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Assessment of Peri-Implant Bone Density Changes in Compressive Dental Implants in Posterior Mandible: A Radiographic Study

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ABSTRACT

Immediate loading of dental implants has witnessed a rapid evolution over the years; New implant designs and systems have appeared. Hence, more studies are needed to better determine the efficacy and clinical outcomes of these systems. This study aimed to assess radiographic bone gray-scale values changes around the newly-designed compressive implants after immediate loading. A prospective clinical study was carried out. 10 compressive implants were placed in patients having missing teeth in the posterior region of the mandible. Cone-beam computed tomography (CBCT) was used to follow-up patients immediately, 6 months, and 12 months postoperatively. Grey-scale values from the CBCT images were implemented as indicators for bone density around dental implants. Changes in grey-scale values around the implants were evaluated from the buccal, lingual, mesial and distal implant sides. An increase in the average values of bone density around implants was observed throughout all studied periods, and these findings were more significant after 6 months post-surgically. In conclusion, the compressive threads and tapered design of compressive dental implants allowed forming a highly dense bone around the implant, and high primary stability was achieved, which in turn contributed to the overall success of these implants in immediate loading.

1. Introduction

Implant-supported restorations represent a unique and reliable treatment modality to rehabilitate partially or fully missing dentition [1]. Over the last few decades, there was a major and continuing development of implant loading protocols, and new implant systems were designed and surgical techniques have been improved to satisfy patients increasing demands [2], [3]. The demand for good results in terms of aesthetics, function and comfort is also accompanied by the desire of decreasing surgical session times, number of procedural stages, and durations to replace missing teeth with appropriate prostheses as soon as possible [4].

The Brånemark original protocol is based on leaving the implants without any loading after placement for 3-4 months in the mandible, and 4-6 months in the maxilla. This long treatment time that includes a temporary prosthetic phase may cause unendurable inconvenience for some patients [5]. Other solutions that can be considered by oral surgeons and implantologists, e.g., immediate implant placement and immediate loading modalities are highly demanded by patients [6]. The immediate loading suggestion, according to the medical literature, can offer a reliable protocol for the rehabilitation of missing tooth or multiple teeth. This procedure may possess several benefits, including preservation of the peri-implant soft tissues and enhancing the density of the peri-implant bone [3], [7].

Compressive implants are usually one-piece implants that have a uniquely-designed monobloc structure that integrates both implant and abutment in a single component to guarantee a fast and easy one-stage procedure [8]. These implants have compressive threads that generate compression forces when inserted into the spongy bone, thereby forming a layer of cortical bone (lateral condensation) around the implant which permits immediate loading with high primary stability. Implant stability is significantly enhanced by a mechanism that could be best described as "corticalization" of the cancellous bone [5], [9]. Peri-implant bone corticalization phenomenon, also known as osseocorticalization, is dependent on dental implant design and prosthetic type [10]. Compressive implants are considered single-threaded implants with an arrow V-thread design that provides bone-condensing characteristics [11]. The parallel-sided implant was regarded as the standard implant design for many years. Later on, the tapered implant design was introduced and presented some advantages compared to the parallel-sided implant design. Tapered implants condenses the surrounding bone, when reduced or unfavorable bone quality exists during the insertion phase. Also, it has a greater ability in distributing the occlusal forces to the surrounding bone [12], [13]. Many studies demonstrated a greater primary stability with tapered implants when compared to cylindrical or parallel-sided implants [14], [15]. No evidence of negative effect of the implant tapered design on peri-implant bone was found according to [13].

Implant surface properties also affect primary stability. It has been shown that rough implant surfaces allow for greater contact area between the implant and surrounding bone [16]. Dental implant primary stability can be defined as the absence of implant mobility immediately after placement, as a result of mechanical engagement with the peri-implant bone [2], [17]. For a successful immediate loading procedure, excellent primary stability must be achieved, and can be verified intraoperatively by checking and measuring the implant insertion torque [18]. Many factors can affect insertion torque values such as the recipient site, bone quality and quantity, implant geometry and the surgical technique [19]. According to the literature, it is typically acknowledged that the concept of immediate loading is based on achieving an insertion torque of 35 N.cm or higher to obtain adequate implant primary stability that can withstand loading forces [20], [21]. It was also highlighted that an implant insertion peak torque of a minimum of 60 N.cm is required to restore a single tooth, 45 N.cm for implants supporting partial prosthesis, and 32 N.cm for implants supporting full-arch prosthesis [22]. In contrast, excessive bone compression may result in undesirable effects on peri-implant bone, e.g., increased crestal bone resorption and osteonecrosis.

