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Microscope-Controlled Internal Sinus Floor Elevation (MCI-SFE): A new technique to evaluate the sinus membrane during transcrestal lifting

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MICROSCOPE-CONTROLLED INTERNAL SINUS FLOOR ELEVATION (MCI-SFE): A NEW TECHNIQUE TO EVALUATE THE SINUS MEMBRANE DURING TRANSCRESTAL LIFTING

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Transcrestal (or "internal") sinus floor elevation (SFE) can be performed when the residual alveolar ridge has adequate vertical (≥6 mm; SA1 and SA3 as classified by Misch) and horizontal dimensions. Although this surgical technique is currently established, it has two shortcomings. First, internal SFE is considered a "blind" approach as far as verification of the elevated osteomucosal layer on the sinus floor is concerned. Also, no guidelines supported by scientific evidence are currently available as to the vertical dimension that can be attained by elevation and grafting without injuring this osteomucosal layer. The present investigation explains a new visual controlling method during evaluation of the osteomucosal layer on the sinus floor, which is based on the use of high-powered optical magnification and accordingly has been termed "microscope-controlled internal" SFE (MCI-SFE), and also examines the influence of elevation heights on the frequency of perforation and other complications during and after SFE.
Fifty-nine internal SFE procedures were verified with this technique in 43 patients, who were divided into three study groups depending on the planned height of elevation and they received a total of 60 implants. The clinical and radiographic results of this study demonstrated that the risk of injury to the osteomucosal layer and the associated risk of incurring additional complications such as implant loss and sinusitis would increase significantly in the presence of elevation and grafting heights of ≥4 mm. Whenever possible, therefore, elevation of the sinus floor in internal SFE procedures should be less than 4 mm. Using an operating microscope for visual inspection of the osteomucosal layer of the sinus floor improves surgical success and contributes to better outcomes of internal SFE. *Int J Microdent 2013;4:**–***

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Vertical bone dimensions in posterior segments of the maxilla are frequently inadequate for placement of endosseous implants to support prosthetic restorations in these areas. Tatum was the first clinician to perform sinus floor elevation (SFE) in 1977, although the technique used was not published until later.[1] Boyne and James reported their own technique in 1980.[2] While Tatum developed instruments allowing SFE procedures to be conducted through the alveolar process, Boyne and James used a lateral access route by modifying the traditional Caldwell-Luc procedure: they performed a horizontal incision in the vestibulum of the posterior maxilla and prepared a mucoperiosteal flap to expose the zygomaticoalveolar crest. A bone window was created to access the sinus cavity, followed by carefully dislodging and relocating the sinus membrane further cranially. This artificial subantral space was used to

TABLE 1 Study design

	Group 1	Group 2	Group 3
Number of patients	16	14	13
Number of MCI-SFE procedures	21	20	18
Number of implants placed	21	20	19
Height of membrane elevation	<2 mm	2–4 mm	>4 mm
Follow-up period	1 year		
Time of occlusal loading	After 3 to 5 months		
Prosthetic superstructure	Single crowns		

place the implants. After filling any residual gaps with autogenous bone, the mucoperiosteal flap was repositioned and primary closure obtained.

This technique of external SFE has since been extensively investigated and, on this basis, has increasingly gained importance to the point of becoming a routine surgical procedure in implant dentistry.[3-5] Provided that the residual bone volume is adequate for primary stability, implants are placed in the same session as the SFE procedure, and it has become common to fill the gap spaces with bone substitutes.[6,7] However, external SFE procedures are occasionally associated with extensive intraoperative and postoperative complications (bleeding, pain, swelling, haematoma) that remain a challenge for all parties involved. A number of technical novelties aiming to reduce the surgical trauma have been proposed to address this issue, most of them new variants of transcrestal SFE.[8-12] One of them – the osteotome technique introduced by Summers – has become an established clinical approach in recent years. Its principle is to measure bone height and then conduct pilot and expansion drillings in the implant bed to a depth 1 mm short of the sinus floor. Subsequently, a diameter-matched osteotome is used to push the bony sinus floor, together with the Schneiderian membrane overlying it, in an upward direction. The implant is placed in the same session, once the subantral space has been filled with a bone substitute.

