Histomorphometry of 2 Immediately Loaded Mini Implants Retrieved From Human Mandible After 3 Months: A Light and Scanning Electron Microscopy Report

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Today, mini implants represent an additional choice for patients and surgeons. They are largely used as anchorage when a severely resorbed mandible is to be rehabilitated with an overdenture, their major advantages being flapless, painless surgery and easy placement in thin alveolar crests without any split-crest or bone-grafting procedure. Unfortunately, the literature provides little information on histomorphometric analysis of immediately loaded mini implants placed in the posterior region of the human mandible. The aim of the present in vivo research is to carry out a histologic evaluation of the bone surrounding 2 mini implants placed in human mandible and immediately loaded with an overdenture after 12 weeks. A patient who underwent extraction of 14 periodontally compromised teeth was selected for the present study. After the extractions, 2 mini implants with ball attachment were placed in sites 19 and 30. Mini implants were immediately loaded with a temporary immediate overdenture. Three months after the extractions, the mini implants were harvested and processed for light and scanning electron microscopy. The bone-to-implant contact and the percentage of bone between the threads of the screw were, respectively, 86.3% and 72.6% for the right implant and 69.8% and 71.9 % for the left implant. Newly formed bone between the implant surface and the preexisting bone was present, with poorly represented medullary spaces. Under a scanning electron microscope it was possible to appreciate the presence of well-organized, newly formed lamellar bone with osteons in the areas near the implant body. From the present in vivo report it is possible to state that immediate load applied on mini implants, placed into the posterior regions of the mandible, leads to a clinically and histologically effective osseointegration.

Key Words: mini implants, histology, overdenture

INTRODUCTION

Mini implants were first introduced for the stabilization of temporary restorations.[1] They were inserted at the same time as standard diameter implants (3.75 and over), immediately loaded with a provisional restoration,

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DOI: 10.1563/AAID-JOI-D-10-00135

and removed at the time of conventional implant restoration (usually 3 to 6 months after surgery).

In 1997, 1999, and 2003, various forms of titanium implants with a diameter less than 3.0 mm, were cleared for long-term use by the US Food And Drug Administration.[2] In the dental literature, such as "mini implants," "small diameter implants," or "narrow implants" are all generally used to refer to implants with a diameter ranging from 1.8 to 3.3 mm. They are very popular today, being indicated for clinical conditions in which standard-diameter implants cannot be placed because of excessive bone resorption in patients who are not candidates for surgical bone-volume augmentation procedures. Thus, mini implants been recognized as being cost-effective and time saving. Although they are used in removable and fixed prosthodontics, their most common use is in the stabilization of lower complete dentures. In such cases, mini implants are placed in the interforaminal area of the mandible with a flapless technique and immediately loaded by relining the patient's preexisting denture. Furthermore, clinical studies state that mini implants show a predictable long-term success rate and are suitable for immediate loading. In 2007, Shatkin and colleagues[3] published a retrospective analysis of 2514 immediately loaded mini implants, 1256 of which were placed in the mandible. In this study, an overall implant survival rate of 94.2%, calculated on mandibular and maxillary mini implants, was reported for a mean observation period of 2.9 years. Mean failure time was 6.4 months. Other studies are available in the literature, but these generally refer to mini implants used for orthodontic anchorage.

