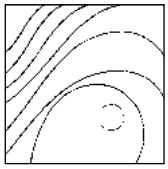
A Human Histologic Report of an Implant Placed With Simultaneous Sinus Floor Elevation Without Bone Graft



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A titanium implant with an acid-etched surface was placed simultaneously with sinus floor elevation in a severely resorbed ridge of a 52-year-old man. The height of the residual crest was less than 3 mm, and no bone substitute was used to graft the sinus cavity. Six months after placement, the implants were uncovered, and no signs of mobility were recorded. The implant at the second molar site and surrounding bone were removed for prosthetic convenience. The specimen was harvested and processed for undecalcified histologic analysis. Poor bone quality around the implant was evident, characterized by large marrow spaces and scarce trabeculation. Signs of osseointegration could be seen mainly toward the apical third of the implant. A cortical wall was present apical to the implant, suggesting the formation of a new sinus floor. The relationship between the histologic evidence and possible clinical implications are discussed. (Int J Periodontics Restorative Dent 2012;32:e122–e130.)

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Extraction of periodontally compromised maxillary posterior teeth followed by maxillary sinus pneumatization may result in severe resorption of the alveolar ridge, increasing the challenge of implant osseointegration. To overcome this limitation, the sinus floor elevation procedure was introduced over 30 years ago.[1] This technique has been widely adopted in clinical practice to manage the atrophic posterior maxilla whenever an implant-supported rehabilitation is required.[2] A high success rate for implants placed into elevated maxillary sinuses has been reported in meta-analyses and systematic reviews.[3–5] Depending on the height of the residual bone crest, the insertion of implants may be performed with simultaneous sinus floor elevation or delayed until the sinus bone graft has matured.[6–8] It has been suggested that at least 5 mm of residual crest should be available to achieve primary stability with simultaneous implant placement.[9] Recently, researchers have challenged the validity of this indication, suggesting that

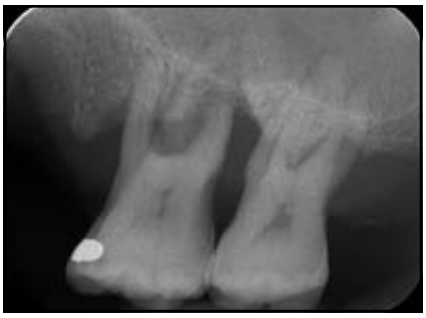

Fig 1 *Periapical radiograph showing the maxillary left first and second molars before extraction. Severe bone loss with furcation involvement is clearly evident. Note that at this stage, the bone loss had already reached the sinus floor, and the palatal roots of both teeth appeared to protrude into the sinus cavity.*

Fig 2 *CT scan taken 4 months after tooth extraction. The residual ridge in the area ranged between 2 and 4 mm. Thickening of the membrane was evident.*

implants may be stabilized in further reduced alveolar ridges at the time of sinus floor elevation.[10,11] To date, there are few histologic reports addressing the biologic integration of implants placed with simultaneous sinus floor elevation in humans.[12–14] Here, the authors report the histologic analysis of an implant placed at the time of sinus augmentation in a severely resorbed ridge without the use of any bone substitute and harvested 6 months after implant placement.

Case report

A 52-year-old nonsmoking man who was in good general health required implant rehabilitation of the maxillary left quadrant because of partial edentulism. The patient underwent a complete periodontal screening and was diagnosed with chronic generalized periodontitis. Full-mouth scaling and root planing was carried out. The 2-month reevaluation showed an overall good response to nonsurgical periodontal therapy. However, the maxillary left molar teeth were deemed hopeless because of furcation involvement, severe attachment loss, and degree II mobility, and were therefore extracted (Fig 1). Four months after extraction, a computed tomography (CT) scan showed a severe reduction of the alveolar ridge and a thickening of the sinus membrane, probably a response to the periodontally compromised teeth in the area. The residual crest height in the edentulous area measured on the CT scan ranged from 2 to 4 mm (Fig 2). Sinus floor elevation with simultaneous implant placement was scheduled.