Nevertheless, two shortcomings associated with these transcrestal/internal SFE procedures remain to be resolved:[13]

1. They do not include the option of intraoperative visual inspection of the Schneiderian membrane.
2. Sufficient evidence to recommend a specific height of elevation and grafting is not available.

The present article focuses on these drawbacks of internal SFE procedures, and a very serviceable method allowing visual inspection of the sinus membrane by optical magnification is presented. In addition, outcomes of clinical and radiographic examinations are reported to define evidence-based guidelines for the augmentation and preoperative ridge heights required in connection with internal SFE procedures.

MATERIALS AND METHODS

From December 2006 through April 2009, 43 patients underwent surgery within the scope of an in-house investigation into microscope-controlled internal SFE (MCI-SFE) performed at a private clinic in Germany. The mean age of these 43 patients was 39 years (17 men, 26 women; Table 1). Only 6 smokers were included in this sample, all of whom reported that they smoked ≤10 cigarettes a day. Their distribution across the three study groups was 3/2/1 (groups 1/2/3). All patients presented with a health status not including any systemic or local contraindications to oral surgery.

Periapical radiographs using the right-angle technique and cone-beam computed tomography (CBCT) scans were obtained for preoperative assessment. The surgical procedures were planned with three-dimensional planning software (coDiagnostiX; IVS-Solutions, Chemnitz, Germany). Baseline findings at the surgical sites ranged from 5.3 to 8.2 mm in the transversal plane. Residual ridge heights were found to vary between 4.3 and 10. 4 mm (SA1 and SA3 as classified by Misch). All procedures were conducted with an operating microscope (OPMI Proergo; Zeiss, Oberkochen, Germany) for visual inspection of the Schneiderian membrane (Fig 1).

Elevation of the sinus floor was accomplished with osteotomes

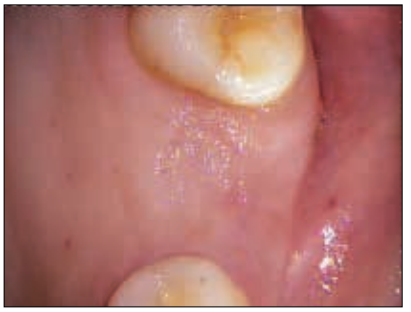
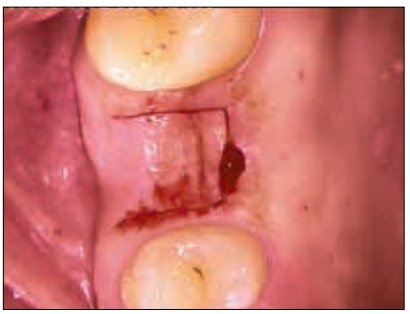
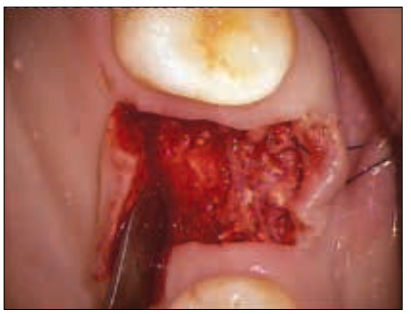


Fig 1 (left) Application of the operating microscope (OPMI Proergo, Carl Zeiss) during implant operation.

Fig 2 (right) Preoperative condition in a patient.





Figs 3a and b Examples of the incision lines used in this study. In all patients, a mucosal flap was prepared while sparing the adjacent papillae. *(a)* Note the vestibular pedicled crestal rectangular incision and *(b)* the crestal "door-leaf incision" after flap reflection.

(Camlog; Altatec, Wimsheim, Germany). Group 1 included cases of elevation ≤2 mm, group 2 cases ranging from 2 to 4 mm, and group 3 cases exceeding 4 mm of elevation. Table 1 summarizes the distribution of patients across the three groups. Group 1 included 16 patients with 21 MCI-SFE procedures and simultaneous placement of 21 implants 3.8–5.0 mm in diameter and 9–11 mm in length (Camlog Screw-Line; Altatec, Wimsheim, Germany). Group 2 included 14 patients with 20 MCI-SFE procedures and simultaneous placement of 20 implants. Group 3 included 13 patients with 18 MCI-SFE procedures and simultaneous placement of 19 implants (Figs 11 to 13).

