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Original Article

Evaluation of Primary and Secondary Stability and Crestal Osseous Changes in Short Implants: A Prospective Clinicoradiograhic Study

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Abstract

Introduction: Alveolar ridges with reduced alveolar bone height are challenging to rehabilitate for many clinicians. Surgical procedures to compensate for tissue deficiency considered, although successful, come with a host of complications. Short dental implants, therefore, offer the clinicians a pragmatic option to facilitate prosthetic restoration in such conditions.

Materials and Methods: Short dental implants (n = 10) placed in edentulous mandibular posterior region were evaluated in this study. Primary and secondary implant stability were measured using resonance frequency analysis, and crestal osseous changes were compared using preoperative and postoperative Cone-beam computed tomography data. Statistical analysis was performed using SPSSv20 software and statistical significance was assessed using paired t-test ($P < 0.05$ was considered significant).

Results: The increase in implant stability quotient from primary to secondary stability in buccolingual (59.7–80.6 ISQ) and apical (61.2–79.3 ISQ) directions were deemed significant. There was a non-significant reduction in crestal bone level at all the sides.

Discussion: Although this study did not follow the short implants through phase of loading, they exhibited satisfactory gradual osseointegration and minimal peri-implant boss loss from the time of its placement to abutment attachment. Short implants may be considered a viable alternative to augmentation procedures in ridges with reduced alveolar height.

Key words: Alveolar bone loss, Dental implant, MegaISQ, Resonance frequency analysis

INTRODUCTION

Over the past two decades, implants have been routinely used to rehabilitate partial and complete edentulous patients due to their biocompatibility and high survival rates. Implants inserted into jawbones can support a prosthesis through osseointegration, the functional and structural connection between bones and implant surface. Implant treatment becomes more challenging to the clinicians when the alveolar bone height is insufficient. The condition is more common in the posterior jaws due to the resorption of alveolar bone and pneumatization of the maxillary sinus.[1,2] Reduced alveolar bone height not only limits the implant placement but also increases the chances of damaging the inferior alveolar nerve, the maxillary sinus, and the nasal cavity. Various procedures such as maxillary sinus floor elevation, bone grafting, guided bone regeneration, distraction osteogenesis, nerve lateralization, and vertical bone augmentation are being used to address the difficulties associated with reduced height in atrophied ridges.[3,4] However, problems associated with these augmentation techniques are high cost and longer treatment time, increased postoperative morbidity, and increased risk of complications.[1,2] Therefore, short implants, tilted implants, zygoma, or pterygoid implants have been proposed as alternatives to avoid bone augmentation. Agreement is lacking about the definition of "short implant" in the literature.

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In the past, short implants were associated with lower survival rates and with unpredictable long-term results. However, recent clinical studies indicate that short implants may adequately support most prosthetic restorations. This is due to improved surgical techniques and advances in implant characteristics, such as implant design, surface, and implant microgeometry. Short implants come with promising advantages of decreased contact possibility with adjacent tooth roots, lower risk of surgical paraesthesia, less bone overheating, and reduced time and cost. Although studies have revealed that the failure rate of short implants was no higher than that of longer implants[5-11] challenges such as less bone to implant contact due to reduced implant surface, more crestal bone resorption due to a reduced surface over which to distribute forces, and the increased crown-to-implant (CI) ratio still exists.

Since more than a decade, resonance frequency analysis (RFA)[12-14] has been used as an objective method of quantifying implant stability. It is a non-invasive, easily predictable system with reliable inter-clinician reproducibility. RFA has been widely used to determine the effects of immediate or early loading and assess changes instability over time. To further study stability of short implants at the time of placement and placement of healing abutment 3 months later, we used RFA.

The objective of this *in vitro* study is to ascertain the primary and secondary stability of ten short implants in the mandibular posterior region as measured by RFA, and osseous changes at the alveolar crest associated with short implants. Understanding these changes will give an insight into the prognosis of short implants as well as their comparative performance to conventional length implants, in terms of osseointegration achieved from time of placement to abutment placement.

