

Does crown/implant ratio influence the survival and marginal bone level of short single implants in the mandibular molar? A preliminary investigation consisting of 12 patients

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SUMMARY Crown/implant (C/I) ratio has been proven to not affect the survival of the implants; however, it is also a fact that no evidence exists with regard to the use of single short implants in the mandibular molar. The aim of this study was to determine whether the crown/implant ratios of single implant-supported fixed restorations on implants of 6–8 mm in the mandibular molar have an impact on the implant survival and marginal bone maintenance. Twelve short dental implants (6–8 mm) were installed and restored with single crowns, loaded after 3 months of healing. The restorations were divided according to crown-to-implant ratio into two groups: Group 1: C/I < 2.0 and Group 2: C/I ≥ 2.0. Alveolar bone loss was

measured using CBCT scan, taken at the implant placement and after 12 months follow-up from loading. Reduced implant/crown ratio shown no statistic significant differences on implant survival and the alveolar bone level compared with recommended implant/crown ratio. Within the limitation of this study, it can be concluded that reduced C/I ratio could be used as a substitute for recommended C/I ratio in severely mandibular atrophic residual alveolar ridges.

KEYWORDS: dental implants, single tooth, mandible, prostheses and implants, bone resorption, treatment outcome

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Background

Crown/root ratio has been one of the diagnostic parameters to decide on the restoration form of the dental prosthesis (1). It has been suggested that restorations with a crown/root ratio higher than 1 had higher risk of failure, when functional loading was applied (2). A negative biomechanical effect of long crowns compared to the endosseous retention part was hypothesised also for implant-based prostheses, although this concept has been disregarded upon the evidence that implants bare functional

loading mostly at their coronal (neck) portion (3–5). This means, theoretically, that the length of the implants does not influence the implant osseointegration and the functionality of the implant-prosthetic unit; therefore, the clinician can select an implant simply based on the availability of the bone, without compromising the outcome of the restoration. As a matter of fact, short implants such as 4- or 6-mm implants are available on the market, and some clinical studies suggest that these implants in fact do function as good as the longer implants (6, 7).

Short implants have attracted attention because they can be placed in sites with high bone atrophy as an alternative to bone augmentation techniques (8). However, long-term clinical evidence on the short implants does not exist in the literature, and the majority of the clinical follow-up studies are within 5 years (7, 9, 10). Moreover, it has also been documented in other reports that implants longer than 10 mm provide higher implant survival than that of the shorter ones (11). Furthermore, if the shorter implants were to function, the indication range suggested from the manufacturers should be equivalent to that of the longer implants. Instead, some of the manufacturers and authors do not recommend single restoration with shorter implants in the molar region (12, 13). It can be suggested that there is still a lack of evidence on the outcome of shorter implants especially when they are used to restore singular molar cases. Therefore, studies are needed to come to a consensus whether this concept functions as good as the longer single implants.

One of the concerns with short implants is that often the vertical height of the superstructures is longer than the implant length, which in other words means that restorations on short implants have a crown/implant ratio higher of 1 (14, 15). To date, insufficient evidence exists concerning the relation of crown/implant ratio to the short implant survival and marginal bone maintenance especially in the mandibular single situations. However, based on the basic biomechanical evidence, it can be hypothesised that this would have no effect on the clinical outcome of the short single implants placed in the mandibular molar regions.

Thus, this preliminary study was designed to prove this hypothesis and it aimed to study the 12-month clinical effect in terms of implant survival or marginal bone levels, of short single implant-based prostheses, with different crown-to-implant ratios, placed in the mandibular molar.

Methods

Twelve short single implants* were used to replace missing mandibular 1st or 2nd molars with Seibert's class III bone resorption. The patients were included

in the study after signed consent was obtained. The Institutional Review Board approved the current study.