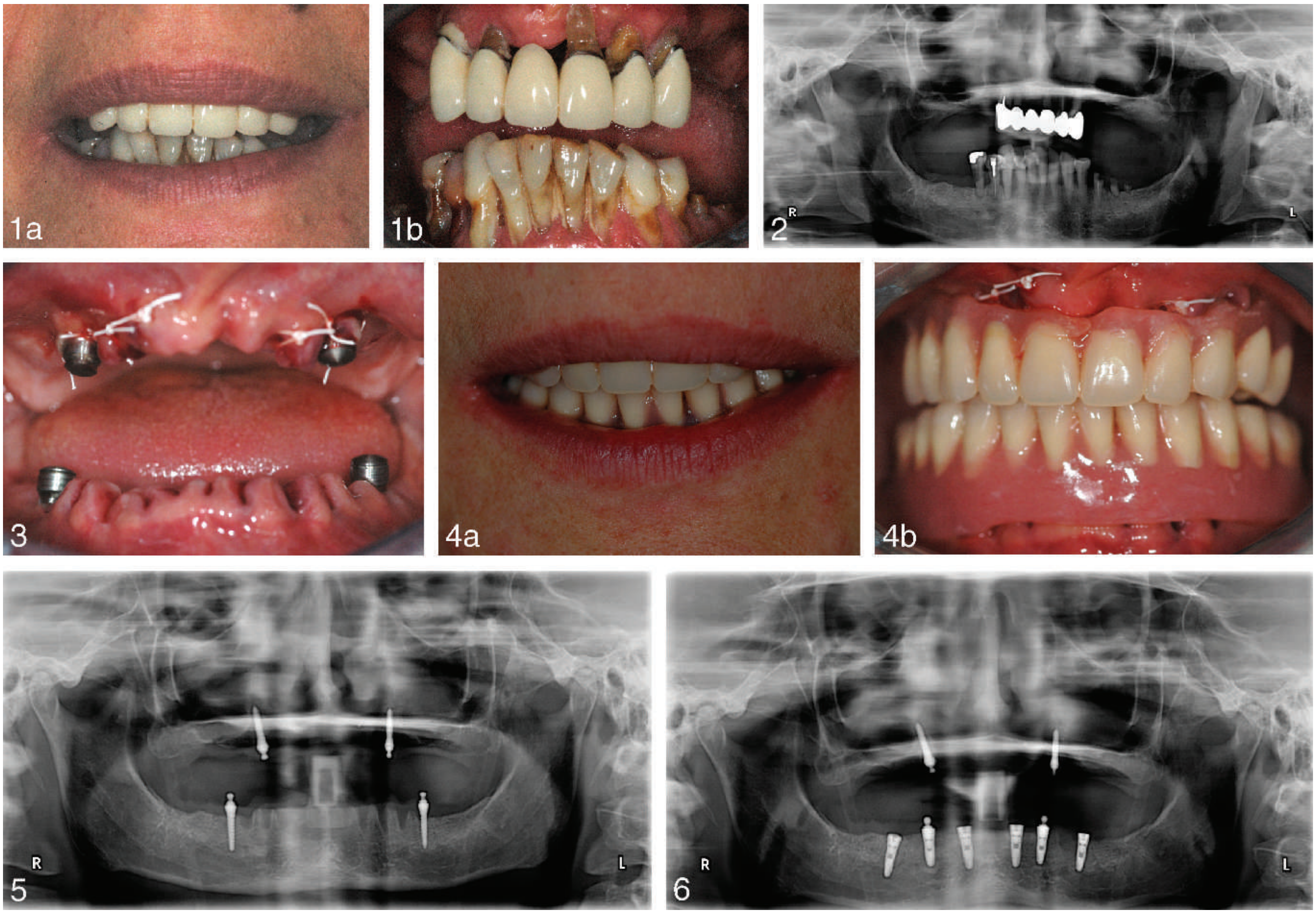
Histomorphometric studies on immediately loaded implants show that osseointegration is comparable to that of conventionally loaded implants. Recently, a histomorphometric and fluorescence analysis of immediately loaded orthodontic mini implants inserted in rabbit tibiae was published by Serra and colleagues[4]; in that study, the authors placed 2.0 mm wide × 6.0 mm long implants in 18 New Zealand rabbits; half of the implants were immediately loaded with a nickel-titanium closed-coil spring. The animals were euthanized for histology at 1, 4, and 12 weeks. Serra and colleagues[4] found that after 12 weeks of healing there was no significant difference in the amount of osseointegration (calculated as percentage of bone-to-implant contact and bone between the threads of the implants) between unloaded and immediately loaded samples, even if the loaded samples exhibited a more organized tissue. However, after 4 weeks of healing, a denser wound tissue was present around immediately loaded mini implants compared with unloaded samples, suggesting an accelerated healing process.