MATERIALS AND METHODS

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975, as revised in 2000. Data shall be obtained from patients reporting at:

1. Department of Oral and Maxillofacial Surgery, Bharati Vidyapeeth Deemed University, Dental College and Hospital, Pune
2. Bharati Hospital, Pune.

Inclusion Criteria

1. Patient's age: 18 years and/or above, male/female
2. Follow-up: <6 months
3. Alveolar bone dimensions (< 9 mm in length)
4. D1, D2, D3 quality of bone
5. Patients without willingness to accept vertical bone augmentation
6. Patients demonstrating good general health with no local or systemic contraindications to oral surgery and implant placement.

Exclusion Criteria

1. Poorly motivated or patients unable to keep the follow-up.
2. Chronic smokers and alcohol abuse
3. Severe intermaxillary skeletal discrepancy
4. Bruxism or TMJ dysfunction.
5. Radiotherapy to the head and neck region for malignancy. (Radiotherapy = 50 Gy)
6. Comorbidity ASA category = III, systemic uncontrolled disease or patients under the medication of intravenous bisphosphonate with significant risk of developing osteoradionecrosis
7. Pregnancy.

MegaISQ utilizes the RFA technology which was originally developed by Osstell.[15] The system [Figure 1] comprises (1) A small L-shaped transducer (SmartPeg) that is tightened to the implant or abutment by a screw, and (2) a handheld probe (3) a display monitor.

The SmartPeg is a small, precision-crafted metal rod that should be assembled with the implant or abutment while a measurement is being performed. It's easy to mount and requires minimal space in the patient's mouth. It is for a single-use. In non-homogenous bone, the SmartPeg automatically resonates in two perpendicular directions - thus providing a value for the highest as well as the lowest stability direction of the implant. It comprises two ceramic elements, one of which is vibrated by a sinusoidal signal (5–15 kHz) while the other serves as a receptor. The

Figure 1: MegaGen ISQ Machine

hand-held probe stimulates the SmartPeg magnetically. An ISQ value is generated and shown on the display [Figure 2]. It reflects the level of stability on the universal ISQ scale from 1 to 100. The higher the ISQ value, the more stable the implant, stronger the bone-implant interface [Figure 3]. It provides plan for postsurgical placement of the implant. RFA has emerged as a useful tool in clinical assessment of osseointegration and prognostic evaluation.[16,17]

Originally, 13 patients were included to be in this prospective experimental study, two of whom were not allowed to participate further as the Insertion Torque Value was achieved to be lower than 25 Ncm and one patient could not be followed up after the implant placement at the first appointment. Ten patients have been a part of this study [Table 1].

Variables such as single operator's surgical technique, the limited numerosity of the sample, and the choice of the surgical site (limited to the posterior mandible) must be taken into account.

Some of the confounding factors that may affect implant stability measurement are patient-specific characteristics (age, sex, bone quality and bone-healing capacity, general health condition, and habits), and implant-related (implant location, design, geometry, and thread exposure).

RESULTS

Of the ten patients included in the study, five were male and five were female [Figure 4]. All patients were between the ages of 50–75 years, with edentulous sites in the mandibular posterior region [Figure 5]. Bone density of these edentulous sites was either D2 or D3 [Figure 6]. Short implants placed were all of the height 7 mm and varying diameters ranging from 3.5mm to 5.5mm [Figure 7]. Statistical software used was SPSSv20, and level of significance was kept at 5%.

