Histologic Evaluation of an Immediately Loaded Titanium Implant Retrieved from a Human After 6 Months in Function

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KEY WORDS

Conical abutment connection
Crestal bone remodelling
Dental implants
Histology
Immediate loading
Microgap

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Clinical and histologic studies have demonstrated that immediate loading can be successfully used in implant dentistry. Many factors are thought to be of importance in obtaining mineralized tissues at the interface. This study describes the implant interface of an immediately loaded implant with a conical implant-abutment connection that had been inserted in the posterior mandible for 6 months. Histology showed that mineralized tissue was present at about 74% ± 6% of the implant interface. No gaps, fibrous tissue, or inflammatory infiltrate were present at the interface. The bone adjacent to the implant was mainly lamellar (90% ± 4.5%). Tetracycline was used to label trabecular bone, and labeled bone was found in direct contact with the implant surface. The extensive labelling by tetracycline demonstrated a large quantity of newly formed bone at the implant interface. The distance between the 2 lines marked by tetracycline was 85 ± 5 mm. The results of this study show that immediately loaded dental implants can form mineralized tissues at the bone-implant interface.

Introduction

An important prerequisite for obtaining mineralized tissues instead of fibrous tissues at the interface of dental implants was an unloaded healing period of 3 to 4 months in the mandible and 6 months in the maxilla.[1,2] Early or immediate loading of dental implants was thought to disturb bone healing and result in fibrous repair.[3–5] However, several clinical and histologic studies in man and experimental animals have demonstrated that implants that were immediately loaded were clinically successful and developed bone at the implant interface.[6–49]

Immediate loading has the advantages of providing immediate restoration of esthetics and functions,[34] reducing the number of patients visits, reducing the morbidity of a second surgical intervention, and facilitating the

TABLE
Teeth replaced with implants

	Diameter, mm	Length, mm
30 implant Ankylos		4.5 × 11
31 implant Ankylos		5.5 × 11
32 implant Ankylos*		3.5 × 8
26 implant XiVE		3.8 × 18
23 implant XiVE		3.8 × 18
21 implant XiVE		4.5 × 15
20 implant XiVE		3.8 × 15
19 implant XiVE		5.5 × 11
18 implant XiVE		4.5 × 11
17 implant XiVE		3.8 × 8

* Retrieved implant.

functional rehabilitation of the patient.[37] Earlier implant restoration and function increase patient satisfaction.[32] Very high implant success rates are reported for early and immediately loaded implants. Jaffin et al[27] reported an overall survival rate of 95%, Ganeles et al[25] reported a rate of 99.4%, and Gatti et al[29] reported a rate of 96%. De Bruyn and Collaert[38] reported a 99.3% implant success in early loaded machined implants inserted in completely edentulous mandibles. Collaert and De Bruyn[39] reported a 100% success in early loaded implants with a fixed cross-arch restoration in the mandible. Romeo et al[49] and Gatti and Chiapasco[40] reported a 100% cumulative success rate after 2 years of functional loading in immediately loaded implant-retained mandibular overdentures. Animal experimentation cannot be extrapolated and transferred to a clinical application in humans. There are few human reports on histologic findings for implants placed by a 1-stage approach,[50] and there is a need to investigate the bone-healing processes at the interface,[32] especially concerning the question of which type of bone response is present around immediately loaded implants inserted in poorer quality bone.[51] Clinical stability is insufficient to evaluate the occurrence of osseointegration, and it has been suggested that an analysis of human biopsies of immediately loaded implants is the best way to ascertain the quality and quantity of the peri-implant hard tissues.[51]

The aim of this study was to evaluate the peri-implant mineralized tissues of an immediately loaded implant, with a conical implant abutment connection placed in the posterior mandible of a man, after a 6-month loading period.

