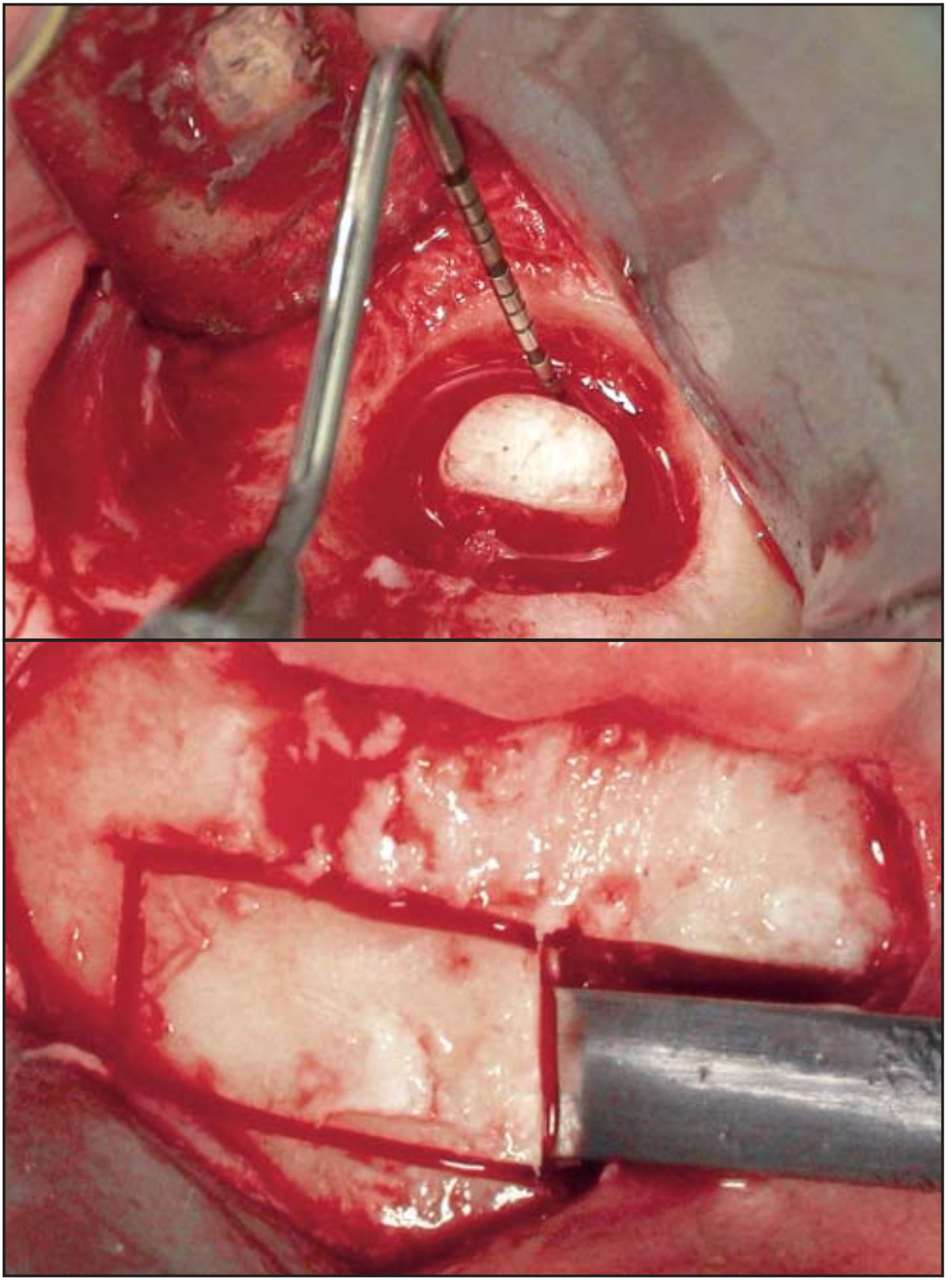
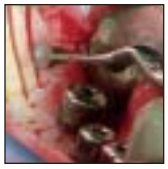