At buccolingual direction, there was an increase in implant stability quotient from S0 to S1 and this difference was

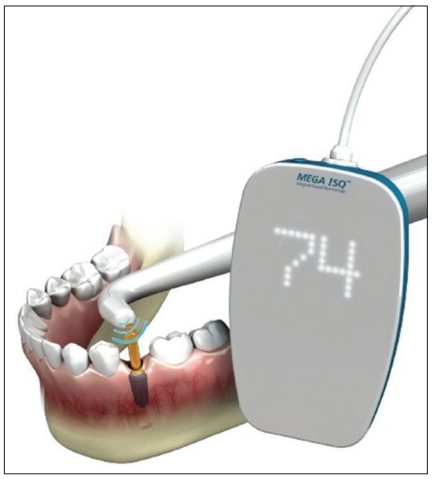

Figure 2: Hand-held probe stimulating the SmartPeg that is attached to the implant magnetically

Figure 3: ISQ Value Interpretation Chart (As provided by MegaGen)

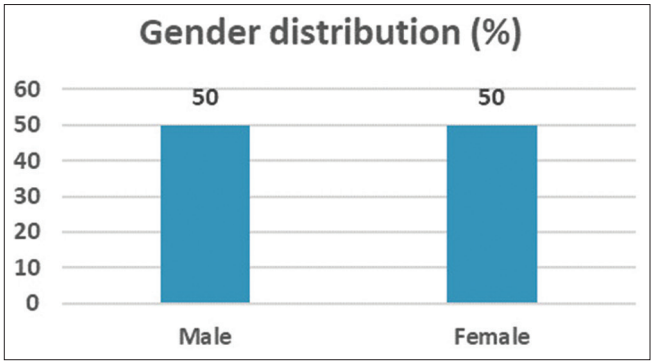

Figure 4: Graph showing the distribution in the gender of the subjects in this study

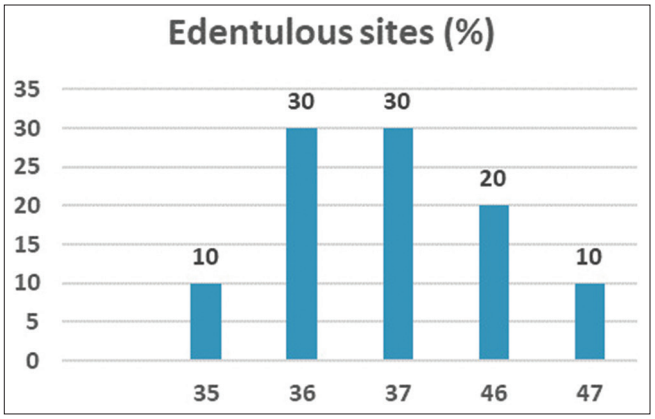

Figure 5: Graph showing the distribution in edentulous sites of the subjects in this study

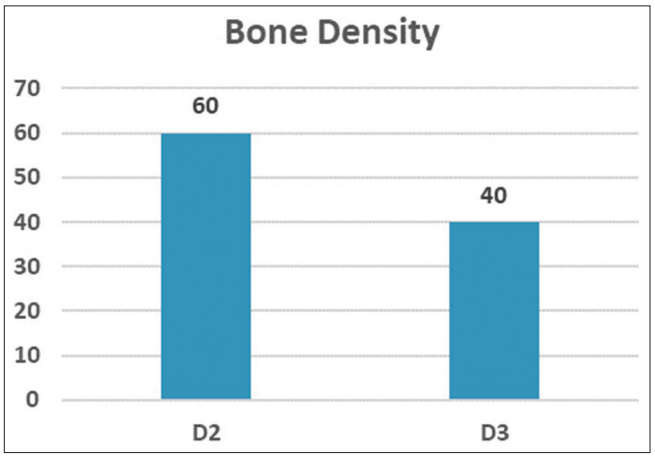

Figure 6: Graph showing the distribution in bone density of the edentulous sites in this study

significant. At apical direction, there was an increase in implant stability quotient from S0 to S1 and this difference was significant [Figure 8].

It was observed that short implants have an average of 59.7 ISQ (when measured buccolingually) and 61.2 ISQ (when measured apically) recorded immediately after implant placement and an average value of 80.6 ISQ (when measured buccolingually) and 79.3 ISQ (when measured apically) 3 months later at the time of placing healing abutment.