Surgical procedure

A long-acting local anesthetic supplemented with epinephrine (1:100,000) was administered on the area to ensure good hemostasis. A paracrestal palatal incision was carried out over the ridge followed by two vertical releasing incisions: The mesial incision was outlined distal to the last tooth present in the arch while the distal incision involved the maxillary tuberosity. A full-thickness flap was raised, and the maxillary ridge was exposed. Using a round carbide bur mounted on a straight handpiece under abundant water cooling, the lateral bony window was outlined. Once the osteotomy was accomplished, the window was carefully moved inward and the sinus membrane detached from the underlying bone. After the membrane was completely elevated up to the medial wall of the antrum, collagen sponges (Gingistat, GABA-Vebas) were packed to keep the membrane lifted. At this point, the implant osteotomy was initiated using a Lindemann bur followed by shaping handpieces (Biomet 3i). The implant sites were underprepared to increase implant primary stability.

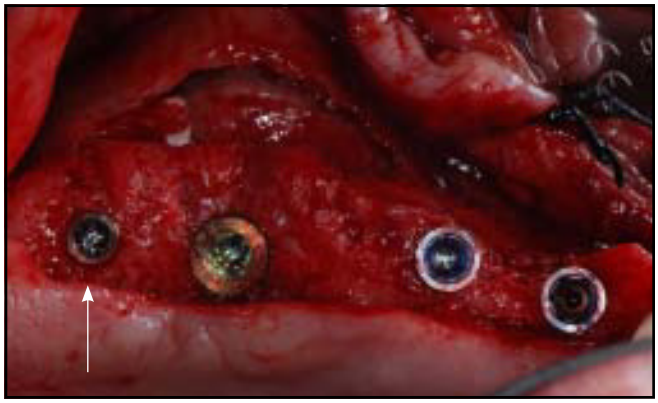

Fig 3 *The bony window was lifted and the implants placed. The arrow indicates the backup implant at the second molar site.*

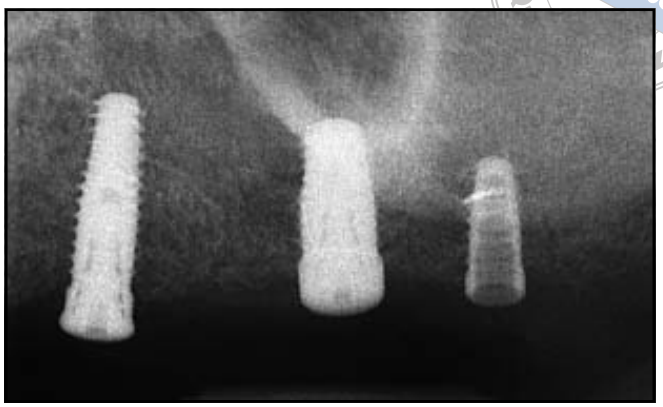

Fig 4 *Digital radiograph taken at completion of the surgical procedure. Note the relationship between the implants and the inferior wall of the sinus.*

A total of four conical-shaped implants (FNT, Biomet 3i) with an Osseotite surface were placed at the maxillary left first and second premolar and first and second molar sites and achieved good primary stability. The two distal implants were placed within the sinus elevation area. The implant at the first molar site was 5 × 11.5 mm while that at the second molar site was 3.25 × 8 mm (Fig 3). This last implant was intended as a backup implant. The two implants protruded approximately 5 mm into the sinus cavity. Collagen sponges were then packed to fill the residual cavity space, and a collagen membrane (Bio-Gide, Geistlich) was used to seal the antrostomy. Tension-free primary closure was achieved by releasing the periosteum at the base of the flap. Interrupted 5-0 GORE-TEX sutures (W.L. Gore) were used to close the surgical wound. Postoperative management included antibiotic (amoxicillin, 1 g bid for 5 days) and anti-inflammatory medication (ibuprofen, 400 mg bid). A chlorhexidine 0.2% mouthwash was also prescribed for 10 days until brushing could be resumed. A radiograph was taken at the end of the procedure and stored for comparison (Fig 4).