For immediate loading, it is crucial that enough bone height and width are available. The favorable bone quality to achieve the necessary insertion torque for immediate loading is the bone of types: D1, D2, and D3. On the other hand, it is almost impossible to reach that insertion torque in situations with bone of low density is available. Therefore, the use of a surgical technique to locally optimize bone density is required. These techniques include under-preparation of the recipient sites, use of osteotomes, osseodensification, and compressive tapered dental implants [12], [13].

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Cone-beam computed tomography (CBCT) may be considered an objective diagnostic tool to evaluate bone healing, and to assess bone quality via measuring the grey-scale values [23], [24]. Positive correlation between CBCT grey-scale values and Hounsfield units of computed tomography (CT) images indicates a valid methodology for assessing bone density on the CBCT image [25]. The primary aim of this study was to assess the bone density values by measuring the CBCT grey-scale values around compressive implants after immediate loading in the posterior region of the mandible.

2. Material and methods

2.1 Study design

This work was conceived and designed as a prospective clinical trial which was carried out between October 2020 and June 2022 in the clinics of Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine at Damascus University. This clinical trial was authorized by the Research Ethics Committee of Damascus University (registration no. 2019-4012).

2.2 Sampling and eligibility criteria

This study included male and female participants with ages ranged between 26-49 years. Inclusion criteria also included: missing posterior mandibular teeth (i.e., premolars and molars); good general health and oral hygiene; sufficient alveolar bone height and width to insert implants of the minimum length of 10 mm and a minimum diameter of 3.5mm. The exclusion criteria were: inadequate interocclusal relation or severe intermaxillary discrepancy; presence of local or general infection (i.e. chronic periodontal disease) in the recipient site; medically-compromised patients having contraindicating factors to implant placement or factors affecting bone density (e.g., osteoporosis, uncontrolled diabetes, radiotherapy, etc.); patients on corticosteroids treatment with possible adverse effects on bone metabolism; and patients with parafunctional habits (i.e., bruxism or clinching). The patients' signed consent was obtained from each participant. The study sample included 10 compressive implants placed in the mandibular posterior region, and subjected to immediate loading.

2.3 Preoperative phase

All detailed data related to patient’s personal, medical and dental history were recorded to ensure that there are no cautions or contraindications for oral surgery. A thorough clinical examination of the oral cavity and interocclusal space assessment were performed. Preoperative CBCT image was obtained to properly plan for implant placement, and to evaluate the alveolar bone dimensions and density at the recipient site. All patients assumed a prophylactic antibiotic therapy (i.e., amoxicillin) before surgery.

Figure 1 : The compressive dental implant used in the present study.

2.4 Surgical phase

Chlorhexidine 0.12% mouthwash was used to rinse the patient's mouth for 30 seconds pre-surgery. Under local anesthesia, a crestal incision was performed. A full-thickness mucoperiosteal flap was elevated. 2-mm pilot and coronal flaring final drills were used for osteotomy in the implant recipient sites. One-piece sandblasted compressive dental implants (Roott Implant system, TRATE AG, Switzerland) were used in this study (Figure 1). These implants are made from titanium alloy Ti-6Al-4V. Implants were placed and threaded clockwise with moderate finger pressure until resistance was felt. A ratchet with a suitable holder was then used to continue the insertion process of the implant to the full depth. At this point, peak insertion torque values were observed and recorded as an assessment of primary stability values. Patients were given the necessary oral hygiene instructions. Post-operative medications included antibiotics (i.e., augmentin 1g, tab, b.i.d.); and non-steroidal anti-inflammatory drugs (i.e., diclofenac 50mg, tab, t.i.d.). Sutures removal and immediate restoration were done within 7 days post-operatively.

2.5 Follow-up

All patients were clinically evaluated and followed up regarding any post-surgical possible complications. All implants were followed up radiographically using CBCT imaging immediately, 6 months and 12 months after the implant placement procedure. Changes in grey-scale values were evaluated from the buccal, lingual, mesial and distal sides using a standardized method; by taking a density profile line along the long axis of the implant at a specific distance of 0.5 mm from the implant. Average radiographic density values from each profile line (Figure 2) were used for statistical analyses.