Following the introduction of xenogeneic matrix (Bio-Oss; Geistlich, Wolhusen, Switzerland) and rinsing with isotonic saline, the osteomucosal layer was visually inspected using the operating microscope at a magnification of ×5 to ×15. Once the site was verified, the implants were immediately placed. Radiographic verification (via periapical films using the right-angle technique) was obtained immediately after the procedure and 3 to 5 months postoperatively (i.e., before the restorative phase was started). For implants exhibiting a primary stability of >25 Ncm, a non-submerged integration protocol was adopted, while in cases of <25 Ncm a submerged protocol was used. Implants left to integrate under the submerged protocol were surgically exposed after 2 to 3 months. Implants were evaluated by resonance frequency analysis (Osstell; Integration Diagnostics AB, Göteborg, Sweden) for osseointegration 3 to 5 months after placement. At this point, the restorative treatment phase was finalized by delivering single-tooth restorations. Follow-up examinations were generally performed around 4 and 8 months after prosthetic delivery.

SURGICAL PROCEDURE

All MCI-SFE procedures were performed under local infiltration anaesthesia (Ultracain D-S forte; Sanofi-Aventis, Berlin, Germany). A three-dimensional drilling template was used to mark the exact position of implant insertion with the help of a periodontal probe. Subsequently, either a "door-leaf incision" or a "vestibular pedicled rectangular incision" was made, depending on the keratinized soft-tissue profile (Figs 2 and 3). All papillae of the neighbouring teeth were spared. The flaps were prepared from mucosa, leaving as much of the crestal periosteum as possible in situ (Fig 3). Subsequently, the pilot drilling was performed, up to approximately 1

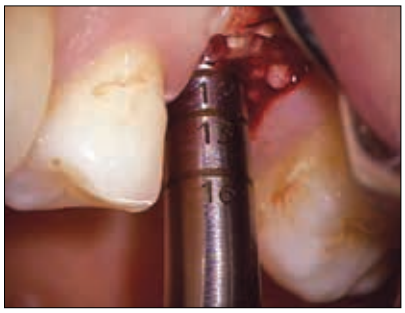


Fig 4 Antral elevation of the osteomucosal layer using a scaled osteotome of Camlog-Altatec.

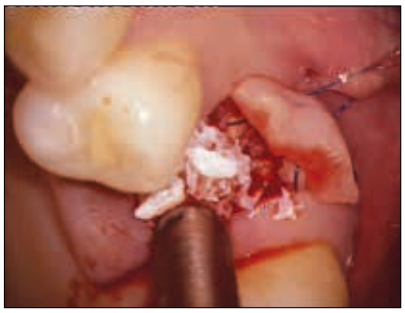


Fig 5 Introducing Bio-Oss particles (size: 1–2 mm) into the antrally extended drill channel.

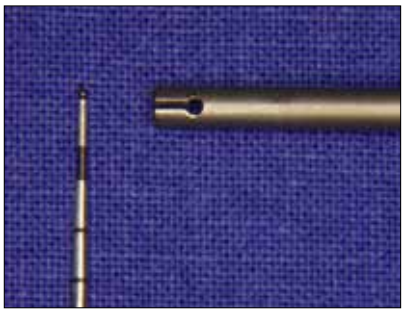
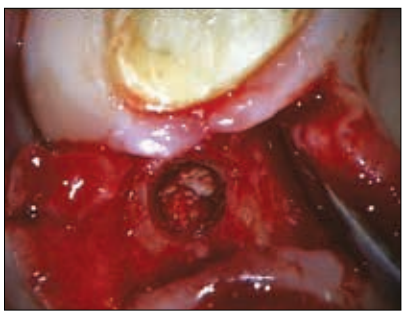
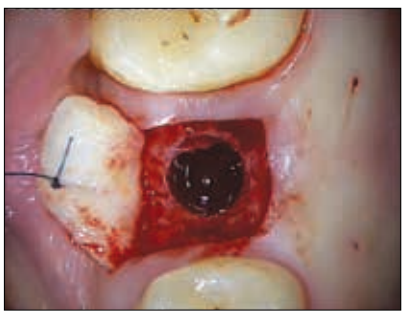
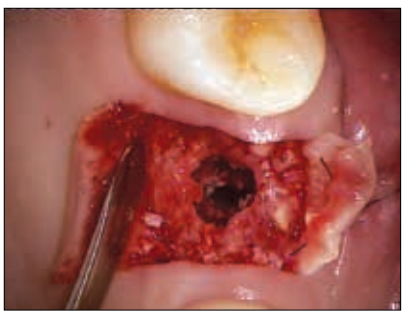


