Light and Scanning Electron Microscopic Report of Four Fractured Implants

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Although they are fortunately rare, implant fractures can cause significant problems for both clinicians and patients. The authors present a light and scanning electron microscopic study of four fractured implants in two patients. Both patients had parafunctional habits (bruxism), hypertrophic masticatory muscles, and wear of occlusal surfaces. The scanning electron microscopic study of the fractured surfaces of all four implants showed the presence of fatigue striations. Bending overload was probably created by a combination of parafunctional forces, bone resorption, posterior location of the implants, and implant diameter.
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Key words: bending moments, biomechanics, bone resorption, bruxism, fractures overload, implant failure, metal fatigue

Very high percentages of long-term success of dental implants have been reported in the literature.[1] Despite the trend toward fewer failures, they do occur. In a retrospective analysis of 4,045 implants, Balshi et al[2] reported only 8 fractures (0.2%), while Rangert et al[3] found 39 patients with fractured implants out of 10,000 implants placed.

Implant failures have been divided into early and late categories.[4] Early failures tend to occur before abutment connection and are mainly related to surgical problems during implant placement.[4] Late failures, on the other hand, may arise from pathologic events involving a previously osseointegrated implant.[4] Some investigators suggest that these problems could be related to prosthetic and functional stresses associated with progressive bone loss.[5,6] Implant fractures may be the result of[2]:

1. Implant design and manufacturing defects
2. Nonpassive fit of the prosthetic framework
3. Physiologic or biomechanical overload

The aim of this report is to evaluate the clinical, histologic, and scanning electron microscopic (SEM) findings of four fractured implants in two patients.

Patient 1

In June 1993, a partially edentulous 63-year-old male patient underwent the placement of seven titanium implants (Astra Tech, Molndäl, Sweden) in the maxilla. In the left maxilla, one 3.5 × 15 mm and two 3.5 × 13 mm titanium implants were placed in the premolar-molar region; a distal cantilever was present. The patient was a heavy smoker with severe parafunctional habits (bruxism). An extraoral examination revealed hypertrophic masticatory muscles, while intraoral examination revealed wear of occlusal surfaces and bad oral hygiene with accumulation of plaque and calculus.

In June 1994, a definitive prosthesis was placed. At the 2-year follow-up radiograph, deep pericoronal "cup" resorption around all three implants was evident (Fig 1). In November 1996, implant mobility was present, and a periapical radiograph showed the presence of a fracture of all three implants. These

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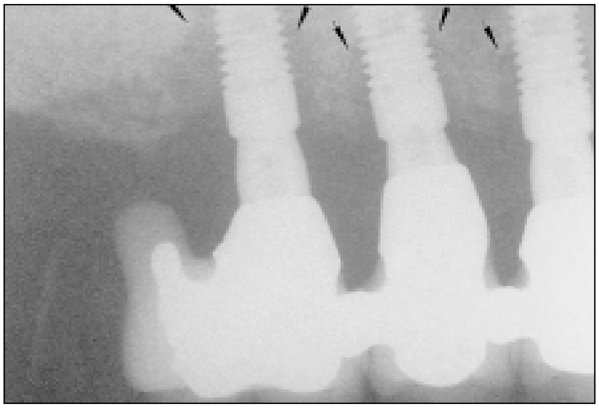

Fig 1 After 2 years, a wide radiolucency is visible around the coronal portion of all three implants *(arrows)* (patient 1).

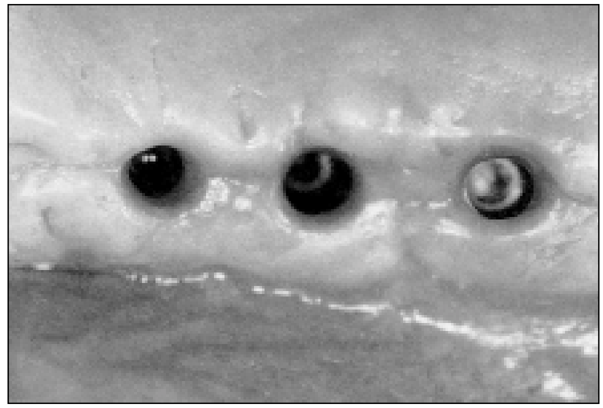

Fig 2 The three fractured implants are located in a straight line (patient 1).

three implants had been placed in a straight-line configuration (Fig 2). They were retrieved with a trephine.