Sinus Bone Grafting Procedures Using Ultrasonic Bone Surgery: 5-Year Experience



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Ultrasonic bone surgery was recently introduced as an osteotomic technique; however, documentation is scarce. This article reports on the application of ultrasonic bone surgery for 53 bone-augmentation procedures in the posterior maxilla in 34 patients over 5 years. The initial residual bone height under the sinus varied between 1 and 9 mm (mean: 3.7 mm). Distribution according to residual bone height classes was 7.7% for Class B, 39.3% for Class C, and 53.0% for Class D. The procedures included bony window opening of the sinus, cortical and cancellous bone harvesting, and activation of the sinus wall. During the sinus approach, 2 of 53 membranes (3.8%) were perforated and covered with a membrane made of platelet-poor plasma. Bone grafting was carried out with autologous bone at 22 implant sites (18.8%), with a mixture of autologous bone and anorganic bovine bone mineral (Bio-Oss) at 29 sites (24.8%), and with Bio-Oss alone at 66 sites (56.4%). The perforated membranes healed uneventfully. At second-stage surgery, four implants failed. The survival rate of the 117 placed implants was 96.6%. No implant failed after loading. Performing the sinus grafting procedure with ultrasonic bone surgery limited the occurrence of membrane perforation; by changing the tips, all surgical steps were performed safely and comfortably. (Int J Periodontics Restorative Dent 2008;28:221–229.)

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Osseointegration of dental implants is highly predictable when implants are completely embedded in bone.[1] In the posterior maxilla, the presence of the maxillary sinuses often limits the available bone height for implant placement. When bone height beneath the maxillary sinus is insufficient, various augmentation procedures are recommended based on the amount of residual bone height (RBH).

In 1996, a consensus conference on sinus lifting issued recommendations for selecting a surgical approach based on the RBH.[2] When the RBH is ≥ 10 mm (Class A), a classical implant procedure should be performed. When the RBH is 7 to 9 mm (Class B), an osteotome technique should be applied in combination with immediate implant placement. When the RBH is 4 to 6 mm (Class C), a lateral approach involving a grafting material with immediate or delayed implant placement is recommended. Finally, when the RBH is 1 to 3 mm (Class D), a lateral approach involving bone grafting material and delayed implant placement should be used.

For classes C and D, the grafting material introduced into the sinus can

be autologous bone, either gained intraorally[3,4] or harvested extraorally.[5,6] The materials can be of human, animal,[7,8] or synthetic origin[9,10] or a mixture of any two.[11–13] Before loading, the created space is usually left to heal for at least 6 to 9 months to allow for bone formation.[2]

Sinus elevation procedures may involve various types of bone surgery, such as opening a bony window through the sinus wall, detachment of the sinus membrane from the sinus wall, and bone harvesting at the chin, maxillary tuberosity, retromolar area, or ramus. Until recently, these hard tissue surgeries were performed with rotary instruments. However, rotary instruments can easily perforate the sinus membrane,[3,14–16] leading to complications.[17–19] Accessing bone harvesting sites with a bur or an oscillating saw is a delicate procedure that requires great technical skill. Further, this approach is slow because it must be performed cautiously. Also, soft tissue or vessel bundles can be encroached and torn away.

Ultrasonic bone surgery (USBS) represents an alternative technique to perform precise bone surgery. The principle of USBS is to induce energetic microvibrations to a metallic knife of a given design. The vibration frequency ranges from 20 to 32 KHz, well above the audible spectrum. The vibrations are generated by a piezoelectric transducer. The idea of applying ultrasonic movement to tools used in bone surgery has been around for approximately 30 years.[20–23] However, the recent introduction of commercially available devices[24,25] devoted to bone surgery boosted interest in this concept and its potential applications.[26–33]

When ultrasonic knives are used to cut hard tissue, soft tissues such as gingiva, membranes, vessels, and nerves are preserved from injury because they vibrate with the tip. This makes USBS especially appropriate for the surgical steps of a sinus lifting procedure.

To establish this recent method as suitable and relevant to the professional community, evidence-based clinical studies are needed. To date, clinical studies involving sinus procedures with USBS have been scarce and are limited by small sample sizes and short follow-up periods.[23,34] Therefore, the purpose of this paper is to retrospectively document the use of USBS to perform sinus lift procedures over a 5-year period, with a consistent number of treated sites.