Unfortunately, the literature lacks information on histomorphometry of immediately loaded mini implants placed in the posterior region of the human mandible. Thus, the aim of the present in vivo research was to conduct a histologic evaluation at 12 weeks of the bone surrounding 2 mini implants placed in human mandible and immediately loaded with an overdenture.

Materials and Methods

A patient (49-year-old woman, heavy smoker) requiring the extraction of 14 periodontally compromised teeth was selected for the present study. The patient was in good health; in particular, during the previous 6 months she had not been affected by acute myocardial infarction, uncontrolled coagulation disorders, or uncontrolled metabolic diseases (eg, diabetes mellitus, bone pathologies). In addition, she had not been treated with radiotherapy to the head/neck area or with intravenous bisphosphonates within the previous 24 months. Oral examination was based on clinical exam, preoperative panoramic radiograph, and study models mounted on a semiadjustable articulator with a face bow. Clinical examination of the upper arch revealed the absence of posterior upper teeth; a metal-ceramic bridge was present in the anterior region. In the lower jaw, teeth from 21 to 29 and roots of 19 and 20 were present. A first-grade mobility of the upper bridge was recorded, and the lower dentition was affected by second-grade mobility (Figure 1). The preoperative panoramic radiograph excluded the presence of periapical radiolucency (Figure 2). Examination of study models and a diagnostic wax-up based on a bilateral balanced occlusion revealed that the patient's centric occlusion and vertical dimension did not need to be modified. Clinical examination based on the evaluation of esthetic and phonetic parameters confirmed the uselessness of modifying the centric occlusion, vertical dimension, and bucco-palatal inclination of the remaining frontal teeth.

The following treatment plan was proposed for the mandibular arch: extraction of the remaining



FIGURES 1–6. FIGURE 1. Clinical examination of the patient. **FIGURE 2.** Radiography of the patient. **FIGURE 3.** Mini implants inserted after extraction of remaining teeth. Matrices were positioned on mini implants. **FIGURE 4.** Temporary overdentures in situ. **FIGURE 5.** Radiographic control at the time the mini implants were inserted. **FIGURE 6.** Radiographic control after harvesting of lower mini implants and placement of 6 standard-diameter implants.

teeth and insertion of a temporary complete overdenture retained by 2 mini implants. The mini implants would be maintained throughout the socket healing time after extraction; thereafter, the mini implants would be removed and 6 standard diameter implants would be placed (4 in the healed bone and 2 in the surgical site from which the mini implants would be removed). Standard implants placed in sites 22 and 27 would be used to retain the provisional overdenture throughout the peri-implant healing time. Afterward, a fixed metal-ceramic bridge would be placed. With regard to the maxillary arch, because the patient refused bilateral sinus lifting, an implant-supported overdenture was planned.

Surgical protocol

Premedication was conducted by administering amoxicillin 2 g/day for 3 days. At the time of surgery, the patient was draped to guarantee maximum asepsis. The perioral skin was disinfected using iodopovidone 10% (Betadine, Purdue Pharma, Stamford, Conn), and the patient was asked to rinse with chlorhexidine mouthwash 0.2 % (Corsodyl, SmithKline Beecham, Brentford, Middlesex, UK) for 30 seconds. The teeth were extracted under local anesthesia with articaine 40 mg/mL + adrenaline 5 μg/mL (Pierrel SpA, Milan, Italy); thereafter, 4 mini-ball implants 2.6 × 10 mm (Pro-Gress, Antogyr, Dentalica SpA, Milan, Italy) were inserted in the posterior areas of the jawbones (approximately in the 5, 12, 19, and 30 sites), avoiding placement in postextraction sites. Surgical sites were prepared using a drill with a diameter of 2.2 mm at 500 rpm under external irrigation with saline solution at room temperature. Because the implants used in the present study were self-tapping, site depth was 7 mm for the mandible and 5 mm for the maxilla;

mini implants were inserted at 5 rpm using a specific mounting attached to the implantology contra-angle handpiece controlled by a physiodispenser (W&H, Dentalwerk, Salzburg, Austria) with a recorded peak insertion torque of 35Ncm (implant positioned in site 19) and 37 Ncm (implant positioned in site 30) (Figure 3).