The increase in stability according to ISQ tester when measured buccolingually is by 20.9 ISQ, and when measured apically is by 18.1 ISQ [Table 2].

The mean crestal osseous changes from the time before the implants were placed to the time of abutment placement was 0.06 mm on the buccal aspect, 0.11 on distal aspect, 0.06 mm on the mesial, and 0.10 mm on the lingual aspect of the bone around the implant [Figure 9]. There was a non-significant reduction in crestal bone level at all the sides [Table 3-5].

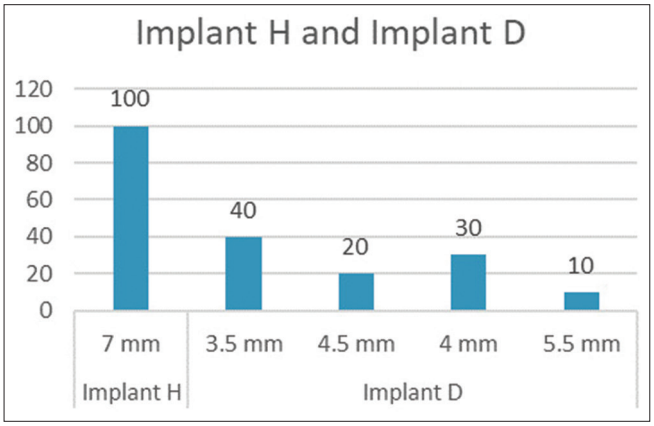

Figure 7: Graph showing the distribution in the dimensions of the implants laced in this study

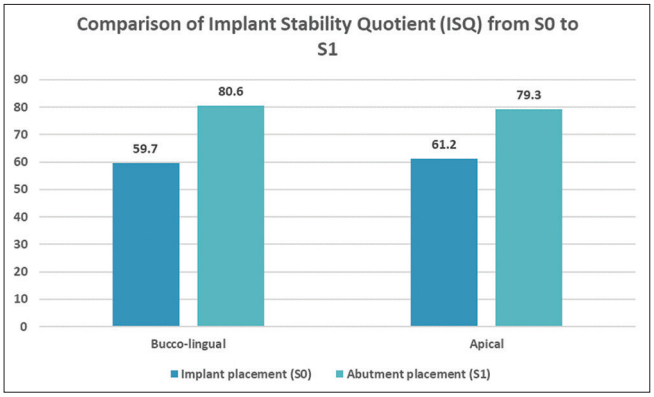

Figure 8: Graph showing the increase in implant stability from the time of implant placement to the time of abutment placement, measured in buccolingual as well apical directions

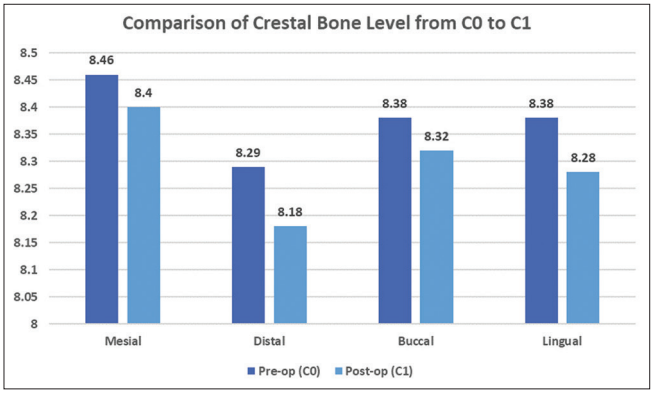

Figure 9: Graph showing the decrease in crestal osseous level from the time of implant placement to the time of abutment placement, measured in 4 aspects of the implant i.e. mesial, distal, buccal, lingual

DISCUSSION

The use of conventional length implants has been defended based on the principle they would exhibit higher survival rates and hence, more favorable prognosis.[2] However, several recent studies have consistently showed that short dental implants pose no more of a risk of failure compared to longer implants.[5,18,19]