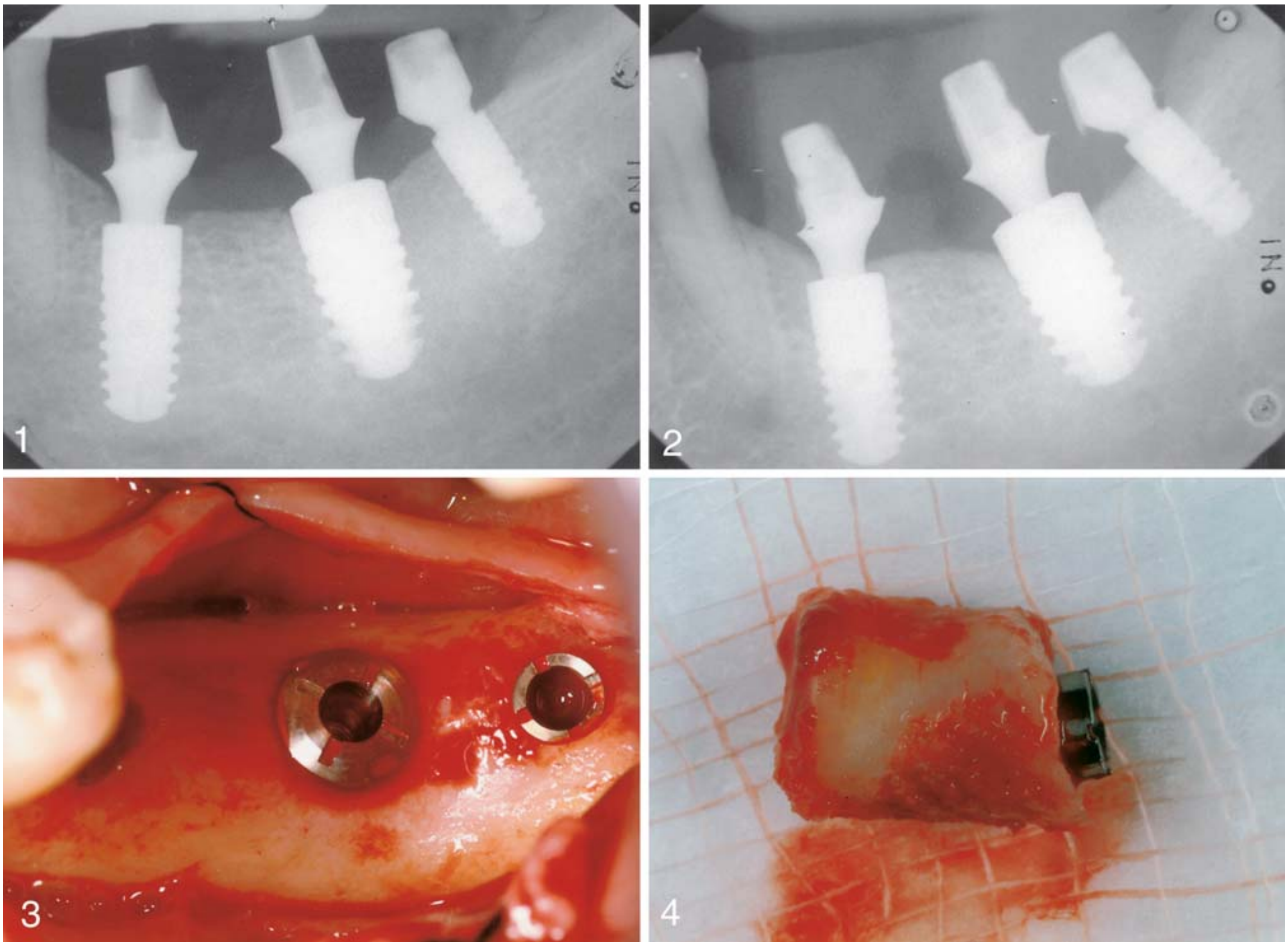
MATERIALS AND METHODS

Three Ankylos dental implants (Dentsply, Friadent, Mannheim, Germany) were inserted in the right posterior mandible and 7 XiVE implants (Dentsply) were inserted in the left posterior mandible of a 65-year-old man with a partially edentulous mandible (Table). The patient did not smoke and he gave a written informed consent to the protocol, which was approved by the Ethical Committee of the University of Chieti, Chieti, Italy. All the implants were immediately loaded with a provisional resin restoration the same day of the implant surgery (Figure 1). The patient was given oxytetracycline (500 mg) at 30 and 60 days after the implant insertion. After a 6-month loading period (Figure 2), the most distal mandibular implant was retrieved with a 5.5-mm trephine bur (Figures 3 and 4). This implant had substituted tooth #32 and was a 3.5- × 8-mm Ankylos implant inserted in D3 bone with an insertion torque of 20 Ncm. The implant stability quotient value was 61 at implant insertion and 65 before implant retrieval.

Specimen processing

The implant and surrounding tissues were washed in saline solution and immediately fixed in 4% paraformaldehyde and 0.1% glutaraldehyde in 0.15 M cacodylate buffer at 4°C and pH 7.4. The specimen was processed by the Precise 1 Automated System (Assing, Rome, Italy),[52] dehydrated in an ascending series of alcohol rinses, and embedded in a glycolmethacrylate resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization, the specimen was sectioned along its longitudinal axis with a high-precision diamond disc at about 150 mm and was ground down to about 30 μm with a specially designed grinding machine. Three slides were obtained, stained with acid fuchsin and toluidine blue, and examined with a transmitted light Leitz Laborlux microscope (Leitz, Wetzlar, Germany) and a Zeiss fluorescence microscope (Zeiss, Göttingen, Germany). Filters of wavelengths 510 to 560 nm (green filter), 450 to 490 nm (blue filter), 355 to 425 nm (violet filter), and 340 to 380 nm (ultraviolet filter) (Zeiss) were used with the fluorescence microscope. The green fluorescent lines, indicative of tetracycline labelling, were photographed with sensitive photographic film (640T Chrome, Imation Spa, Segrate, Italy).

The histomorphometry was carried out with a light microscope (Laborlux S, Leitz) connected to a high-resolution video camera (3CCD, JVC KY-F55B, Media Cybernetics Inc, Immagini & and Computer SnC, Milano, Italy) and interfaced to a monitor and personal computer (Intel Pentium III 1200 MMX, Media Cybernetics Inc, Immagini & and Computer SnC, Milano, Italy). This optical system was associated with a digitizing pad (Matrix Vision GmbH, Media Cybernetics Inc, Immagini & and Computer SnC, Milano, Italy) and a histome-



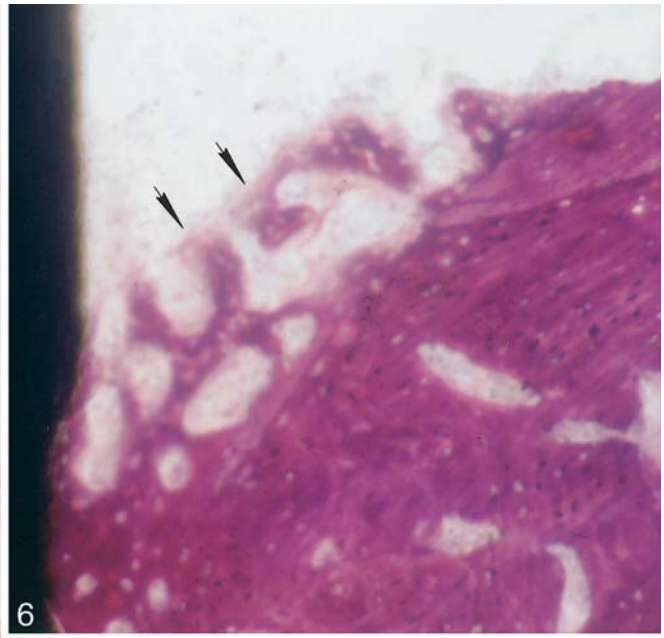
FIGURES 1–4. FIGURE 1. Periapical X ray after implant placement. FIGURE 2. Periapical X ray 6 months after immediate loading of the implants. FIGURE 3. Clinical aspect during implant removal. FIGURE 4. Implant removed by trephine.

try software package with image-capturing capabilities (Image-Pro Plus 4.5, Media Cybernetics Inc, Immagini & Computer Snc, Milano, Italy). The images were analyzed for the percentage of woven bone and lamellar bone, the percentage of bone with a tetracycline label, and the distance between the 2 tetracycline-labeled fluorescent lines. The birefringent organization of bone collagen fibers was determined under polarized light microscopy, in conjunction with the microphotographic image, and was used to distinguish lamellar from woven bone. Only the portion of the implant inserted in bone, with the exclusion of the epithelial and connective supracrestal tissues, was used in the histomorphometrical evaluation.