Preoperatively, a radiographic stents were fabricated using vacuum-pressed sheet (Easy-Vac[†]; 3A MEDES). Bis-acrylic radiopaque material (Luxatemp Plus[‡]; DMG) was injected in the area of missing teeth in the stent. Thereafter, the patients were subjected to cone beam computed tomography (CBCT[§]; CS 9000 3D) with the stents placed. The files were exported as DICOM files for pre-surgical planning and simulation with a virtual implant placement software (Carestream software[¶]). The length of the implants to be placed was decided at this time based on the distance of the alveolar ridge to the mandibular canal, setting a safety margin of at least 2 mm from the apical part of the implant to the canal.

After a standard sequence of osteotomies recommended by the manufacturer, implants were inserted manually using implant-seating tip attached to a special handle with gentle tapping force until fully seated. Healing abutments were screwed, and the flap was sutured over the implants.

Post-operatively, CBCT was taken again immediately after implant placement to ensure proper placement and alignment. Patients were prescribed with post-operative antibiotics: Augmentin** 1 g and non-steroidal anti-inflammatory drugs (Profinal 400 mg 1 × 3 × 7^{††}) for 7 days after surgery. Warm chlorhexidine gluconate 0.20% mouthwash (Perio-Kin^{‡‡}) was also prescribed three times a day from the second post-operative day for 1 week. All sutures were removed 1 week after the surgery. The implants were allowed to heal for 3 months until the second surgery was performed.

After soft tissue healing, a silicon impression was taken for prosthetic construction. Appropriate prefabricated stock abutments were connected for each implant, on which porcelain-fused-to-metal (PFM) final prosthesis was constructed. After the healing of the soft tissue, final restorations were cemented over

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Table 1. Inserted implant length and their crown/implant (C/I) ratio

Patient	A	B	C	D	E	F	G	H	I	J	K	L
Implant Length (mm)	5	6	8	8	8	8	8	6	6	6	6	6
C/I Ratio	1,8	1,9	1,3	1,6	1,5	1,9	1,7	2,4	2,3	2,7	2,1	2
Group	1	1	1	1	1	1	1	2	2	2	2	2

the abutments using glass-ionomer cement (Ketac Cem^{§§}; 3M ESPE). Occlusal adjustment was performed, so that the crowns were in full occlusal contact and in light articulation. Occlusal adjustments were conducted if necessary at check-ups. Based on the length of the crowns and the length of the implants, the crown/implant ratio was calculated. The implants were divided into two groups ($C/I < 2.0$ and $C/I > 2.0$) for statistical comparison.

Radiographic evaluations were performed again 12 months after implant loading with CBCT and were used for assessment of alveolar bone level around implant at mesial and distal first bone to implant contact level. Crestal bone changes were measured mesially and distally by comparing CBCTs on the day of the loading of the implant (T_0) and the follow-up CBCTs after 12 months from loading (T_1). Two distinct measurements were made as follows: first measurement was from first bone to implant contact (FBIC) to the implant–abutment interface (IAI), and second measurement was from crest of the bone (CB) to the implant–abutment interface (IAI). Linear measurements from the implant–abutment interface (IAI) to the FBIC were obtained mesially and distally. Linear measurements from the IAI to the highest bone level were obtained mesially and distally (16).

All data were collected, tabulated and statistically analysed for normality of distribution and correlation.

Results

No implant losses were experienced and all 12 implants could be included in the study. The inserted implant length and respective C/R ratio are presented in Table 1. In total, seven sites (in seven patients) were classified as Group 1 ($C/I < 2.0$), and five sites (in five patients) were classified as Group 2 ($C/I \geq 2.0$). The mean C/I ratio for all 12 cases was 1.918 ± 0.386 , ranging from 1.275 to 2.667.

Shapiro–Wilk statistics were calculated to provide a formal assessment of normality of the data distributions in the total sample and in the two groups (Table 2). All the tests were not statistically significant with $P > 0.05$, indicating a normal distribution of the data and, thus, allowing the use of parametric statistical tests, despite the small sample size of 12 patients.

One exception was the measurement to FBIC on the mesial surface in the experimental group ($P = 0.039$), which was not normally distributed. Nevertheless, this measurement was not used to compare between the two groups as the difference between T_1 and T_0 was the outcome measure.