The specimens were washed in saline solution and immediately fixed in 4% paraformaldehyde and 0.1% glutaraldehyde in 0.15 mol/L cacodylate buffer at 4°C and pH 7.4, to be processed for histology. Thin ground sections were obtained with the Precise 1 Automated System (Assing, Rome, Italy).[7] The specimens were dehydrated in an ascending series of alcohol rinses and embedded in a glycolmethacrylate resin (Technovit 7200 VLC, Kulzer, Germany).

After polymerization, the specimens were sectioned longitudinally with a high-precision diamond disk at about 150 µm and ground to about 30 µm. A total of four slides were obtained. The slides were stained with basic fuchsin, toluidine blue, and von Kossa, and observed under normal and polarized light in a Leitz Laborlux microscope (Leitz, Wetzlar, Germany). The histochemical analysis of acid and alkaline phosphatases was carried out according to a previously described protocol.[8] The histomorphometry was done with a Microvid System (Leitz) connected to an IBM PC. The coronal portion of the implant was observed under a Cambridge 360 scanning electron microscope.

Patient 2

In November 1994, a 70-year-old male patient underwent the placement of two 3.5 × 15 titanium implants (Astra Tech) in the right posterior mandible. The patient demonstrated poor oral hygiene, a severe overbite, and parafunctional habits. In April 1995, a definitive prosthesis was placed. In November 1995, the patient had an abscess on the distal implant in the posterior mandible. A radiograph showed the presence of a pericoronal radiolucency and a fracture of the implant 5 mm from the coronal extremity. The implant was retrieved with a trephine and treated to obtain thin ground sections according to the technique previously described. The coronal portion of the implant underwent SEM analysis as in patient 1.

Results

In patient 1 under SEM at low-power magnification, it was possible to see that no porosities or defects of the titanium were present (Fig 3). At higher magnification, fatigue striations were present (Fig 4). Under light microscopy at low magnification, a direct bone-implant contact was visible around all the implants without signs of inflammation or bone resorption (Fig 5). The histomorphometry showed 84% (± 3.8%) bone-implant contact for all three implants. Under polarized light, the peri-implant bone appeared compact, mature, lamellar, and osteonic. Bone and titanium had very close and tight contact without the presence of gaps or connective tissue at the interface. With von Kossa stain, it was possible to see that the peri-implant bone was highly mineralized. Some osteocytes were present near the metal surface. No cells positive to acid phosphatase and only a few cells positive to alkaline phosphatase were present. In only a few areas was a small, 5- to 10-µm gap present at the bone-implant interface. In some areas of the interface, remodeling processes were present, and it was possible to observe a rim of osteoblasts that were deposing bone toward the titanium surface (Fig 6). Resorption phenomena could be observed on the most coronal part of the bone-implant interface, and in some areas epithelial cells were in close contact with bone. In patient 2, similar features were observed. The bone-implant contact in patient 2 was 81% (± 2.4%).

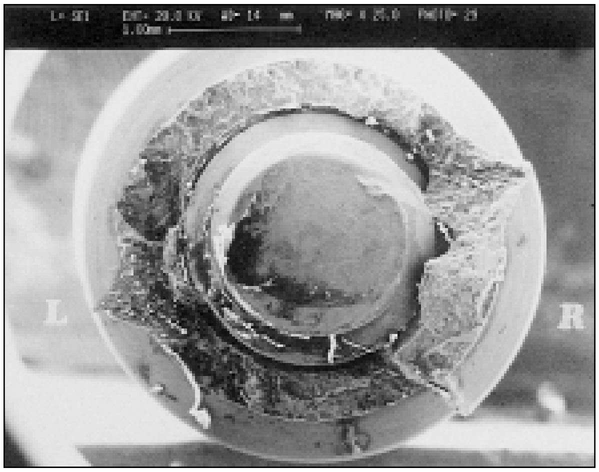

Fig 3 At low-power SEM magnification, it is possible to observe that no porosities are present inside the titanium and that the fracture is situated in different planes (patient 1; R = right; L = left; original magnification ×25).