RESULTS

Mature mineralized bone was in close contact with the implant surface (Figure 5). Actively secreting osteoblasts were observed in the marrow spaces in only a few portions of the interface. The cortical bone peri-implant trabeculae were thick. This cortical bone tissue was recognized as mature lamellar bone under polarized-light microscopy. At low magnification, it was possible to observe a small quantity of newly formed bone trabeculae at the most coronal portion on 1 side of the implant (Figure 6). At higher magnification, it was possible to see that these trabeculae were surrounded by osteoblasts actively secreting osteoid matrix. No osteoclast activity was present in the coronal portion, and no inflammatory cells were observed near the implant surface. The bone adjacent to the implant surface was mainly lamellar (90% ± 4.5%) and the remaining 9% ± 0.21% was woven bone.

The fluorescence was observed in the newly formed bone layer. In many areas, the trabecular bone labeled with the tetracycline was in direct contact with the implant surface (Figure 7).



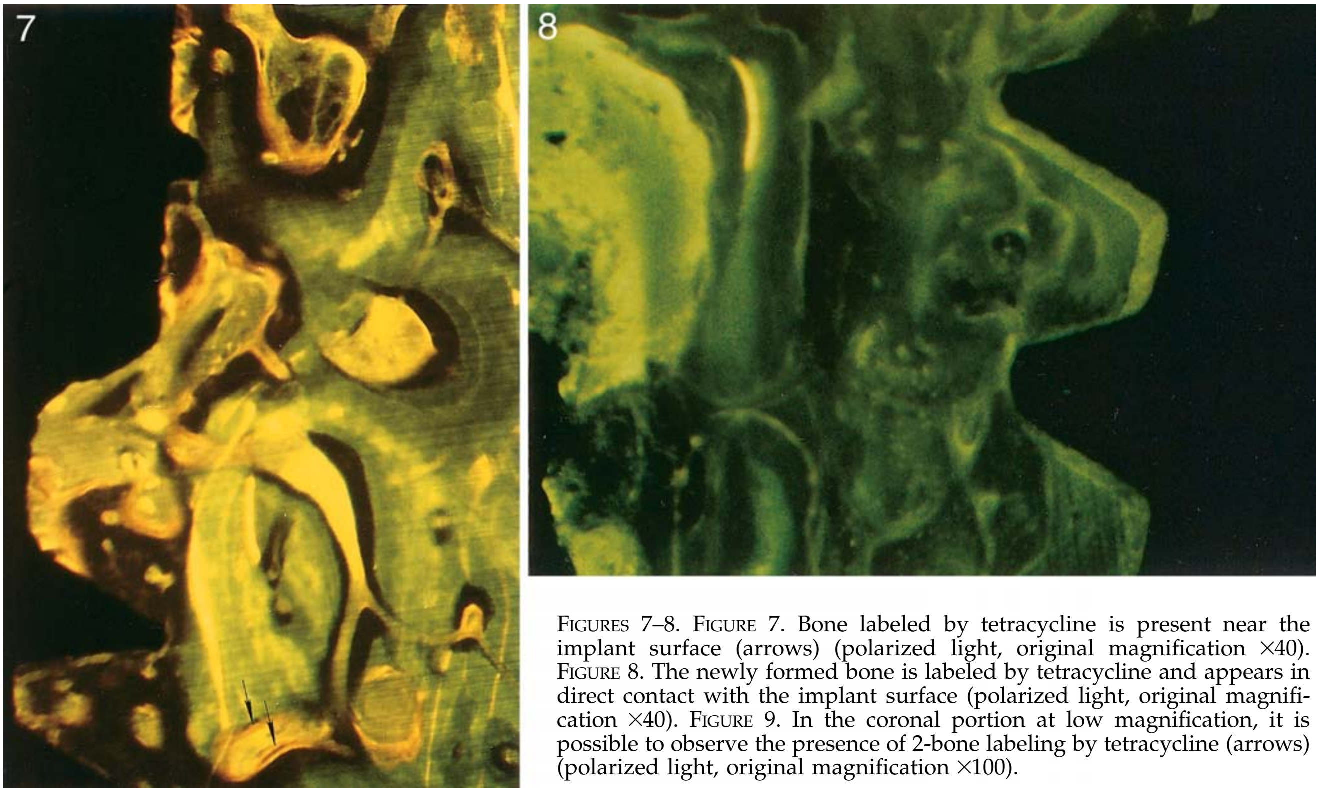
FIGURES 5–6. FIGURE 5. The implant is surrounded by lamellar bone. This bone is in close contact with the implant surface (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 6. Small newly formed bone trabeculae present in the most coronal portion of the implant (arrows) (acid fuchsin and toluidine blue, original magnification ×40).