Influence of C/I ratio on alveolar bone level

The Pearson correlation coefficient was computed to quantify the correlation between the C/I ratio and the difference in bone level between T_0 and T_1 in the total sample ($n = 12$). The C/I ratio did not correlate with any of the alveolar bone measurements, except for the average change when the FBIC was measured with a correlation coefficient $r = -0.582$, $P = 0.047$. The positive correlation suggested that when the C/I ratio increases, there was a tendency for more marginal bone loss after 12 months (Fig. 1). The absence of association between C/I ratio and the other measurements is clearly conveyed by the random scatter of the dots in the plots displayed in Figs 1 and 2.

When comparing the alveolar bone level between the two groups using the t -test, the results showed no statistically significant difference in all measurements (Table 3).

Comparison between marginal bone levels at the two different time points

When comparing the marginal bone level between T_1 and T_0 in the total sample, there was a statistically significant difference in the average measurement to the FBIC, indicating that the bone level at T_0 was 0.165 mm higher than T_1 on average, with a 95% confidence interval ranging from -0.326 to

^{§§}3M ESPE, Minneapolis, MN, USA.

Variable	Baseline (T_0)	Follow-up (T_1)	Difference (T_1-T_0)
Total			
To FBIC			
Mesial	0.962 ($P = 0.808$)	0.94 ($P = 0.498$)	0.903 ($P = 0.172$)
Distal	0.938 ($P = 0.49$)	0.905 ($P = 0.182$)	0.96 ($P = 0.782$)
Average	0.981 ($P = 0.989$)	0.943 ($P = 0.541$)	0.912 ($P = 0.223$)
To CB			
Mesial	0.942 ($P = 0.524$)	0.885 ($P = 0.102$)	0.889 ($P = 0.115$)
Distal	0.941 ($P = 0.509$)	0.927 ($P = 0.35$)	0.91 ($P = 0.211$)
Average	0.944 ($P = 0.545$)	0.944 ($P = 0.548$)	0.867 ($P = 0.059$)
G 1			
To FBIC			
Mesial	0.85 ($P = 0.194$)	0.927 ($P = 0.177$)	0.846 ($P = 0.181$)
Distal	0.845 ($P = 0.138$)	0.844 ($P = 0.182$)	0.992 ($P = 0.985$)
Average	0.91 ($P = 0.47$)	0.803 ($P = 0.086$)	0.82 ($P = 0.117$)
To CB			
Mesial	0.92 ($P = 0.532$)	0.776 ($P = 0.051$)	0.866 ($P = 0.252$)
Distal	0.997 ($P = 0.997$)	0.841 ($P = 0.168$)	0.883 ($P = 0.325$)
Average	0.887 ($P = 0.34$)	0.944 ($P = 0.667$)	0.833 ($P = 0.146$)
G 2			
To FBIC			
Mesial	0.798 ($P = 0.039$)*	0.912 ($P = 0.409$)	0.948 ($P = 0.713$)
Distal	0.932 ($P = 0.566$)	0.883 ($P = 0.239$)	0.983 ($P = 0.973$)
Average	0.901 ($P = 0.337$)	0.969 ($P = 0.893$)	0.933 ($P = 0.573$)
To CB			
Mesial	0.907 ($P = 0.524$)	0.855 ($P = 0.135$)	0.815 ($P = 0.057$)
Distal	0.927 ($P = 0.527$)	0.94 ($P = 0.667$)	0.933 ($P = 0.575$)
Average	0.93 ($P = 0.553$)	0.918 ($P = 0.456$)	0.839 ($P = 0.097$)

*Significant: $P < 0.05$.

−0.005 mm and a P value of 0.044 (Table 3; Fig. 3). Moreover, the marginal bone measurements to CB were all significantly larger at T_0 compared to T_1 , indicating an average bone loss of 0.719 mm mesially, 0.618 mm distally and 0.668 mm on average (Fig. 4).

Considering each group separately, none of the measurements were statistically significant at T_1 compared to T_0 in the control group (G_1), whereas all measurements except those on the mesial surfaces were significantly lower at T_1 compared to T_0 in the experimental group (G_2).