Fig 6 This suction device (featuring an external working end diameter of 1.5 mm and an internal diameter of 1.0 mm) of Helmut-Zepf-Medical Techniques/DCV has been specially developed for microsurgical SFE procedures. Note the lateral grooves, which prevent the instrument from being stuck on the osteomucosal layer, thereby minimizing the risk of perforation.







Figs 7a to c Three clinical findings are typical on visual inspection of the drill channel before implant placement, after introduction of the Bio-Oss particles: *(a)* visible and safely deposited Bio-Oss particles in the bottom area, *(b)* blood in the bottom area and *(c)* visible perforation in the bottom area.

mm short of the deepest point of the sinus floor, in accordance with the vertical distance identified by the three-dimensional scan and software. Then, the implant bed was prepared to the required diameter, taking care not to alter the established depth of drilling.

At this point, a diameter-matched osteotome (Camlog; Altatec, Wimsheim, Germany) was applied to elevate the bony sinus floor, together with the osteomucosal layer overlying it, to the planned insertion level of the prospective implant design (Fig 4). The amount by which the sinus floor was elevated varied with the residual bone heights measured in the three study groups. Bio-Oss (particle size of 1–2 mm) was then introduced into the implant bed and carefully pushed upwards with the osteotome (Fig 5). Roughly 0.1 g of Bio-Oss was applied in group 1 (elevation height of ≤2 mm), 0.2 g in group 2 (elevation height of 2–4 mm) and 0.3 g in group 3 (elevation height >4 mm).

Subsequently, the implant bed was carefully rinsed with saline and dried, using a suction device indicated for maxillary sinus applications (Helmut-Zepf-Medical Techniques/DCV, Tuttlingen, Germany), which was inserted around 5 mm into the implant bed. This suction device was specially designed for microsurgical (microscope-guided external and microscope-controlled internal) SFE procedures and features lateral grooves that prevents the instrument from getting stuck on the sensitive osteomucosal layer, thereby minimizing the risk of accidental perforation (Fig 6).[12,13] Immediately after, the bottom of the implant bed was visually inspected under an operating microscope, via a mirror at a magnification of ×5 to ×15.

Any perforations of the osteomucosal layer were usually spotted right away, although the careful process of rinsing and aspiration had to be repeated in some cases prior to microscopic verification. When the osteomucosal layer was not perforated, bone or

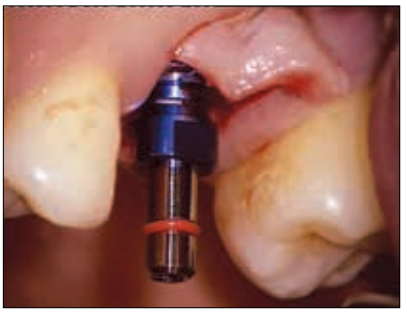


Fig 8 Insertion of a Camlog Screw-Line implant 5.0 mm in diameter and 11 mm in length.

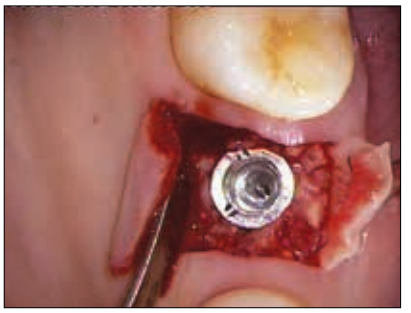


Fig 9 Occlusal view after insertion of the Camlog Screw-Line implant and removal of the insertion aid.