Method and materials

Ultrasonic bone surgery devices

The Piezosurgery device (Mectron) and the UBS device (Resista) were used. The Piezosurgery device operates between 24 and 29 KHz, and the power ranges from 5 to 16 W.[35] The round, stainless steel, diamond-coated tip was used (diameter: 2.2 mm).

The UBS device operates from 20 to 32 KHz, and the maximum ultrasonic power is 90 W.[36] The tips are made of titanium alloy. To open the bony window, a round 2.8-mm-diameter tip was used. To harvest bone from the chin, the ramus, or the horizontal branch of the mandible, angled or straight saw-shaped tips were used. Cortical activation of the lower part of the sinus wall was performed with a pyramidal tip to horizontally augment the maxillary edge with a mixture of anorganic bovine bone mineral (Bio-Oss, Geistlich) and platelet-rich plasma membrane.

Inclusion criteria

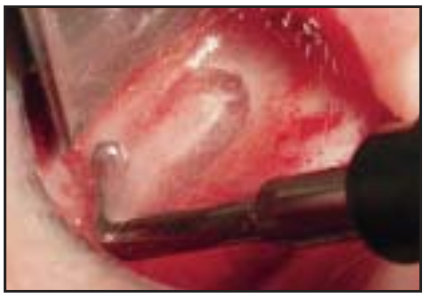
Patients were treated if the following criteria were satisfied: *(1)* implant therapy was the elective treatment to restore partial or total edentulism, *(2)* at least one implant site had a RBH of less than 6 mm when measured on an orthopantomogram, *(3)* the ridge width at the grafted sites could accommodate 3.75- to 5-mm implants as measured on a radiograph, and *(4)* the patient was in good general health and able to undergo bone surgery. Patients undergoing anticoagulant therapy were included if the treatment was interrupted 10 days before surgery.

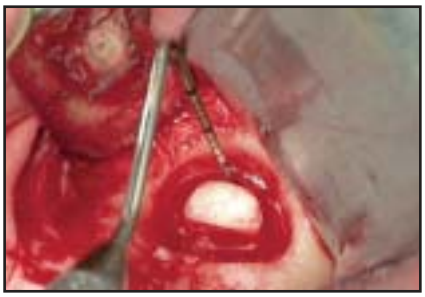
Exclusion criteria

The exclusion criteria were as follows: *(1)* patients with noncompensated diabetes, *(2)* patients treated with radiotherapy, *(3)* patients with autoimmune disease and immune deficiency, and *(4)* patients with deprived platelet content.

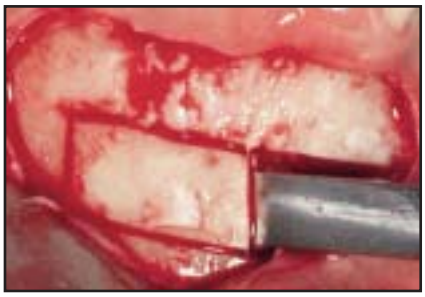
Surgical procedure

A midcrestal gingival incision was made, and a full-thickness mucoperiosteal flap was raised. Mesial and distal soft tissue discharges were pre-

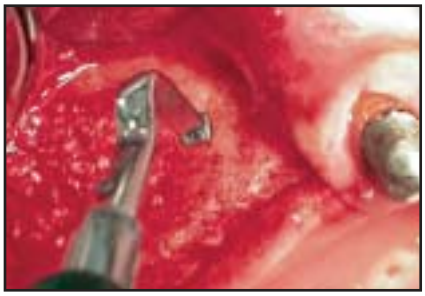




Figs 1a and 1b *Bony window opening.* (a, left) *Round tip in motion with water cooling and cavitation.* (b, right) *Thick sinus wall opened with the round vibrating tip. The use of USBS proved to be time consuming.*



Figs 2a and 2b *Bone harvesting.* (a, left) *Harvesting from the chin after osteotomy preparation using a vibrating saw. Note the squared angle of the osteotomy.* (b, right) *Harvesting from the ramus using a straight saw.*