Difference in marginal bone change between the mesial and distal surfaces of the implants

The results of the bone level changes (T_1-T_0) between the mesial and distal surfaces of the implants are summarised in Table 4. No statistically significant difference was found between the mesial and distal measurements of bone level, when assessed using both distances, to FBIC and CB.

Table 2. Shapiro–Wilk statistics to test normality of distribution

Correlation between FBIC and CB measurements of marginal bone level

Measurements of marginal bone level to FBIC and CB did not correlate with each other at any time point, as illustrated in Fig. 5.

Discussion

It has been a general consensus that the crown/implant ratio does not influence the survival of the implant restorations (9, 10, 17). However, it is also a fact that we do not have much information about how long crowns influence the survival of shorter implants. Short implants offer the possibility to avoid bone augmentation for the patients with advanced marginal bone resorption, where the insertion of longer implants is not possible. From a clinical perspective, it can be said that in many occasions, superstructures for these short implants have relatively longer crowns when compared to the length of the

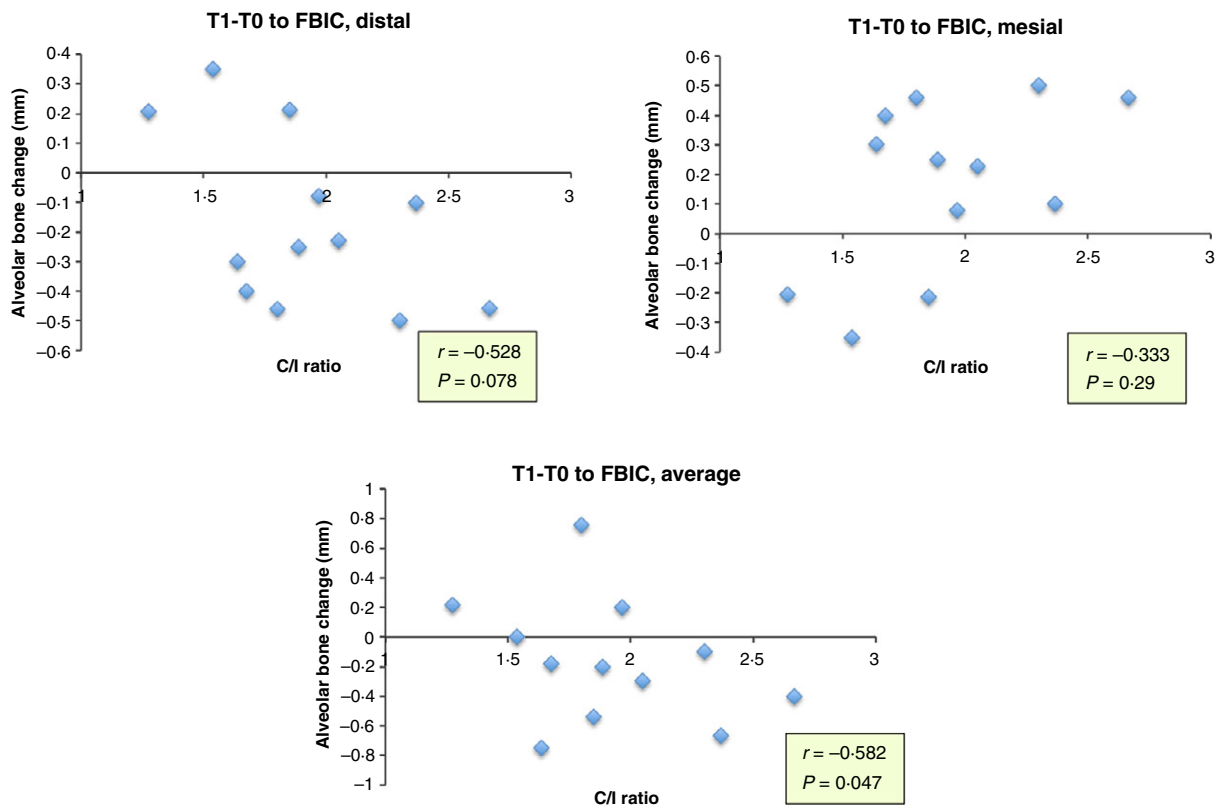


Fig. 1. Scattergrams showing the correlation between C/I ratio and difference in alveolar bone level between baseline and follow-up, when measured to FBIC.

implants (18). This could be one of the reasons why the application of short single implants in the mandibular molar regions has been a topic of discussion.