Healing was uneventful. Six months later, a new radiograph of the area was taken (Fig 5). No signs of pathology around the implants could be detected, and abutment connection surgery was scheduled. Again under local anesthesia, a full-thickness flap was raised and the healing abutments tightened manually. All implants were clinically stable. Some crestal bone resorption took place around the implants exposing the polished collar (Fig 6). At this point, a decision was made regarding the implant at the second molar site. This implant had a reduced diameter (3.25 mm), was placed as a backup in case the implant at the first molar site failed, and was difficult to restore because of a reduced interocclusal space. Several options were discussed with the patient, including recovering the implant. The patient agreed to have the implant removed and gave his written consent. Using a 4-mm trephine bur (4-mm internal diameter, 15-mm long) mounted on a low-speed handpiece under abundant water cooling, the implant and surrounding bone were carefully harvested (Fig 7). The specimen was rinsed with sterile water, immersed in a 10% formalin-buffered solution, and sent for histologic analysis (Fig 8). After harvesting, the integrity of the sinus membrane was checked with a blunt instrument. The harvesting wound was filled with a collagen sponge, and the flap was sutured (Vycril, Ethicon). Anti-inflammatory drugs were prescribed together with chlorhexidine 0.2% mouthwash. Healing was again uneventful, and 1 week later, the sutures were removed. Prosthetic rehabilitation of the implants was completed 2 months later.

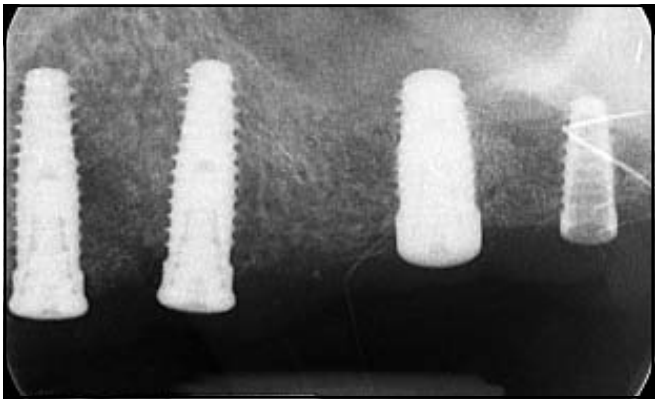

Fig 5 *Radiograph taken 6 months after the surgical procedure. A certain degree of radiopacity of the peri-implant area can be observed, suggesting that some mineralization of the elevated area may have taken place.*

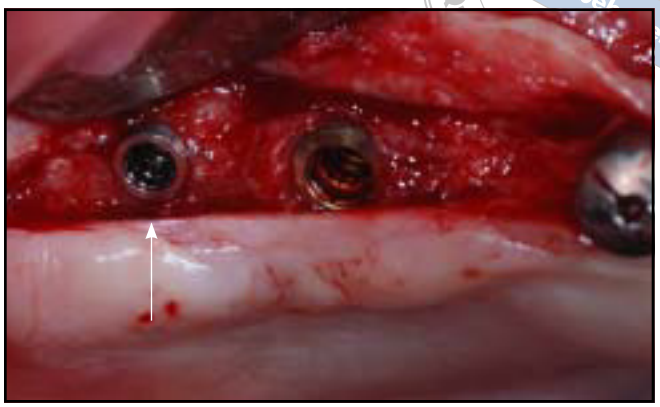

Fig 6 *Stage-two surgery after flap reflection. Some bone remodeling took place around the implants with a certain degree of buccal bone resorption. The arrow indicates the backup implant at the second molar site. The implant collar was exposed at the vestibular aspect without any further signs of bone loss.*

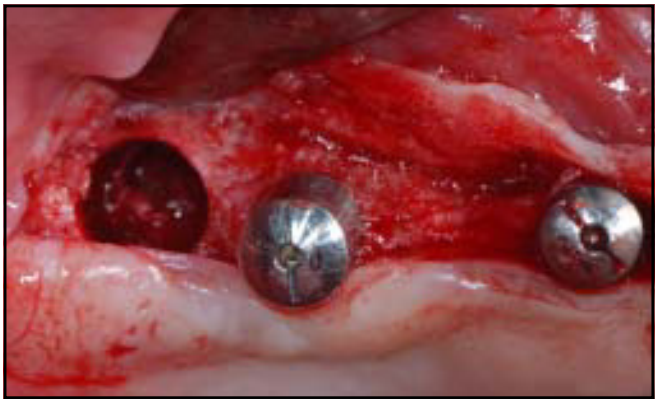

Fig 7 *The implant together with surrounding bone was removed using a trephine bur. After removing the implant, the newly formed sinus membrane could be appreciated.*