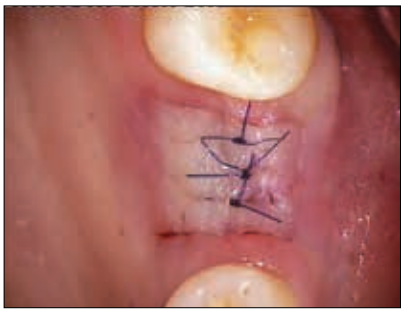
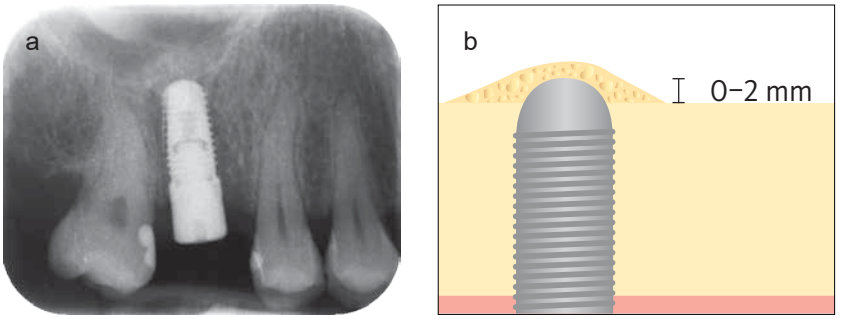
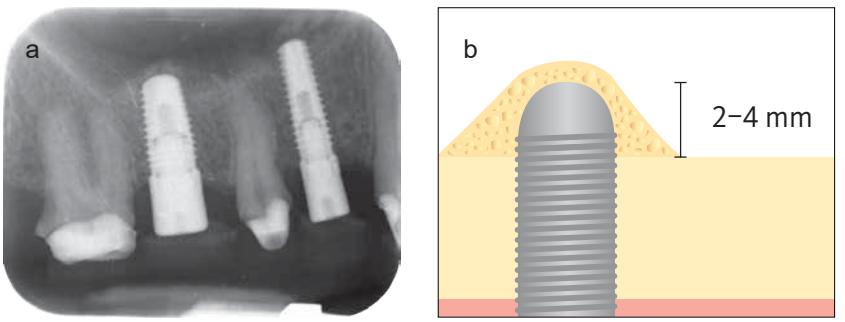


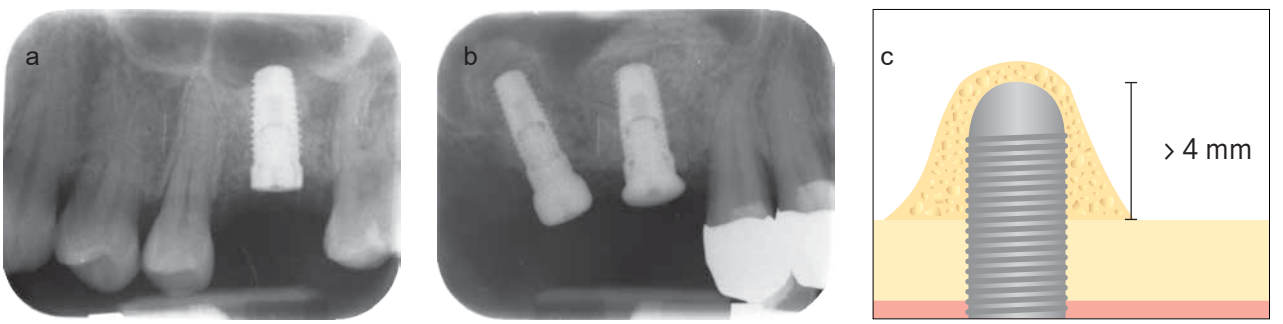
Fig 10 Occlusal view following wound closure with 6-0 Seralon.



Figs 11a and b Radiograph and additional graphic of group 1 (elevation heights of ≤ 2 mm) obtained 4 months postoperatively.