The results of this study presented that C/I ratio did not influence the survival of the implants that was 100% in both groups. Moreover, C/I ratio higher than 2.0 did not result in a higher marginal bone loss as compared to the control group, in which the C/I ratio was between 1.0 and 2.0. The implants were divided into two different ratio groups based on the passed studies indicating that the prognosis of the natural dentition was doubtful when the crown-to-root ratio.

From a biomechanical viewpoint, it was demonstrated on finite element analyses that the stress concentration of implant-supported prosthesis under functional loading was localised at the neck portion of the implants regardless of their length (3–5). It can be said that the results from our study corroborated the computed simulation, showing that single implants in the mandibular molar regions and with C/I ratio

higher than 2 have similar outcome to those found in the literature.

However, it must be noted here that in the above-mentioned theoretical finite element analyses, mainly the vertical occlusal forces were taken into account. It can be said that the lateral functional movements (jiggling forces) and parafunction generate stress to the implants with unpredictable localisation and it is uncertain whether in such cases implants with a longer suprastructure could loose more bone than implants with a shorter crown. Recently, two studies have used 3D finite element analyses incorporating also oblique forces to investigate the dynamics of stress distribution in the peri-implant bone and in the prosthetic components in the case of increased crown-to-implant ratio (19, 20). Both cases used a mandibular simulation. These studies demonstrated that increased crown heights generated a proportional increase of the stress in the peri-implant bone during lateral forces and, more importantly, they observed that longer crowns distribute higher stresses on the

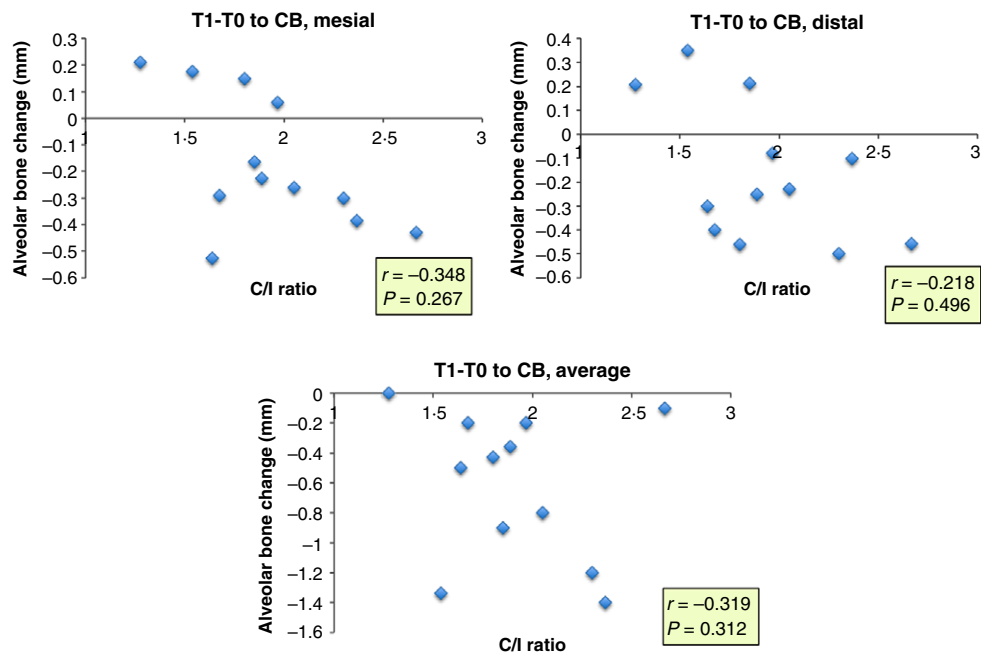


Fig. 2. Scattergrams showing the correlation between C/I ratio and difference in alveolar bone level between baseline and follow-up, when measured to CB.