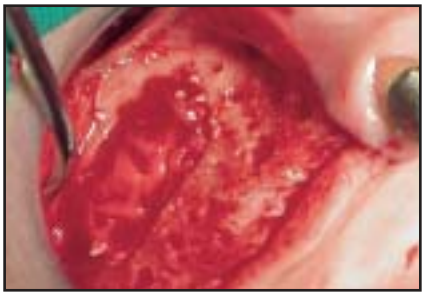


Fig 3a (left) *Sinus wall activation using the pyramidal tip.*

Fig 3b (right) *Sinus wall after activation. Note the drilled cavities and subsequent bleeding.*

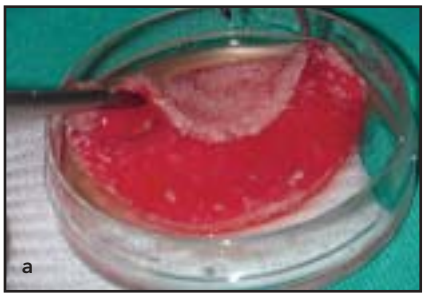
pared to provide access to the sinus wall. The bony window was opened using a spherical tip by applying oval continuous gentle forward-backward movement to the vibrating round tip. First, the general shape of the window was defined. The furrow was then deepened until reaching the membrane (Fig 1a). The thickness of the sinus wall ranged from 0.5 to 6 mm (Fig 1b). The membrane was detached manually along the window height. The bony window was then elevated inside the sinus to roof the filled area.

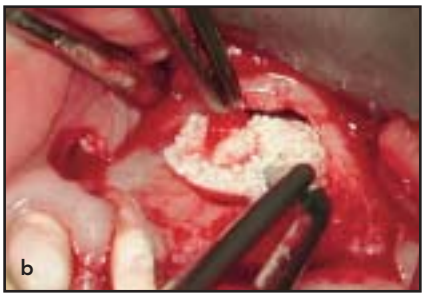
If necessary, autologous bone was harvested with the ultrasonic saw from the chin (Fig 2a), tuberosity, or ramus (Fig 2b). In some cases, horizontal augmentation was also needed to place larger implants. The lower part of the sinus wall was then perforated with the pyramidal tip to enlarge bleeding (Figs 3a and 3b). Bio-Oss particles with a platelet-poor plasma membrane were positioned against the wall to enlarge the alveolar ridge.

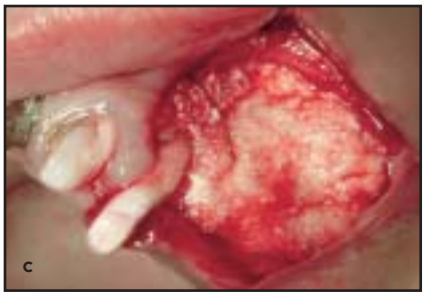
Bone grafting material and platelet-rich plasma

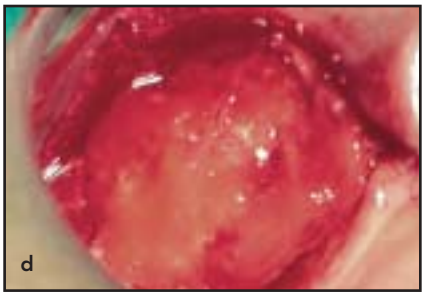
At the beginning of this study, only autologous bone was used as a filling material. In a second phase, the grafting material consisted of a mix of autologous bone and Bio-Oss. In a later stage, Bio-Oss alone was used to fill the sinus.[37,38]

All grafting materials were mixed with a platelet-rich plasma membrane (Fig 4a).[39,40] A thick gel was obtained and densely packed in the sinus (Figs









Figs 4a to 4d *Bone grafting with the platelet-rich plasma membrane and Bio-Oss.* (a) *Preparation of the platelet-rich plasma membrane mixed with the Bio-Oss particles.* (b) *Introduction of the jellified membrane filled with Bio-Oss into the sinus.* (c) *The grafting material was densely packed into the sinus.* (d) *The bony window was covered with a platelet-poor plasma membrane.*

4b and 4c). The opened bony window was closed with a platelet-poor plasma membrane mixed with Bio-Oss (Fig 4d). This membrane was obtained from the same blood sample and activated in the same way as the platelet-rich plasma. All patients received preventive antibiotic therapy.