The extensive labelling by tetracycline indicated a large quantity of newly formed bone (Figure 8). Tetracycline labeled 15.2% ± 0.8 % trabecular bone. The distance between the 2 lines marked by tetracycline was 85 ± 5 μm (Figure 9). The bone-implant contact percentage was 74% ± 6%.

DISCUSSION

Only a few immediately loaded implants have been retrieved from humans and examined histologically.[17,21–24,28,35,47] Surface characteristics of each implant type are important in determining the pattern of healing under loading, and histologic evidence of osseointegration is needed for each implant type with a different surface.[28] This documentation can be obtained only by histologic analysis of loaded implants retrieved from human.[23] The special thread design of the Ankylos implant system is characteristic for the progressive different shape of the threads, provided from the coronal to the apical aspects.[33,34] These implants are made from grade II c.p. titanium and have a high-polished collar of 2 mm and a sandblasted surface.[33] Moreover, the Ankylos implant system has an internal seal between the implant and the abutment and does not have a microgap.[33]

Reports indicate that once immediately loaded implants have clinically osseointegrated, they appear to take on the long-term predictability of conventionally healed and loaded implants.[25] The surface characteristics of an implant are extremely important for the osseointegration, especially in the very demanding situations of immediate loading. Several surface treatments (eg, particle blasting, plasma spray coatings, acid etching) have been



FIGURES 7–8. FIGURE 7. Bone labeled by tetracycline is present near the implant surface (arrows) (polarized light, original magnification ×40). FIGURE 8. The newly formed bone is labeled by tetracycline and appears in direct contact with the implant surface (polarized light, original magnification ×40). FIGURE 9. In the coronal portion at low magnification, it is possible to observe the presence of 2-bone labeling by tetracycline (arrows) (polarized light, original magnification ×100).

proposed to improve the implant-surface characteristics and to increase the quantity and quality of bone at the interface with increased interlocking. The surface of the Ankylos implant system is sandblasted with 120-μm aluminum-oxide particles, which may positively influence bone integration under loading conditions because of its high porosity.[33] The histologic data from the present study confirm that immediate loading did not impede osseointegration and that the bone-healing sequence was not disturbed by the stresses transmitted at the interface under these mechanical conditions, even if the implant had been inserted in soft bone (D3). Rocci et al[35] reported very high bone-implant contact (84.2%), with apparent undisturbed healing in implants that had been inserted in bone-quality sites 3 or 4 and that had been biomechanically challenged.[15] The results of this study, moreover, confirmed those reported by Testori et al.[51] The load-bearing capacity of the implant interface was maintained over replacement of the necrotic bone, and the loading of the implants did not interfere with osseointegration. Using the same implants in an experimental study in monkeys, Romanos et al[33] found no statistically significant differences in the bone-implant contact percentages in the immediate-loading and delayed-loading groups. They concluded that immediately loaded splinted implants inserted in the posterior mandible can osseointegrate with a peri-implant response similar to that of delayed-loaded implants.[33] New bone formation and active remodelling may be observed when the bone is mechanically stimulated.[33] Also, Rocci et al[35] showed that signs of active remodelling were more marked near the implant surface: this remodelling was seen as formation of secondary osteons or resorption and bone formation at the surface of bone trabeculae.