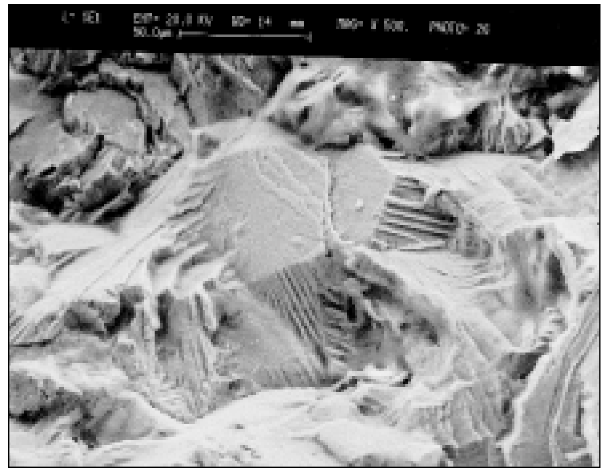

Fig 4 High-power SEM magnification of the implant. Fatigue striations are present (patient 1; ×500).

Fig 5 Histology showing a high percentage of bone-implant contact percentage. No gaps are visible at the interface (patient 1; basic fuchsin-toluidine blue; ×25).

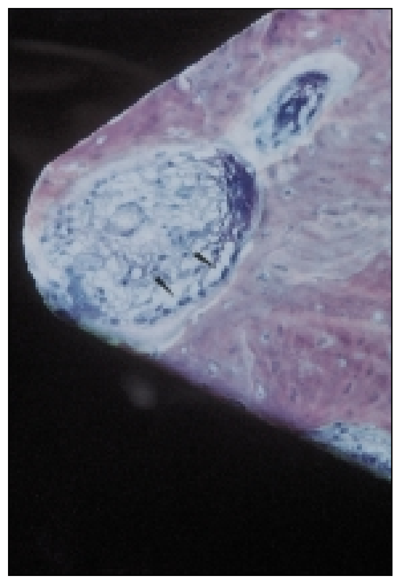

Fig 6 At higher magnification, it is possible to observe an area of bone apposed by a rim of osteoblasts *(arrows)* near the implant (patient 1; basic fuchsin-toluidine blue; ×200).

Discussion

Peri-implant bone resorption and implant fracture are said to be related to excessive bending moments.[3,6] Peri-implant bone resorption has been found before implant fracture in many patients, particularly when single-molar implants were involved.[3] Coronal bone resorption produces a higher bending stress of the implant because of the loss of supporting bone.[9] In addition, this type of bone resorption usually extends to the level corresponding to the end of the abutment screw, and in this region the resistance to bending is diminished.[9] An area of stress concentration could be produced at the root of a thread with the formation of crack initiation and propagation.[9] Metal fatigue seems to be the most common cause of structural failure.[10] The cracks grow from the site of maximum stress and can produce a sudden failure.[10]

In all specimens, the present SEM study showed the presence of fatigue striations, which constituted the crack front under cyclic loading. These striations were, according to Morgan et al,[9] the pathognomonic mark of fractures resulting not from overload, where a dimpled surface related to plastic deformation is present, but from fatigue failure. The histologic evaluation of the portion of the implant that remained in the bone always showed a very high percentage of bone-implant contact. In these patients a combination of bruxism and bone resorption probably led to bending overload. Moreover, the fracture also could easily have been produced by a weakness in implant design. A higher predisposition of the maxilla for implant fracture could be related to the fact that the presence of a weaker bone can lead to bone loss at high loads and an increased bending moment on the implants.[3]

Conclusion

In two patients with fractured implants, no porosities or defects of titanium were observed under SEM, and no manufacturing defects were present. Parafunctional habits were present. Bone loss around the fractured implants could have contributed to the fracture. A very high percentage of bone-implant contact also could have helped in increasing the bending moments. The implants, which had a diameter of 3.5 mm, were located in the posterior quadrants.

It is suggested that only when a certain number of adverse parameters are present simultaneously is the load limit of the implants likely to be surpassed.[3]

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