Table 3. Comparison of alveolar bone difference between Group 1 and Group 2 measured to FBIC and to CB, mesially, distally and on average

Difference T_1-T_0	Difference between G_1 and G_2					
	Mean (G_1-G_2)	SE mean	95% confidence interval of the difference		t	P value
			Lower	Upper		
To FBIC						
Mesial	0.08	0.176	-0.313	0.473	0.453	0.66
Distal	0.295	0.242	-0.245	0.835	1.216	0.252
Average	0.187	0.161	-0.217	0.592	1.166	0.293
To CB						
Mesial	0.366	0.561	-0.884	1.616	0.652	0.529
Distal	0.216	0.296	-0.444	0.876	0.728	0.483
Average	0.291	0.406	-0.614	1.196	0.716	0.49

fixation screws of internally connected implants, with a higher risk for screw loosening or fatigue fracture.

In the case if our clinical study, the restorations have undergone functional loading for 1 year and therefore the implants have received loading in the directions of all functional movements and, nevertheless, the implants with longer crowns have not shown a statistical significant increase of marginal bone loss and no

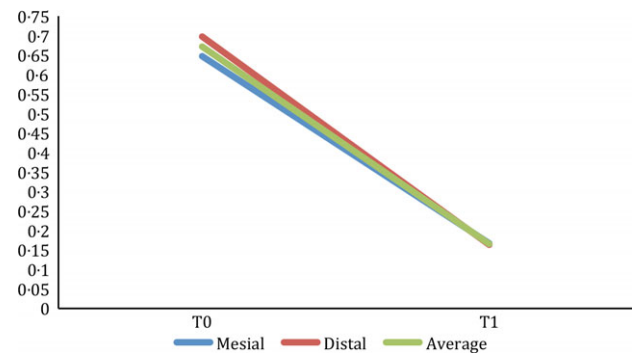


Fig. 3. Change in marginal bone level between T_0 and T_1 when measured to the FBIC.

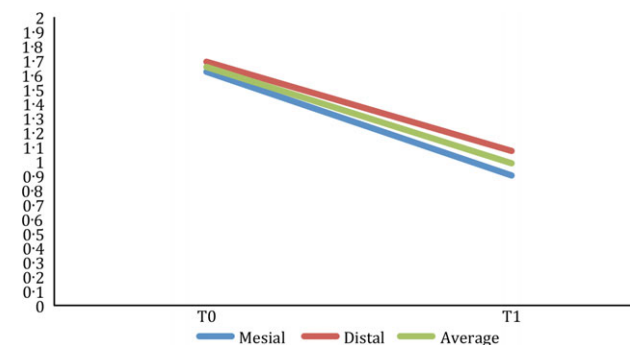
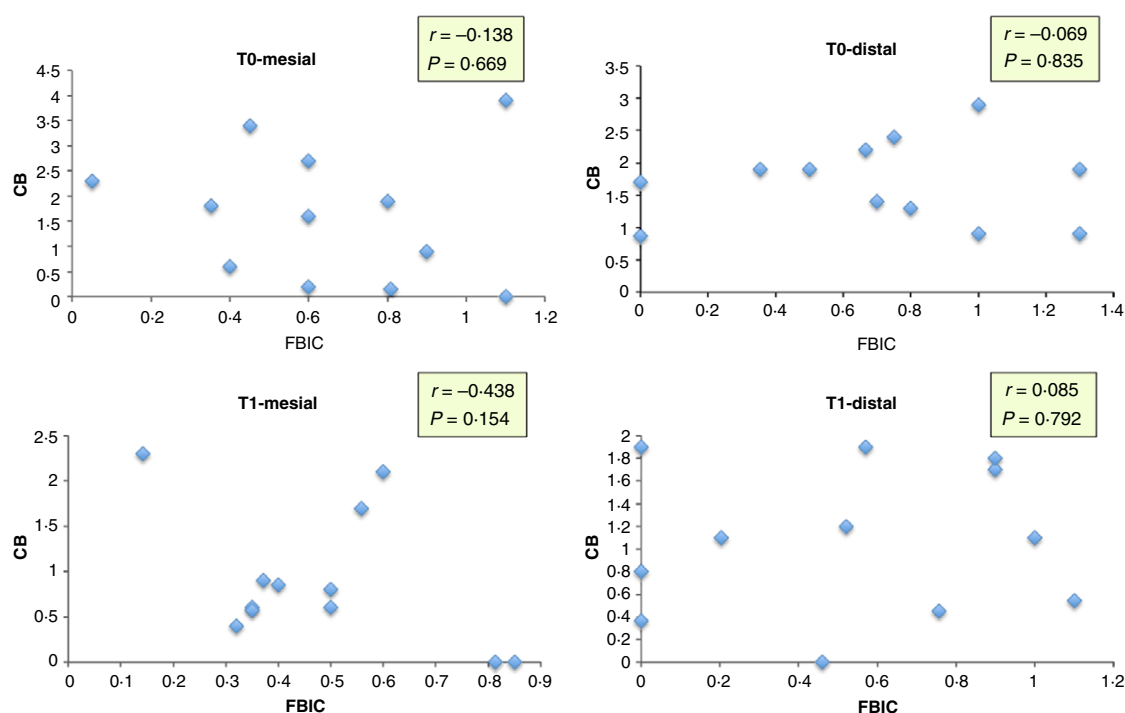