2.6 Statistical analysis

Variables were studied using SPSS software version 19 (Released 2010; IBM Corp., Armonk, New York, United States). Significance level was set at P value < 0.05. Distributions of qualitative frequency were calculated. Means and standard deviations were measured at the confidence level of 95%. One-way repeated measurements ANOVA tests were used to compare differences in mean grey-scale values between time intervals.

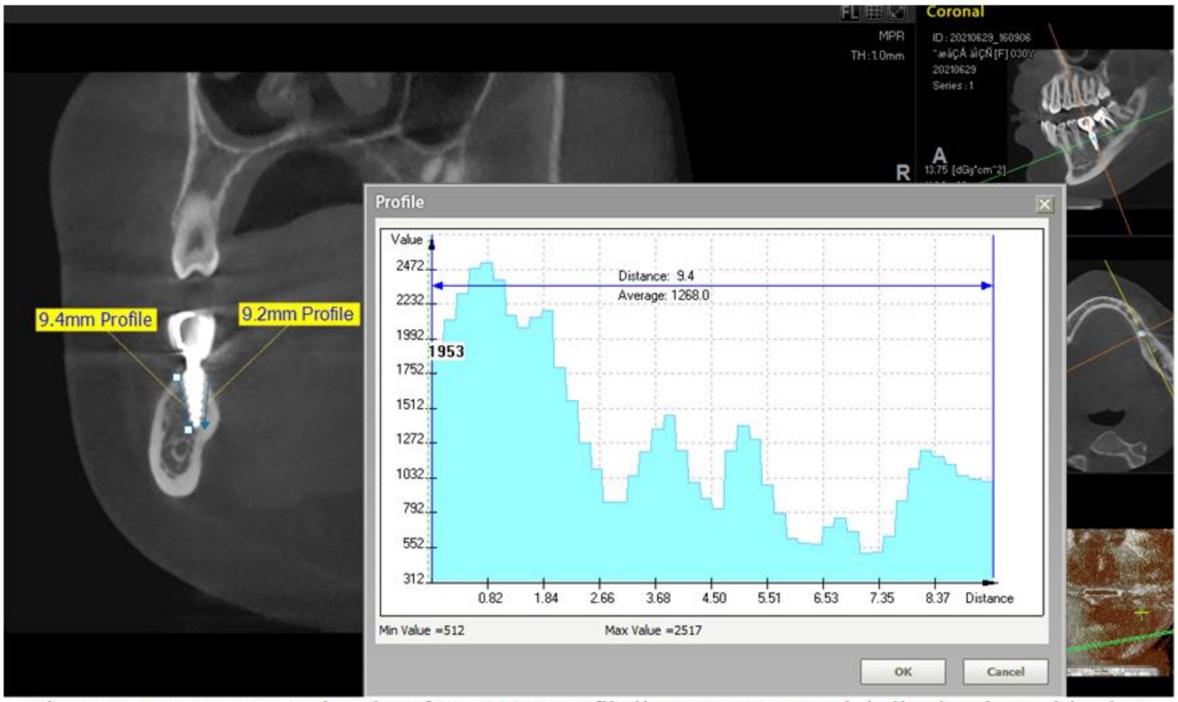

Figure 2: Average grey-scale values from CBCT profile lines were measured, indicating the peri-implant bone density in different follow-up timepoints. CBCT, Cone-beam computed tomography.

Table 1: Evaluation of grey-scale values around implants showing an increase in mean values, especially after 6 months post-surgery. Data were presented as means ± standard deviation.

Peri-Implant Side	Radiographic grey-scale mean values				P
	Baseline	Immediately	6-Month	12-Month	
Buccal	983 ± 226	1033 ± 228	1667 ± 211	1731 ± 208	0.000
Lingual	1014 ± 210	1078 ± 195	1703 ± 162	1773 ± 166	0.000
Mesial	775 ± 203	811 ± 192	1420 ± 227	1439 ± 283	0.000
Distal	814 ± 189	838 ± 189	1435 ± 244	1455 ± 284	0.000