Prosthodontic

Before surgery, a technician made an upper and a lower temporary completely removable denture in acrylic resin from wax-up. Provisional dentures were in centric occlusion at the same vertical dimension registered at the preliminary impression-making time. Mini implants were immediately loaded with temporary immediate dentures: caps containing silicone O-ring matrices were attached to the balls and connected to the denture base at chairside using a self-curing resin (Tokuyama Rebase II, Tokuyama Dental Corporation, Tokyo, Japan); areas of prosthetic base in contact with postextraction sites were relined using a soft resin (Sofreliner Tough, Tokuyama Dental Corporation) (Figures 4 and 5). Postextraction sites and peri-implant healing were controlled monthly, and the dentures were relined during the healing of postextraction sockets.

Specimen collecting and processing

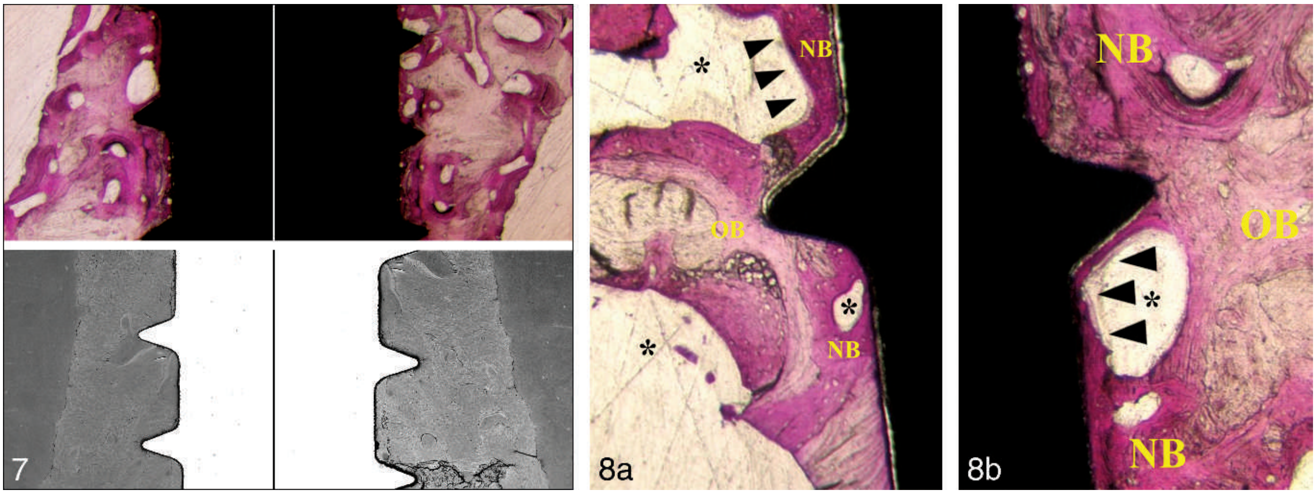
Three months after placement, the mini implants positioned in the mandible were harvested using a 4-mm trephine drill, and 6 standard-diameter implants were positioned (Figure 6); the temporary mandibular overdenture was connected to 2 of the standard implants to ensure retention. After harvesting procedure, mini implants were washed in phosphate buffered saline, fixed in 4% formalin, and dehydrated in an ascending series of alcohol. Afterward, the samples were embedded in resin (LR White EM, TAAB Laboratories Equipment Ltd, Aldermaston, UK) and sectioned in the longitudinal plane with a microtome (Micromet, Remet s.a.s., Casalecchio di Reno, Bologna, Italy). One central slide about 300 μm thick was obtained from each sample. Slides were ground and polished to about 90 μm using a specially designed grinding machine (LS2, Micromet, Remet s.a.s.). Subsequently, the slides were stained with toluidine blue and acid fuchsine and analyzed under a light microscope (Leitz Laborlux, Leica Microsystems, Wetzlar, Germany) equipped with a digital camera (3CCD JVC KY-F55B, JVC, Yokohama, Japan). The same slices were then etched for 5 seconds with a 37% orthophosphoric acid, coated with gold (Emitech K 550, Emitech Ltd, Ashford, Kent, UK) and analyzed under a scanning electron microscope (EVO 50, Carl Zeiss AG, Oberkochen, Germany).