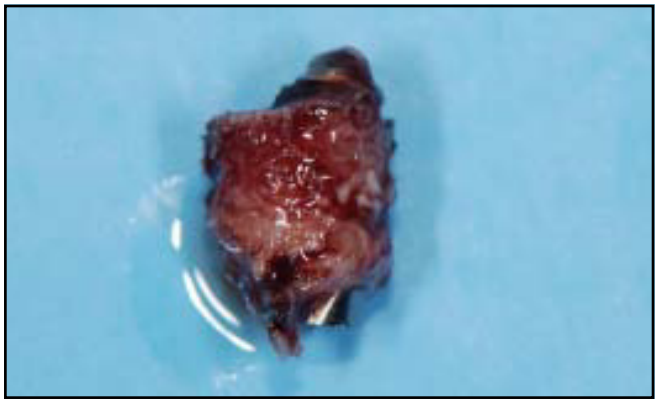

Fig 8 *Bone-implant specimen after harvesting and before fixation. Note that the implant apex is beyond the apical border of the bone block.*

Histologic processing

The specimen was kept refrigerated at 4°C in buffered solution for approximately 10 days before processing. After fixation, the specimen was rinsed thoroughly, dehydrated in an ascending series of alcohols, and then embedded in methyl methacrylate resin (Technovit 7200, Heraeus Kulzer). Processing was carried out according to the Donath and Breuner[15] technique for undecalcified specimens. The specimen was then sectioned longitudinally with an Exakt sawing machine to obtain sections of approximately 150 µm. Three sections were then ground to a thickness of approximately 40 µm. The sections were mounted on a glass slide and stained with toluidine blue for light microscopic analysis.

Histologic analysis

It was not possible to clearly discriminate between the native alveolar bone and newly formed bone in the sections analyzed. This was mainly because of the absence of a cortical wall at the coronal portion of the section, which could help to make this assessment. At low-power magnification, the implant appeared to be surrounded by alveolar bone of a very low density (Fig 9). No cortex could be identified in the coronal portion of the specimen. The bone was cancellous in nature with large marrow spaces and loose connective tissue, particularly around the implant body. No adipocytes could be detected in the marrow spaces. The trabeculae were scarce and oriented parallel to the implant body. The majority of the trabeculae were free-ending, and the trabeculae separation was extremely wide. Osteocyte lacunae deprived of nuclei was a common feature of the bone trabeculae. Limited signs of remodeling activity could be seen with the staining used. However, some osteoblastic activity could be identified in isolated areas around the implant apex (Fig 10). Remnants of woven bone were still present at the coronal portion as well as apical to the implant. A higher bone density could be found toward the implant apex with some limited areas of lamellation (Fig 11). Signs of osseointegration could be detected mainly at the apical third of the implant and in limited areas of the coronal portion (Fig 12). Dense parallel-oriented fibrous connective tissue was present along the implant surface (Fig 13). No signs of inflammatory cell infiltrate could be seen in all sections observed. Quite interestingly, a thin cortical bone layer could be seen apical to the implant apex, resembling a newly formed sinus floor.

Discussion

Inadequate bone crest height for implant placement is often encountered in the posterior maxilla. This may be the consequence of advanced periodontal disease and maxillary sinus pneumatization. Longitudinal studies on periodontal disease have clearly shown that maxillary furcated molars are at a greater risk for extraction,[16] and depending on their root trunk anatomy, the pattern of bone loss, and the relationship between the roots and the maxillary sinus floor, a wide range of alveolar bone resorption may take place.[17] This reduction in bone height is associated with a physiologic low bone density in the maxillary posterior sextants.[18] Coupled together, those factors translate into a greater risk for implant failure because of reduced biologic and biomechanical ability to achieve and maintain osseointegration with dental implants.[19]