Residual bone height measurements

At each implant site, the RBH was measured to the nearest 0.5 mm on orthopantomograms without magnification before sinus lifting and 6 months later before implant placement. All radiographs were taken with the same equipment (Scanora, Soredex) at a fixed deformation coefficient of ×1.3.

Demographics

Between January 2001 and May 2004, 53 sinus lift procedures were performed in 34 patients. The aim was to place 117 implants to support 46 fixed partial dentures and 8 single crowns. Twelve (22.6%) sinus lift procedures were prepared with the Piezosurgery device, while the other 41 (77.4%) procedures were prepared with the UBS device when it became available. Patient age ranged from 30 to 81 years (mean age: 55.0 ± 8.5 years). Eighteen (52.9%) of the patients were women and 16 (47.1%) were men.

The initial RBH varied from 1 to 9 mm (mean: 3.7 mm). In terms of RBH classes, 7.7% of the sites were Class B, 39.3% were Class C, and 53.0% were Class D. Class B sites were treated in the same way as the adjacent Class C or Class D sites, ie, with delayed implant placement.

Bone grafting was carried out with autologous bone alone at 22 (18.8%) implant sites, with a mixture of autologous bone and Bio-Oss at 29 (24.8%) sites, and with Bio-Oss alone at 66 sites (56.4%).

Follow-up and survival criteria

The survival criteria for the sinus lift procedures with USBS were as follows: *(1)* procedure performed without membrane perforation; *(2)* effective implant placement and achievement of primary stability in the augmented bone; *(3)* implant stability at second-stage surgery and at each control, ie,

Fig 5 *Preparation of the platelet-poor plasma membrane to close a perforated membrane or cover the bony window opening.*

at 3, 6, and 12 months after loading and annually thereafter; *(4)* absence of pain or any subjective sensation at second-stage surgery and at each control; *(5)* absence of recurrent periimplant infection; and *(6)* absence of continuous radiolucency around the implant.

Results

During the sinus approach, two Schneiderian membranes (3.8%) were perforated. Both occurred with the Piezosurgery device at the beginning of the learning curve. The first occurred because too much pressure was exerted as a result of sensation of limited cutting efficiency, while the second resulted from the presence of a bony septum.

After perforation, the rest of the membrane was separated manually, and the perforated membrane was covered with a platelet-poor plasma membrane (Fig 5) before elevation into the sinus. The platelet-poor plasma membrane adhered well to the perforated membrane and isolated the grafting material from the sinus cavity. No complications were recorded following membrane perforation. An orthopantomogram taken 2 weeks after surgery showed no pathologic sign of sinus densification.

After bone grafting, the augmented bone height beneath the sinus ranged from 12 to 24 mm (mean: 16.4 mm). Of the bone sites, 50.4% showed a final bone height of 10 to 15 mm, 26.6% showed a final bone height of 16 to 20 mm, and 23.1% showed a final bone height of > 20 mm.

Implants were placed 6 to 8 months (mean: 7.3 months) after the elevation procedure and then left submerged to heal for 4 to 6 months. Two types of implants were placed: 13 (11.1%) Osseotite implants (3i) with an external hex and 104 (88.9%) Leader implants (Leader Italia) with an internal hex. Fifty-eight (49.6%) implants had a diameter of 3.75 mm, and 59 (50.4%) implants had a diameter of 4.5 mm. The implant length was either 10 mm (11 implants, 9.4%), 11.5 mm (20, 17.1%), or 13 mm (86, 73.5%).

At second-stage surgery, four implants failed to osseointegrate in three patients. The initial RBH was 2 (at two sites), 3, or 4 mm. The final bone height before placement was 13 (at two sites), 14, or 15 mm. The failed implants were 4.5 mm in diameter and 11.5 mm (at one site) and 13 mm (at three sites) long. The survival rate for the implants placed was 96.6%.