Finite element analysis performed by Pierrisnard *et al.* showed that maximum stress in the implant area was largely independent of the implant length.[10,11] Some important factors noted throughout literature that affect survival rates of short implants are bone quality and quantity, CI ratio, surface topography of the implant, prosthesis type, occlusal/parafunctional loads, and splinting to other implants, diameter and length of the implant, and overheating during surgical preparation.[20,21] Furthermore, additional influences such as systemic factors, smoking

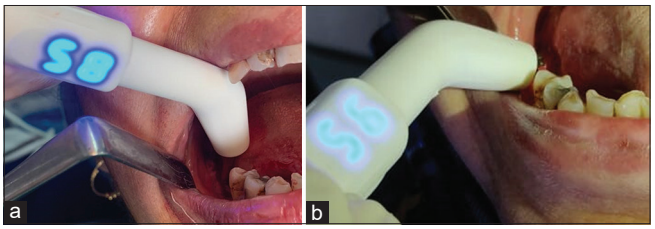

Figure 10: (a and b) Measurement of implant stability using the handheld probe at the time of implant placement

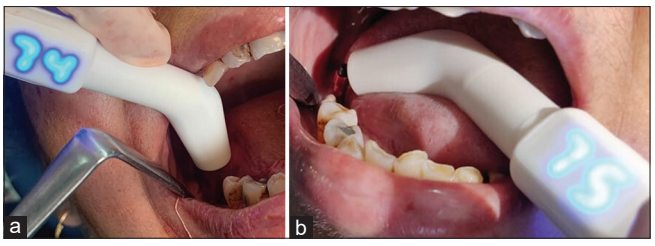

Figure 11: (a and b) Measurement of implant stability using the handheld probe at the time of abutment placement

Table 1*: Implant stability quotient values of 10 subjects using Implant Stability Tester

Sr. No.	Pt Details	Edentulous Site	Implant H (mm)	Implant D (mm)	Bone Density	S_0 BL	S_0 A	S_1 BL	S_1 A	S_2 BL	S_2 A
1.	56y/F	46	7	4	D2	56	58	75	74	19	16
2.	46y/M	37	7	4	D3	62	66	86	83	24	17
3.	54y/M	36	7	4.5	D2	60	67	87	89	27	22
4.	52y/M	37	7	5.5	D3	58	54	78	76	20	22
5.	48y/F	36	7	3.5	D2	67	61	83	84	16	23
6.	51y/F	35	7	3.5	D2	53	59	80	78	27	19
7.	53y/M	36	7	3.5	D2	60	64	89	73	29	09
8.	53y/M	37	7	4	D2	55	51	64	65	09	14
9.	59y/F	46	7	3.5	D3	62	62	83	85	21	23
10.	62y/M	47	7	4.5	D3	64	70	81	86	17	16

*Measured at the time of implant (So) and abutment placement (S1) in apical (A) and buccolingual directions (BL)

Table 2*: Increase in implant stability quotient value from the time of implant placement (S0) to abutment placement (S1)

	Implant placement (S_0)	Abutment placement (S_1)	Difference	t value	p value
BL	59.70±4.07	80.60±6.82	–20.90	–10.133	0.001**
A	61.20±5.60	79.30±7.01	–18.10	–12.8	0.001**

*Comparison of implant stability quotient from S_0 to S_1. Paired *t*-test; **Indicates significant difference at $P \leq 0.05$

habits, and implant placement in host versus grafted bone have also been observed to be contributing factors [Figures 10 and 11]. Östman *et al.*[22] discovered higher stability with increased implant width yet diminishing stability with increasing implant length.