Results

At harvesting time, the implants were radiographically osseointegrated and clinically stable. The bone-to-implant contact and the percentage of bone between the threads of the screw were, respectively, 86.3% and 72.6% for the right implant and 69.8% and 71.9% for the left implant. No infrabony pockets, fibrous connective tissue, or inflammatory cells were present (Figure 7). Light microscopy analysis showed the presence of newly formed bone interposing between the implant surface and the preexisting bone, with poorly represented medullary spaces. Where medullary spaces were present, newly formed bone appeared in close contact to the implant surface, suggesting that a contact osteogenesis had occurred (Figure 8). At the apical level of the implant positioned in site 19, a gap appeared between the bone and the implant profile, but at higher magnification it was possible to appreciate that there was a match between the implant and the bone profile, suggesting that the gap was due to an artefact. Scanning electron microscopy analyses on etched samples confirmed the tight contact of the bone to the implant surface and revealed that bone lamellae were oriented around the tip of the implant threads. Also, it was possible to note the presence of well-organized newly formed lamellar bone with osteones in the areas near the implant body (Figures 9 and 10).

Discussion

Insertion of 2 mini implants for temporary lower denture stabilization was planned as part of prosthetic rehabilitation. Also, the harvesting of mini implants was carried out using a 4 mm wide trephine, which left a surgical site suitable for standard-diameter implant positioning; therefore, the harvesting procedure did not harm to the patient. Also, mini implants have been replaced with standard implants because ball attachments



FIGURES 7 AND 8. FIGURE 7. After 3 months, the implants were osteointegrated; both specimens were characterized by trabecular bone with narrow marrow spaces. Newly formed bone, which appears strongly stained by acid fuchsin, was in close contact with the implant surface and the old bone. From the scanning electron microscope image it is possible to note the presence of mature bone with well-organized lamellae and osteones (above: optical microscope images, toluidine blue and acid fuchsin, original magnification ×5; below: scanning electron microscope images; original magnification ×35). **FIGURE 8.** At higher magnification, it is possible to see that newly formed bone (NB) is in close contact with the implant surface. Old bone (OB) is in contact with the tip of implant threads. A thin layer of newly formed bone (arrowheads) separates marrow spaces (*) from implant surface (optical microscope images, toluidine blue and acid fuchsin, original magnification: ×10).

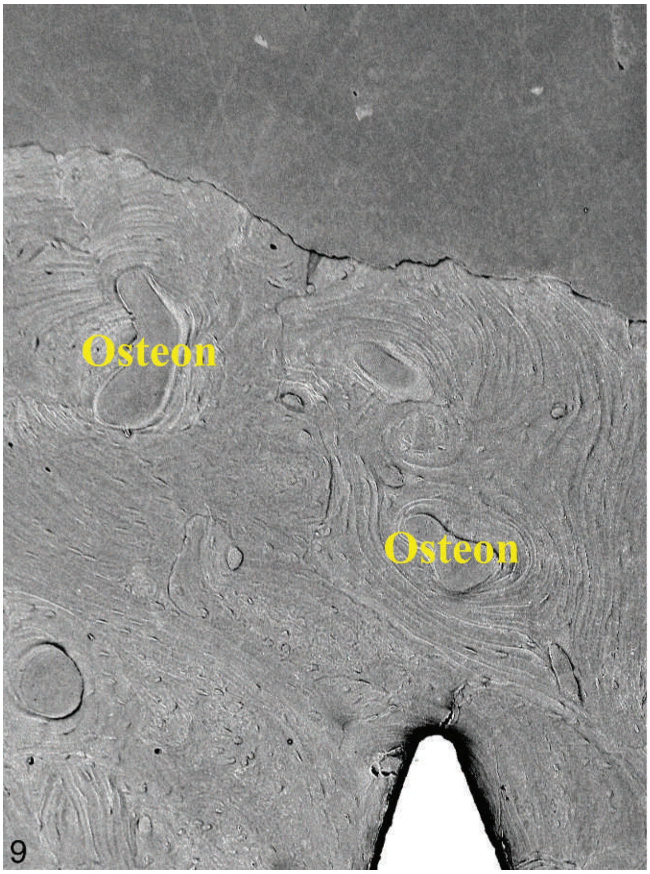
are not suitable to support a fixed metal ceramic bridge. The insertion of 6 postextraction implants to be immediately loaded with a fixed temporary restoration was avoided because of the difficulties in soft tissue management.