3. Results

A total of 10 compressive implants were placed for patients having missing teeth in the posterior mandibular region. Patients' age ranged between 26-49 years, with a mean age of 39.2 years. Primary stability was clinically acceptable in all implants, as the insertion torque ranged between 35 and 55 N.cm, with a mean value of 42 (±3.5) N.cm. Table 1 shows mean grey-scale values as bone density values around implants at baseline, immediately after, 6 months, and 12 months post-surgery. Assessment of buccal bone showed that mean bone density values after 1 year was significantly higher than before implant placement by 748 units, higher than after implant placement by 698 units, and higher than after 6 months by 64 units ($P<0.001$). Lingually, mean bone density values after 1 year was significantly higher than before implant placement by 759 units, higher than after implant placement by 696 units, and higher than after 6 months by 70 units ($P<0.001$). Mesially, bone density after 1 year was significantly increased compared to pre-treatment by 663 units, and it was higher than after implant placement by 628 units ($P<0.001$). A same trend was found distally; Bone density after 1 year was significantly more than before implant placement by 641 units, and higher than after implant placement by 617 units ($P<0.001$). Measurements from the proximal (mesial and distal) sides showed insignificant increase (by ~20 units) in mean grey-scale values from 6-

month to 12-month follow-up timepoints.

4. Discussion

Compressive one-piece implants are cost- and time-effective compared to conventional implants, with no need for cover screws, healing abutments or any additional implant abutments. The compressive one-piece implant can be used to create single restorations whenever high primary stability is achieved during implant insertion. It can be also used for multiple unit restorations with immediate loading in the upper and lower jaws with adequate bone tissue. It can be also used in cases where a combination with a conventional implant is necessary and it allows flap or flapless implant placement. The minimum recommended insertion torque for these implants is 35 N.cm [9].

In this study, 10 one-piece compressive implants were placed in the posterior mandibular region. Medically-compromised patients or patients with the systemic diseases were excluded to prevent any possible interference with the healing process. Patients with intermaxillary discrepancies or parafunctional habits were also excluded to prevent any excessive loading or multi-directional forces on the implants. All implants were placed in function immediately within 7 days. No post-surgical complications were recorded except for mild pain and swelling in the early postoperative period.

A significant increase in bone density was noticed around all implants during the follow-up periods. This had contributed to the success of these implants, as the survival rate after one year of follow-up was 100%. Similar findings were reported in the literature; dental implants and immediate loading offered many advantages, and resulted in significant increase in peri-implant bone density [7]. Changes in bone densities were minimum during the first month after implants placement and increased significantly later on after 6 months and 12 months, respectively. These findings were in line with [26]. They demonstrated the role of osteoclasts activity, particularly during the first month after implant insertion (remodeling phase) and the consequent bone resorption. Within 1 to 6 months postoperatively, a stable increase in bone density values can be observed, reflecting the role of osteoblasts in alveolar bone apposition [26].

The mean value for insertion torque was 42 N.cm, these results seemed to be in agreement with a study performed by [27] which concluded that it is preferable to insert single implants with a high insertion torque to minimize early implant failures, when loading them immediately. Similar results were shown in a systematic review; it demonstrated that immediately-loaded single implants were successful when inserted with a torque ranging between 20 and 45 N.cm [28].

One of the main advantages of compressive implants is that they are less likely to exhibit micromotion after immediate loading. This can lead to better success rate, as micromotion can lead to failed implant osseointegration [29]. Another benefit of compressive one-piece implants is that they can be placed more easily, with less trauma, and less potential contamination to the surrounding tissues than traditional implants. This is because they do not require a separate abutment connecting the implant body to the functioning restoration. Instead, the implant and abutment are integrated into a single unit, which can simplify the implant placement process and reduce the risk of complications. Guidelines and a novel classification system were recently proposed to improve the outcomes of single-piece compressive dental implants [30].

Nevertheless, this prospective clinical study had some limitations. First, all implants were placed in the posterior region of the mandible, so, outcomes may not necessarily be generalizable to other regions. Although radiographic study using CBCT is essential and valid in comparing grey-scale density values, lack of a histological study would comprise a study limitation. The clinical nature of this study made it impossible from the ethical viewpoint to perform a histological analysis. Finally, given the limited sample size and short-term follow-up period, a recommendation for future study with larger sample size with long-term follow up is warranted.

5. Conclusion

Within the limitations of this study, it was concluded that bone density around immediately loaded compressive single-piece dental implants has significantly increased mainly over the period of 6 months after implant procedure. This would have a positive effect on the overall success of these implants. It is important to highlight that the success of these implants in immediate loading is highly dependent on patient selection, bone quality and implant primary stability.

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