4	16	Test	2.3	2.7	5.3	-0.2	-1.9	12.4	12.8	4.6	2.4
	26	Control	3.6	3.3	5.6	-1.0	-2.9	12.0	14.1	3.6	2.5
	27	Control	3.5	3.1	6.6	-0.9	-1.6	10.3	11.4	3.3	1.7
5	16	Control	2.7	4.2	6.9	-0.1	-0.4	14.1	14.1	3.4	2.1
	17	Control	2.0	3.4	8.0	-0.1	1.0	13.2	12.6	3.9	1.6
6	16	Control	2.8	4.1	6.9	-1.0	-0.6	15.0	15.0	3.7	2.2
	17	Control	1.6	2.8	7.7	-0.2	0.7	16.0	16.1	5.8	2.1
	26	Test	2.7	2.9	7.2	-1.6	-0.5	12.7	12.6	4.3	1.7
	27	Test	1.7	3.2	5.7	-0.4	0.1	12.7	12.1	4.0	2.1
7	16	Test	2.1	4.2	–	-1.3	–	12.7	-	3.0	-
	17	Test	3.0	6.6	5.5	-0.6	-1.8	12.8	14.2	2.0	2.6
8	16	Control	2.3	3.4	7.9	-0.6	-0.5	13.0	12.4	3.8	1.6
	17	Control	1.6	2.3	7.7	-0.4	-0.3	12.2	11.8	5.3	1.5
	26	Test	1.8	1.7	7.8	-0.7	0.5	13.2	11.6	7.8	1.5
	27	Test	1.4	1.6	6.2	-0.4	-0.6	14.9	13.8	9.3	2.2
9	25	Control	2.4	3.6	7.2	-0.8	-1.0	12.4	11.9	3.5	1.6
	26	Control	2.6	3.1	7.2	-0.3	0.8	13.7	14.2	4.5	2.0
10	15	Test	3.8	4.5	8.0	0.0	0.7	13.1	13.5	3.0	1.7
	16	Test	2.4	2.7	7.3	-0.2	0.3	12.8	12.7	4.7	1.7
	25	Control	2.1	4.0	7.1	-0.7	-1.3	13.7	13.6	3.4	1.9

	26	Control	1.4	3.4	8.0	-0.1	0.7	12.3	12.3	3.7	1.5
11	16	Control	3.7	5.2	7.8	-0.7	0.2	15.3	14.9	3.0	1.9
	17	Control	2.2	5.1	7.4	-0.8	0.3	16.5	15.8	3.2	2.1
	26	Test	4.2	4.8	6.5	-1.2	-0.7	13.8	13.1	2.9	2.0
	27	Test	4.0	5.0	5.9	-1.0	-1.4	14.5	14.5	2.9	2.5
12	15	Test	3.9	4.2	6.2	-1.5	-2.1	14	14.3	3.4	2.3
	16	Test	3.3	4.3	6.2	-1.4	-0.9	13.6	13.3	3.2	2.1
	26	Control	2.7	3.0	6.1	-0.7	-1.8	13.6	14.0	4.6	2.3
	27	Control	2.1	–	–	–	–	-	-	-	-
Mean			**2.6**	**3.6**	**6.7**	**-0.6**	**-0.6**	**13.4**	**13.5**	**4.2**	**2.1**
Standard deviation			**0.9**	**1.1**	**1.0**	**0.5**	**1.1**	**1.3**	**1.4**	**1.5**	**0.6**

Table 1 Values of bone anchorage (I), crestal bone level, C and C/I ratio.