In this study, the bone labeled by tetracycline was in direct contact with the implant surface in many areas. The splinting of the implant probably decreased the amount of micromotion during the early healing phase, giving the implant a higher tolerance to deleterious micromotion. Rigid splinting and minimal lateral forces may be critical factors for success.[25] Loading within physiologic limits could have stimulated bone formation as a result of the bone adaptation to loading.[35] Also, it has been shown that early daily periods of cyclic micromotion increase the rate of healing.[53]

The presence of newly formed bone in the coronal peri-implant area is striking and could be related to the absence of a microgap because of the conical connection. In this way, there is probably no bacterial colonization and leak-

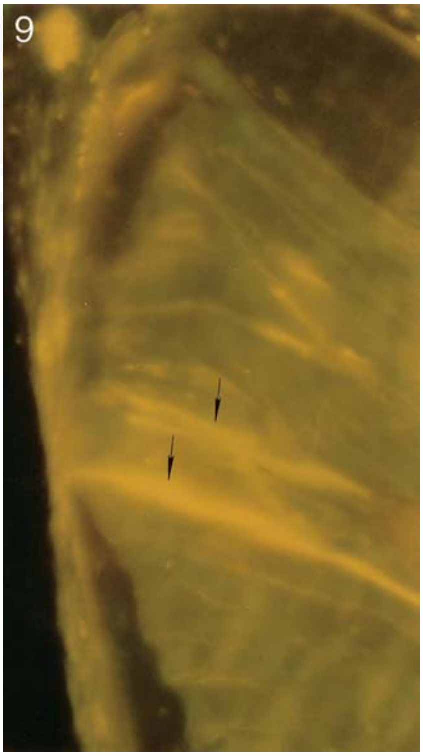


FIGURE 9. In the coronal portion at low magnification, it is possible to observe the presence of 2-bone labeling by tetracycline (arrows) (polarized light, original magnification ×100).

age at the implant-abutment interface; this bacterial leakage has been correlated to peri-implant bone crestal loss.[54–64]

Remodelling is a process of resorption and formation that replaces the preexisting bone and permits the bone adaptation.[65] The remodelling rate or bone turnover is the period of time needed for new bone to substitute the preexisting bone.[65] The bone remodelling rate is also expressed as a percentage or volume of new bone within a specific time period and may be directly related to the strength of the implant interface and the degree of risk for the bone-implant interface.[65] Lamellar bone forms at a rate of 1 to 5 mm each day, whereas woven bone can form at rates of more that 60 mm each day.[65] A higher risk is related to a higher turnover rate because the bone that is formed at the interface is less mineralized, less organized, and weaker.[65] In the specimen in this study, the distance between the 2 fluorescent lines was 85 mm. This total divided by 30 days produces a rate of new bone formation of 2.83 mm per day, which is well within the above-mentioned limits of lamellar bone formation. The presence of lamellar bone at the interface is, in theory, advantageous for long-term implant survival because it is more mature and resistant to resorption.[65]

CONCLUSION

The results of this study show that a high percentage of bone contact can be obtained even in immediately loaded implants inserted in low bone quality. Immediate loading does not interfere with bone formation and does not impede osseointegration.

ACKNOWLEDGMENTS

This work was partially supported by the National Research Council (C.N.R.), Rome, Italy; the Ministry of Education, University, and Research (M.I.U.R.), Rome, Italy; and the Research Association for Dentistry and Dermatology (A.R.O.D.), Chieti, Italy. The help of Friadent (Mannheim, Germany) is gratefully acknowledged.

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