Successful osseointegration from the clinical standpoint is a measure of implant stability, which occurs after implant integration. Primary stability refers to the mechanical engagement of an implant with the surrounding bone, whereas bone regeneration and remodeling phenomena determine the secondary (biological) stability of the implant. A secure primary stability has been noted to be positively associated with a secondary stability. Bone quantity and quality, implant geometry, and surgical technique adopted are some of the clinical factors that affect implant stability.[12] It was hypothetized that primary stability may be more difficult to achieve with short implants due to decreased bone-implant contact.[23] The contact area is determined by length, taper, diameter, and the surface texture.[24] Therefore, osseointegration of the bone-implant interface has been suggested to be increased using wide-diameter or rough-surface implants.[6,25]

Meredith *et al.*,[13] and Sennerby and Meredith[14] were the first to propose RFA as a highly effective qualitative method to assess implant stability. In 2000, the results of a study on the biological, biomechanical, and clinical aspects of measuring implant stability by RFA were reported. The stability of various types of implants as well as their behavior under different bone and loading conditions can be analyzed quantitatively and qualitatively using the RFA.[26]

Alonso *et al.*[27] assessed the effect of bone quality on the primary and secondary stability of 39 single short implants (4.1 × 6-mm long) placed in the posterior region of the maxilla or mandible in 18 patients. The mean ISQ values were higher at abutment installation than at implant placement ($P < 0.05$), regardless the bone type. They concluded that bone quality influences both the primary and secondary stability of single short implants in the posterior region.

Kim *et al.*[28] evaluated the clinical prognoses of 46 short implants (7-mm long) in the mandible of 20 study subjects. Primary and secondary implant stability, and marginal bone loss, and peri-implant soft-tissue index 12 months after the final prosthetic delivery were assessed. The short implants in this study categorized as Group 1 (Two-stage and submerged placement) and Group 2 (One-stage and non-submerged placement). The authors of this study found no statistically significant differences in the primary and secondary stability between the two groups ($P > .05$).

Balleri *et al.*[29] studied stability of 45 implants were placed in 14 patients after 1 year of loading, using RFA measurements using Osstell (Integration Diagnostics, Savedalen, Sweden) after 1 year of loading. Implant stability levels were in the range of 57–82 ISQ units. No correlation could be found between implant length and stability, and only minor marginal bone resorption was observed.

Marginal bone loss is considered a biological complication[30] and a consistent parameter to rate the success of an implant.[31] The success criteria proposed by Albrektsson *et al.*[32] states MBL as the first parameter, wherein an implant losing 1 mm MBL after the 1st year of implant placement and 0.2 mm in the following years was considered successful.[33] Studies across literature have shown a great range of values with mean marginal bone loss varying from 0 to 2 mm after 1-year follow-

Table 3*: Crestal osseous level values of 10 subjects at the time of implant placement (C0)

Sr. No.	Pt Details	Edentulous Site	Implant H (mm)	Implant D (mm)	Bone Density	C_0			
						M	D	B	P
1.	56y/F	46	7	4	D2	8.91	8.49	8.64	8.25
2.	46y/M	37	7	4	D3	8.50	8.55	8.44	8.49
3.	54y/M	36	7	4.5	D2	8.68	7.37	8.82	8.98
4.	52y/M	37	7	5.5	D3	8.56	8.37	8.98	8.04
5.	48y/F	36	7	3.5	D2	8.63	8.08	7.79	8.64
6.	51y/F	35	7	3.5	D2	8.32	8.49	8.10	8.56
7.	53y/M	36	7	3.5	D2	8.19	8.68	8.55	8.36
8.	53y/M	37	7	4	D2	8.45	8.80	8.83	8.72
9.	59y/F	46	7	3.5	D3	8.47	8.74	8.35	8.19
10.	62y/M	47	7	4.5	D3	7.98	7.33	7.30	7.56

*Evaluation of Crestal Bone Levels using Cone-beam computed tomography at the time of implant placement (Co)

Table 4*: Crestal osseous level values of 10 subjects at the time of abutment placement (C1)