While inadequate bone height for implant insertion may be overcome through a sinus floor elevation procedure, the quality of the bone in the area may be difficult to improve.[2] Implant success in grafted maxillary sinuses has been shown to be equal to if not better than that in nonatrophic maxillary edentulous ridges.[4,20] A staged approach to sinus floor elevation has been suggested whenever less than 5 mm of bone crest is available.[9] This approach includes delayed placement of implants, ie, once the graft is completely matured. This indication is based mainly on the ability of the implant to reach adequate primary stability in a reduced bone crest. Fenner and coworkers[21] conducted an experimental study on minipigs to test the hypothesis that 5 mm of residual bone crest is necessary for immediate implant placement with simultaneous sinus floor elevation. While primary stability was directly related to alveolar ridge height, the latter failed to influence implant success. Their conclusions were that there was no scientific evidence to assume that 5 mm should be used as a threshold to decide whether an implant can be placed with simultaneous sinus floor elevation. Those conclusions have been corroborated recently by clinical studies on simultaneous implant placement in severely resorbed ridges (< 5 mm), suggesting that adequate primary stability might be achieved even in cases of severe atrophy.[10,11,22]

The present report deals with two implants placed with simultaneous sinus floor elevation that achieved good primary stability in less than 3 mm of crestal bone. This was accomplished by a careful underpreparation of the osteotomy site and the use of tapered implants to increase mechanical resistance

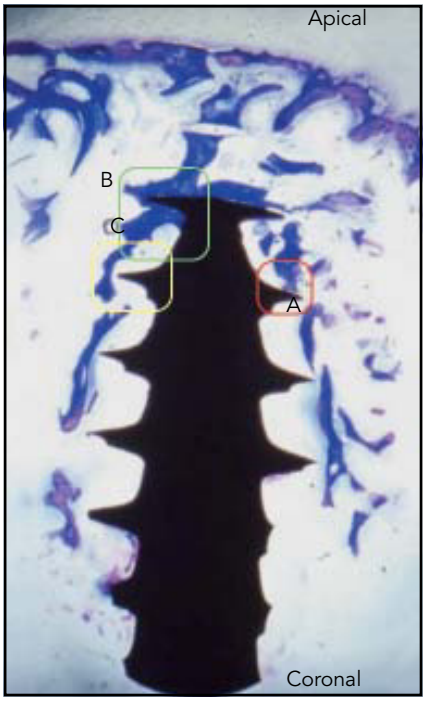

Fig 9 (left) *Histologic microslide of the specimen at low-power magnification. Cortical bone can be seen apical to the implant resembling the newly formed sinus floor. Loosely trabeculated alveolar bone is present surrounding the implant. Only limited signs of bone-to-implant contact can be seen around the apex of the implant and at the coronal portion (toluidine blue, original magnification ×6).*

Fig 10 (right) *At this particular area, bone-to-implant contact can be seen. Some remodeling activity took place* (arrows) *with recently deposited bone matrix that can be appreciated in the lighter staining (magnified view of outlined section A; toluidine blue, original magnification ×100).*

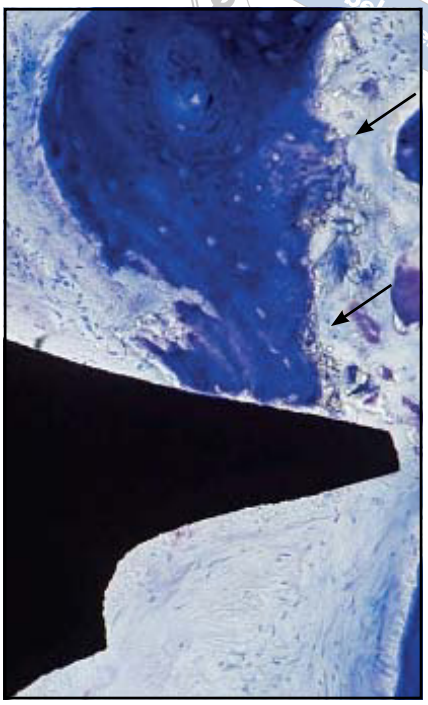

Fig 11 *The apical portion of the implant showed an area of good bone-to-implant contact. Bone appeared to be lamellar in nature with osteocytes inside of lacunae. No remodeling activity was evident (magnified view of outlined section B; toluidine blue, original magnification ×40).*