Fig. 4. Change in marginal bone level between T_0 and T_1 when measured to CB.

Table 4. Difference in marginal bone levels between the mesial and distal surfaces at both time points (T_0 and T_1)

Mes–Dis	Paired Differences			95% confidence interval of the difference		<i>t</i>	<i>P</i> value
	Mean	SD	SE mean	Lower	Upper		
To FBIC							
<i>T</i> ₀	−0.05	0.38	0.11	−0.292	0.191	−0.46	0.654
<i>T</i> ₁	−0.055	0.427	0.123	−0.326	0.217	−0.442	0.667
To CB							
<i>T</i> ₀	−0.069	0.757	0.218	−0.549	0.412	−0.314	0.759
<i>T</i> ₁	−0.169	0.528	0.153	−0.505	0.167	−1.108	0.291

Mes, Mesial; Dis, distal; SD, standard deviation; SE, standard error.

**Fig. 5.** Scattergrams showing the correlation between FBIC and CB at the two time points, mesially and distally.

prosthetic complication where recorded. However, cemented restorations were used and not screwed.

Although the difference did not reach a statistical significance, the results of the current study suggested that there was a tendency for more marginal bone loss as the C/I ratio increased. Thus, the risk for more marginal bone loss for the short implants possessing crowns longer than the length of the implants cannot be discarded. One of the reasons why the difference have not reached the statistical level for significance may be that the number of included patients.

However, our study confirmed the results of previous investigations, supporting the hypothesis that the C/I ratio does not influence the survival and marginal bone level of the short implants. In a systematic review, Garaicoa-Pazmino and colleagues (21) collected the studies that investigated the influence of crown-to-implant ratio on marginal bone loss. When they pooled the results of the 13 studies fulfilling their inclusion criteria, they found a statistical significant negative association between C/I and marginal bone loss, which in other terms means that shorter

implants (<10 mm) may induce less bone loss in the peri-implant marginal bone (21).

Within the limitation of our clinical study, it can be said that short single implants (<8 mm) with relatively long crowns have a comparable clinical outcome than short implants with shorter crowns and do not generate an increased marginal bone loss.

Despite these favourable results, one should bear in mind that marginal bone loss around short implants further reduce the length of the endosseous retentive part relative to the suprastructure and cause the C/I ratio to increase, with a possible role in the implant failure timing (10). As marginal bone maintenance is one of the main parameters of long-term clinical success of oral implants, it is crucial that short as well as standard implants are meticulously maintained, to avoid excessive bone loss. Moreover, the number of samples included in the current study is a relatively small number, and conducting future studies with a larger sample size is necessary to provide a clinical indication.

Conclusion

Within the limitation of this study, we can conclude that reduced C/I ratio could be an alternative for recommended C/I ratio in severely mandibular atrophic residual alveolar ridges.

Acknowledgments

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