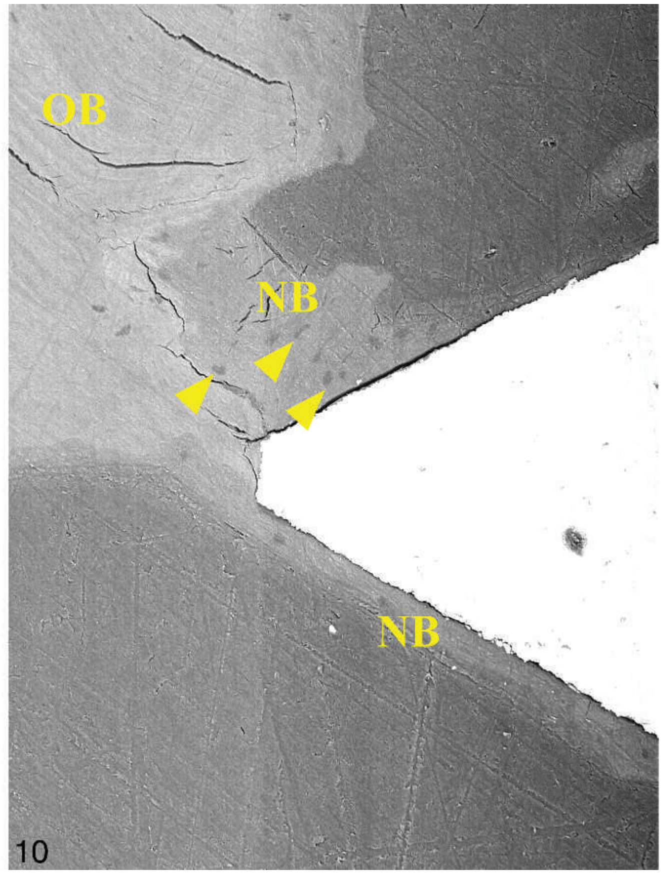
Histologic evaluations of implants retrieved from humans are rare in the literature; case reports published on osseointegrated implants are usually conducted on implants retrieved after fracture or other complications. Also, in such reports the time at which histology is conducted is not scheduled because of the occasional nature of sample collection.

In 2003, Rocci and colleagues[5] published a study in which 9 implants were inserted in the posterior region of mandible; 2 were immediately loaded and harvested after 9 months. Implants analyzed by Rocci and colleagues[5] were a straight 3.75 mm and a tapered 4.0 mm wide. The authors stated that there was no significant difference between implants loaded immediately and after a healing time of 2 months. Supposedly, 9 months of function is too long a time to highlight differences between load modalities. As reported in a human case report[6] and in a monkey histologic study,[7] it seems that immediate loading influences the bone deposition rate rather than the total amount of newly formed bone. In fact, after 2 months of load, Romanos and colleagues[7] described a higher density of bone between the threads of immediately loaded implants; similar conclusions were provided by Testori and colleagues.[6] According to Frost law, it could be speculated that loading within a physiologic range stimulates bone formation.