Fig 12 *High-power magnification of a coronal portion of the implant. Bone-to-implant contact is visible, and almost completely remodeled bone with signs of lamellation can be appreciated (toluidine blue, original magnification ×40).*

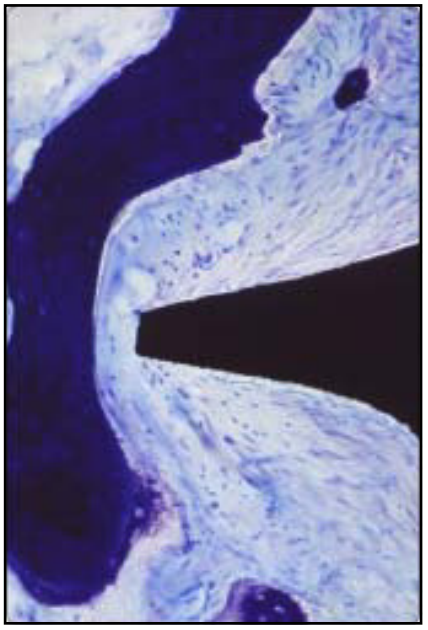

Fig 13 *High-power magnification of a thread located at the apical third of the implant. No signs of osseointegration can be seen. Dense parallel-oriented fibrous tissue is present. No signs of inflammatory infiltrate are detectable (magnified view of outlined section C; toluidine blue, original magnification ×100).*

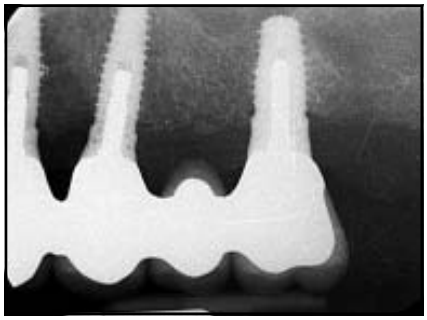

Fig 14 *Periapical radiograph taken 12 months after implant restoration and loading. The implant at the first molar site acted as a tent pole, determining the morphology of the newly formed sinus floor. Note that the sinus floor collapsed where the backup implant was removed, leaving only 3 to 4 mm of bone crest.*

to implant tapping. After implant stabilization, the sinus cavity was filled with collagen sponges, and no bone graft was used. Few speculations on the healing mechanisms involved in this case may be drawn. The elevated sinus membrane and the connected bony window were sustained by the inserted implants, providing adequate space for new bone formation. The lifting of the sinus membrane through the stimulation of the periosteal cambium layer may have activated osteoprogenitor cells at the endosteal surface.[23] This event, coupled with the space-making effect of the implant protruding in the sinus cavity and the stabilization of the coagulum through use of collagen sponges, may have fulfilled all the prerequisites for bone regeneration.[10,11,24] The use of bovine-derived type I collagen sponges may have helped to create and maintain the space for regeneration, enhance clot stability, and exert a stimulating effect of the proliferation of several osteoprogenitor cell lineages.[25]

Histologic analysis of the retrieved implant was rather remarkable. The specimen showed very limited implant osseointegration and poor bone quality. Bone-to-implant contact was mainly detected around the apical threads, while only a limited area of the coronal portion of the implant showed osseointegration. Low-density cancellous bone was present around the implant with large marrow spaces and free-ending trabeculae. The bone appeared completely remodeled for the most part, with some isolated areas of woven bone still detectable. These findings fit well with the 6-month healing period, which may have allowed complete bone turnover and given insight into the spontaneous healing potential of the area since no bone grafting was used. The bone quality would therefore resemble the physiologic nature of the bone in that area.

The authors' findings seem to corroborate those reported by Jensen and Sennerby.[12] In their histologic report, 12 mini-implants placed with simultaneous sinus floor elevation were retrieved. Two grafting materials were used: autogenous bone and particulated irradiated cancellous allograft. Six to 12 months after implant insertion, the mini-implants and surrounding bone were harvested. They found very limited osseointegration, particularly in allograft specimens.