Sr. No.	Pt Details	Edentulous Site	Implant H (mm)	Implant D (mm)	Bone Density	C_1			
						M	D	B	L
1.	56y/F	46	7	4	D2	8.58	8.23	8.29	8.20
2.	46y/M	37	7	4	D3	8.74	8.19	8.06	8.04
3.	54y/M	36	7	4.5	D2	8.39	7.30	8.34	8.69
4.	52y/M	37	7	5.5	D3	8.25	8.57	8.59	8.99
5.	48y/F	36	7	3.5	D2	8.35	8.44	7.53	8.35
6.	51y/F	35	7	3.5	D2	7.93	8.14	8.31	8.06
7.	53y/M	36	7	3.5	D2	8.42	8.36	8.24	8.13
8.	53y/M	37	7	4	D2	8.17	8.47	8.58	8.59
9.	59y/F	46	7	3.5	D3	8.25	8.42	8.09	8.47
10.	62y/M	47	7	4.5	D3	7.70	7.69	7.07	7.30

*Evaluation of crestal bone levels using cone-beam computed tomography at the time of abutment placement (C1)

Table 5*: Decrease in crestal osseous level values from the time of implant placement (C0) to abutment placement (C1)

	Pre-op (C_0)	Post-op (C_1)	Difference	t value	p value
Mesial	8.46±0.26	8.40±0.25	0.06	1.194	0.263 (NS)
Distal	8.29±0.54	8.18±0.40	0.11	1.143	0.283 (NS)
Buccal	8.38±0.52	8.32±0.50	0.06	2.045	0.071 (NS)
Lingual	8.38±0.40	8.28±0.46	0.10	0.717	0.492 (NS)

*Comparison of Crestal Bone Level from C_0 to C_1. Paired *t*-test; NS: Non-significant

up. These differences may be attributed to the limits used as a reference to measure the marginal bone loss or the placement of the implants at different levels of the crestal bone.[32,34,35]

The initial bone loss occurring during the 3 months after placement can be explained as result of early remodeling. Nonetheless, in a study performed by Isidor,[36] a bone gain occurred after the implants were loaded. Most of the peri-implant bone loss changes occur during the 1st year after implant placement.[32,36,37]

Zadeh *et al.*[38] compared the marginal bone loss (MBL) changes and survival of 6- and 11-mm implants in 95 patients receiving a total of 209 dental implants. Radiographic assessment of marginal bone loss (MBL) 3 years after loading revealed the MBLs for test and control groups were significantly different in favor of short implants. The cumulative survival rates from placement after 3 years were 96% and 99% for the 6- and 11- mm implants, respectively, with no statistical significance.

Anitua *et al.*'s[39] study evaluated the influence of CI on marginal bone loss (MBL) in 168 short implants (<8.5 mm in length) placed in posterior areas of maxilla and mandible of 63 patients. The data were split into two groups according to the value of CI ratio (CI <2 and CI ≥2). 86 implants (67.2%) had a CI ratio of <2, whereas it was ≥2 in 42 implants (32.8%). The study concluded that CI ratio had not a significant influence on MBL.

A study by Nunes *et al.*[40] evaluated the influence of CI in implants on MBL using Periapical radiographs considering 111 dental implants measuring 4 × 7 mm in 59 patients, in function for 36 months. A weak non-significant correlation was registered between CI and MBL.

The deficiency of this prospective study lies in a small sample size, and lack of long-term follow-up. In addition to inconsistencies across literature regarding the definition of short implants, dearth of data assessing the stability and crestal osseous changes of short implants necessitates further trials involving a larger sample size.

SUMMARY AND CONCLUSION

Our study suggests that short implants may prove to be a reliable and predictable alternative to conventional implants at edentulous sites with reduced alveolar height. Short implants will reduce the number of surgical interventions, total treatment time, and expenses related to augmentation procedures involving increase in alveolar height. Our prospective study used the most accurate methods available today to objectively measure implant stability as well as osseous crestal changes in the peri-implant region. Although the results of our study are encouraging, the small sample size, the lack of exposure of short implants to masticatory loads, and the limited duration of our study limits the significance of our study. This necessitates further clinical research in this aspect of dental implantology.

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