It is advocated that primary stability is an essential prerequisite for successful implant osseointegration, especially in an immediate-loading protocol. Surgical technique, recipient bone density, and implant design directly influence the primary stability. Tabassum and colleagues,[8] using the undersized surgical technique on an in vitro model, established that a cortical bone thickness over 2 mm is able to significantly improve the primary stability.

With regard to the role of surgical technique in peri-implant bone healing, an interesting article was recently published by Tabassum et al.[9] In this research, the authors suggest that when an undersized surgical technique is used, bone particles are moved in the depths of the surgical site during implant placement; such bone particles show osteogenic potential and could positively influence the peri-implant healing process. However, the study of Tabassum et al[9] was carried out on incubated fresh cadaver bones and provides no information regarding the long-term effects of such





Figures 9 and 10. Figure 9. Scanning electron microscopy analysis conducted on etched sections confirms the presence of lamellar bone with well developed osteones (original magnification ×35). **Figure 10.** Scanning electron microscopy analysis with backscattered electrons. Old bone (OB) is distinguishable from new bone (NB), which shows the presence of many osteocytes (arrowheads). Also, a thin layer of new bone is in close contact with the lower flank of the implant thread (original magnification ×50).

a surgical approach; therefore, caution should be emphasized for undersized technique. It should also be taken into account that an excessive compressive load at the implant/bone interface could have a negative effect on bone healing.

Regarding bone quality, Trisi et al[10] established in an ex vivo model that implant micro-motion is related to torque insertion level and bone density of the recipient site; furthermore, they conclude that it is not possible to register an insertion torque exceeding 35 Ncm in soft bone. Unfortunately, Trisi and colleagues categorized bone quality as “hard,” “normal,” and “soft” rather than DI to DIV, so a direct comparison of their results with those of the present study should be made with caution.

Recently, the group of Toyoshima[11] investigated the relationship between primary stability and implant design with respect to standard and undersized surgical protocol in porcine iliac cancellous bones. They concluded that the self-tapping implant design improves primary stability.

In the present study, bone density was of grade DII to DIII. Also, surgical sites were undersized in respect to diameter and depth, while the self-tapping design of the implants allowed their complete insertion. As suggested by the implant manufacturer, sites with a diameter of 2.2 mm were prepared, and a depth of 7 mm was chosen because the bone was of a medium quality.

The scientific literature[12] suggests that implants should be splinted to avoid deleterious micromotions during the healing process. A rigid connection is generally recommended, and the temporary prosthesis is usually nonoccluding in the centric and eccentric positions of the mandible. With regard to the latter recommendation, because tongue, cheeks, and lips load the temporary restoration during oral functions, researchers are still discussing the clinical relevancy of a nonoccluding provisional restoration. In the present report, the patient was fitted with 2 complete dentures that were worn all through the day, so functional load was inevitably applied to the implants. However, because overdentures are supported by implants and oral mucosa, it should be argued that the implants were partially loaded.

In this study, the implants were connected to each other; however, the connection was not rigid as it is when a bar or a fixed temporary bridge is cemented or screwed onto implants. Because of anatomic reasons, in this report it was not possible to make a retaining bar. In fact, the implants were positioned in the posterior regions of the mandible, as there were postextraction sockets in the anterior area. The retaining systems we used ensure a certain degree of freedom to the prosthesis around implants in order to distribute functional load to implants and oral mucosa at the same time. It is likely that the nonrigid nature of the connection influenced the outcome of the present work. Because of the resilience of the ball attachments, the implants were protected from overload. On the other hand, it is also possible to argue that the implants were not completely protected from micro-movements. However, further studies are necessary to fully understand the clinical relevancy of a nonrigid connection on the success of immediately loaded mini implants.

Conclusions

From the present in vivo report it is possible to state that immediate load applied on mini implants placed into the posterior areas of the mandible leads to a clinically and histologically effective osseointegration. Further research is necessary to establish the long-term efficacy of immediately loaded mini implants.

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