Figs 12a and b Radiograph and additional graphic of group 2 (elevation heights of 2–4 mm) obtained 4 months postoperatively.



Figs 13a to c Radiographs and additional graphic of group 3. Radiograph *(a)* was obtained 5 months postoperatively and illustrates a case of perforation of antral osteomucosal layer with no radiographically demonstrable augmentation above the implant apex. Radiograph *(b)* was obtained 6 months postoperatively and illustrates a rare case of extreme elasticity of the perforation of antral osteomucosal layer with successful augmentation in the implant area.

TABLE 2 Intraoperative and postoperative complications across the study groups

	Group 1	Group 2	Group 3
Membrane perforations	none	2	5
Postoperative bleeding	none	0	2
Sinus complications	none	1	3
Implant losses	none	1	3

blood was visible in the bottom area of the implant bed, whereas perforations were immediately discernible (Figs 7a to c). Then the prospective implants were placed, irrespective of whether a perforation was present (Figs 8 and 9). For implants exhibiting a primary stability of >25 Ncm, a non-submerged integration protocol was adopted, while in cases of <25 Ncm a submerged protocol was used (Fig 10). A 6 0 microsurgical needle-thread combination (Seralon; Serag-Wiessner, Naila, Germany) was employed to achieve primary wound closure (Fig 10).

RESULTS

Microscopically visible perforations of the osteomucosal layer were exclusively noted in groups 2 and 3. No perforations were observed in group 1, which involved elevation of the sinus floor by no more than 2 mm. The postoperative radiographs in groups 1 and 2 revealed subantral grafting heights of 0.5–1.5 mm above the implant apex, based on all patients and implants that were not associated with perforations (Figs 11 and 12). Judging from the postoperative radiographs, no augmentation above the implant apex was observed when a perforation had occurred (Fig 13a). Some of the postoperative images showed a mucosal layer above the implant apex within the sinus cavity, and some revealed no tissue structure in this area (Fig 13a). Interesting and unexpected findings with regard to the height and shape of subantral augmentation were notably seen in group 3, which involved elevation of the sinus floor by ≥4 mm up to a maximum of 8 mm (Fig 13b).

In group 1, all implants placed simultaneously with the MCI-SFE procedure easily achieved osseointegration and could be loaded after 3 to 5 months as scheduled. Also, the clinical follow-up examinations performed 4 and 8 months after delivery of the prosthetic restorations did not reveal any abnormalities among the patients in this group.

Group 2 revealed a total of 2 (10%) microscopically visible perforations of the osteomucosal layer based on 20 MCI-SFE procedures and implants. Two patients in this group were affected: one woman reported a sensation of pressure on the treated side of the alveolar ridge 4 days postoperatively, associated with persistent pain radiating up to the orbit. Her symptoms gradually improved after 2 weeks of analgesic and antibiotic treatment using ibuprofen 800 mg (Ratiopharm, Ulm, Germany) and amoxicillin 1500 mg (Ratiopharm). However, the implant was found to lack osseointegration 3 months after the procedure (during second-stage surgery for implant exposure) and had to be removed (Table 2). The second perforation, observed in a male patient, was not associated with any sequelae by the end of the study. Likewise, the clinical course also remained uneventful in all other patients of this group right down to the second follow-up examination after prosthetic delivery.

Group 3 revealed 5 microscopically visible perforations of the osteomucosal layer in 4 patients. Three of these patients developed symptoms similar to the ones experienced by the patient in group 2. Two of them, however, additionally showed nasal secretion with pus in the wake of perforation, which resolved under antibiotic treatment with amoxicillin 1500 mg (Ratiopharm). In addition, the same patients presented with postoperative nasal bleeding on the treated side, which could be arrested by tamponade of the nasal meatus affected. Two of the patients who revealed symptoms of sinusitis lost their implants within 3 days of the procedure. One of these implants was removed during the second-stage procedure scheduled for implant exposure, while the second implant was explanted because of mobility after 1 month of transmucosal healing. The remaining case of implant removal during second-stage surgery in group 3 had not been pre-

ceded by an intraoperative finding of osteomucosal layer perforation (Table 2).