The present histologic findings are significantly different from those reported by others, who placed implants with simultaneous sinus floor elevation and an anorganic bovine bone graft that were subjected to occlusal loading for 2.5[14] and 4 years.[13] A high bone-to-implant contact was detectable mainly around the middle coronal third of the implant, with active signs of remodeling taking place at the implant surface. Several factors may account for the different results, the most important of which being the presence of functional loading. It is well documented that functional loading may increase bone-to-implant contact over time,[26] and this may partially explain the differences between these findings and those reported by other authors.[13,14] In this case, the residual implant at the first molar site was successfully restored and loaded. The 12-month radiographic control showed an increase in the peri-implant radiopacity over time, suggesting that some bone remodeling was taking place (Fig 14).

Another rather interesting feature of this histologic specimen was the lack of a clearly identifiable cortical layer around the implant neck. This made it difficult to clearly discriminate the basal bone crest from the newly formed bone. This may be partially explained by the histologic sectioning or may indicate that active remodeling activity was taking place around the implant with the resorption of the cortical wall and opening of the marrow spaces. Crestal bone resorption could be seen clinically at abutment connection (see Fig 7) and may be related to the compressive forces used to tap the implant. The technique requires a severe underpreparation of the site and the use of a conical-shaped implant to enhance primary stability. This may have exerted great stress on the thin cortex, triggering this bone remodeling.[27]

Some crestal resorption around implants placed with the same technique was also reported in a series of cases by the authors' group.[28] On the other hand, the presence of a thin cortical wall apical to the implant may have been compatible with the formation of a new sinus floor. At low-power magnification (see Fig 10), the implant apex seems to be surrounded by newly formed bone. This is in contrast with the clinical view of the specimen (see Fig 9), which clearly shows the implant apex protruding approximately 1.5 mm beyond the sinus floor. This is the result of the histologic processing since the embedded block specimen could not be sectioned exactly along the implant long axis. A different sectioning axis would probably have been able to show the collapse of the sinus membrane over the implant apex. This coating phenomenon around the implant apex has been reported in humans[12] as well as animal models[28] and may be the result of negative pressure within the maxillary sinus. In this respect, it may be speculated that the use of particulated slowly resorbable graft may help to maintain the space above the implant apex more predictably compared to a blood clot.[29,30]

Several authors have recently proposed the insertion of implants at the time of sinus floor elevation without the use of any bone substitutes.[10,11,22] Hatano et al[11] reported a 92.9% implant success rate for up to 26 months of follow-up. They used the peripheral blood to fill the antrum space and repositioned the bony window using fibrin glue without the addition of a membrane. Because of the wide range of residual alveolar bone (from 2 to 11 mm), it may be difficult to assess the predictability of this procedure in severely resorbed ridges. On the other hand, Chen et al[22] showed a 100% success rate at the 2-year follow-up for 47 implants in 33 patients inserted with simultaneous sinus floor elevation without any bone graft. At least 5 mm of residual crest was required to be included in that study. Although encouraging, these preliminary results should be validated by further controlled randomized studies in a more homogenous anatomical and clinical population to clearly determine the predictability of this technique.

Conclusions

This histologic case report describes the healing of a titanium implant with an acid-etched surface placed with simultaneous sinus floor elevation without bone graft. Six months after placement, the implant at the second molar site was clinically immobile but removed for prosthetic convenience. Histologically, poor bone quality around the implant was found, with limited bone-to-implant contact. No sign of cortical bone could be seen at the coronal portion of the implant, while a newly formed cortical layer could be seen toward the implant apex. Although clinically immobile, the ability of the implant to withstand functional loading given its limited osseointegration should be questioned. Bone regeneration within an elevated sinus may take place in the absence of bone grafting whenever implants are placed simultaneously so that space may be provided. However, as the regenerative potential of the sinus membrane has yet to be fully understood, further histologic as well as long-term clinical data on implant success should be gathered to validate this technique.

Acknowledgments

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