All other implants passed the second-stage surgery and remained loaded for at least 1 year. The 5-year life-table analysis of loaded implants (Table 1) showed that 113 and 94 implants were loaded for at least 1 and 2 years, respectively. No implant failed after loading; therefore, the cumulative survival rate of loaded implants was 100%.

Discussion

The most frequent complication during sinus elevation is membrane perforation. The literature shows a frequency of membrane perforation ranging from 16.7% to 44%, with an average of 28.6% (Table 2).[3,14–18,41,42] Possible consequences are postoperative sinus inflammation[14,16,18] and a higher implant failure rate (up to 30%).[19] In all cases, membrane repair makes the surgery more complex and lengthy.

In the present study, membrane perforation was a rare event, occurring in only 2 of 54 cases (3.8%). Both perforations occurred at the beginning of the learning curve. Vercellotti et al[34] reported a similar rate of 4.8% (1 of 21), and more recently, Wallace et al[42] reported a rate of 0% (0 of 100) (Table 2).

Table 1 Life-table analysis of loaded implants

Loading interval (mo)	Loaded implants at risk	Dropouts	Failures	Survival rate at interval	Cumulative survival rate
0–12	113	0	0	100%	100%
12–24	113	0	0	100%	100%
24–36	92	0	0	100%	100%
36–48	66	1	0	100%	100%
48–60	33	1	0	100%	100%

Table 2 Membrane perforation rates using rotating burs versus USBS tips

	Perforation rate	
Reference	Rotating	USBS
Raghoebar et al[3]	47/162 (29.0%)	—
Tawil and Mawla[17]	5/30 (16.7%)	—
Engelke et al[14]	28/118 (23.7%)	—
Shlomi et al[15]	20/73 (27.4%)	—
Schwartz-Arad et al[18]	38/81 (46.9%)	—
Barone et al[16]	31/124 (25.0%)	—
Ardekian et al[41]	35/110 (31.8%)	—
Vercellotti et al[34]	—	1/21 (4.8%)
Blus et al (present study)	—	2/53 (3.8%)
Wallace et al[42]	—	7/100 (7.0%)
Average	28.6%	5.2%

While using USBS, two reasons for possible membrane perforation were identified. First, perforation may occur when the vibrating tip runs into a bony septum during the membrane approach. When a septum is identified via radiographs, two smaller windows on each side of the septum should be prepared. Second, perforation may result when high pressure is exerted on the membrane by the tip. This occurs when the surgeon seeks to increase the cutting efficacy of the tip because of the limited power of the device used or a worn out tip.

Closure of a perforated membrane can be performed using membranes of cross-linked type I collagen,[43] resorbable collagen,[17] or autologous fibrin glue.[44] The two perforations in this study were closed with a platelet-poor plasma membrane and healed uneventfully. No pathologic sign of sinus densification was found on orthopantomograms taken 2 weeks after surgery. The present implant survival rate of 96.6% is in accordance with other studies.[37,38]

USBS offers the following advantages: *(1)* low occurrence of membrane

perforation, *(2)* clean and blood-free surgical field because of cavitation and the collapsing action of the ultrasound on the blood vessels, *(3)* better visual access to the surgical area, and *(4)* easier access to bone harvesting sites with no risk of injury to the surrounding neurovascular bundles and soft tissues.

The tips of the two ultrasonic devices used in this study differed notably in material, size, and shape. The UBS tips are made of titanium alloy, while stainless steel is used for the Piezosurgery tips. The UBS tips are longer, and straight tips instead of angled tips were also available to harvest bone. The reason for these differences is the higher power offered by the UBS. Under 90 W, stainless steel tips are more prone to fatigue fracture. The higher power of the UBS device means that longer tips can be used, allowing for easier access to remote areas in the oral cavity. Further, the tips do not need to be angled to develop resonance and ultrasonic motion.

Conclusion

Opening the bony window of the sinus with USBS led to a 3.8% occurrence of membrane perforation. Implant placement in augmented sinuses was highly predictable: 96.6% of the implants osseointegrated at second-stage surgery, and no loaded implants failed. Bone harvesting from the oral cavity or the chin was simplified. The procedure was safe, less technique sensitive, and comfortable, and it did not encroach on the surrounding soft tissues.

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