DISCUSSION

External SFE has become a scientifically acknowledged treatment modality. These procedures are today routinely used to facilitate therapy with oral implants. Provided that the residual bone volume is adequate, they will also permit simultaneous placement of implants.[7, 12, 13] However, since the conventional technique of external SFE is associated with considerable trauma to patients, a number of alternative procedures for minimally invasive SFE have been proposed in recent years,[8-12] most popular among them being transcrestal augmentation as described by Summers, also known as "internal" SFE or "osteotomy technique".[8-10] Implant survival and success rates of up to 96% have been reported for implants placed in conjunction with internal SFE.[18] In addition to invariably allowing visual inspection of the sinus membrane, this technique requires both a residual bone height of ≥6 mm and an adequate horizontal dimension of the residual bone depending on the diameter of the prospective implant.[14, 15]

Whether a bone substitute is required for internal SFE has been a matter of scientific debate. Although the osteotomy technique included the use of bone substitutes in its initial form, Nedir et al.[15] have contended that the sinus floor has sufficient bone-forming potential on its own in defined situations (adequate ridge height/width and primary implant stability) and that this even holds true if the sinus membrane gets perforated. Indisputably, however, any perforations of the sinus membrane occurring during internal SFE procedures will usually result in complete or partial loss of the introduced grafting material both circumferentially and above the implant apex in the subantral space. This, in turn, will either cause antral exposure of a variable longitudinal surface segment of the implant or, at best, coverage of the implant by sinus membrane via secondary healing. However, the objective of SFE is to yield sufficient augmentation of the subantral space to prevent any implants placed in this area both from extending into the contaminated antral space and from interfering with mucociliary clearance of the sinus cavity.[19] This, in turn, will crucially depend on the residual bone height and width, the planned height of elevation, and the elasticity of the layer comprising the sinus membrane and the periosteum. Endoscopic investigations have demonstrated the maximum elastic limit of the Schneiderian membrane to be 4 mm. To avoid perforations, this limit should not be exceeded during internal SFE procedures.[20, 21] That said, endoscopic sinus monitoring has not yielded good results during SFE procedures in daily practice.

The present investigation had two objectives: to describe a new technique that can be readily implemented for visual inspection of the osteomucosal layer, and to define accurate recommendations for the height of elevation that can be attained without putting the outcome of internal SFE procedures at risk. The verification technique presented is based on optical magnification using a powerful loupe or microscope. Recent reports by Shakibaie-M.[12, 13] demonstrate that optical magnification has become an indispensable part of minimally invasive implant dentistry. During external SFE procedures in particular, the combination of microsurgical instruments and optical magnification offers significant advantages in terms of minimizing sinus membrane perforation rates and preserving the vestibular bone lamella, by reducing the size of the window created for SFE. In addition to significantly minimizing trauma, there is another immediate benefit in the fact that simultaneous implant placement becomes more predictable in this way even in situations of advanced ridge resorption.[12, 13] Being comparable to the use of optical magnification during endodontic treatment of maxillary molars, indirect visual inspection of the bottom of the implant bed via a mirror to verify intactness of the osteomucosal layer is a method that can be applied effectively after proper training.[17] It is important, however, to use a microsuction device, so that the bottom area becomes visible after careful aspiration.

The fact that the risk of damaging the osteomucosal layer during internal SFE procedures increases with the height of elevation stands to reason and was reported at an early stage by Rosen et al.[14] The present investigation confirms that no technical risk is present if elevation of the osteomucosal layer is kept to a minimum (≤2 mm in group 1). Two perforations of the osteomucosal layer (14%) and one implant loss (5%) occurred in group 2. All these events were related to procedures with elevation of the sinus floor by almost exactly 4 mm. Judging from the results in group 3, including a 28% rate of osteomucosal layer perforation and a 16% rate of implant loss, antral elevations in excess of 4 mm are not recommended. Based on the findings of this investigation, the maximum height of elevation at which internal SFE procedures are still safe appears to be between 3 mm and 4 mm. This finding is consistent with the results of other endoscopic and clinical studies.[16, 20, 21] As the smokers among the patients were

distributed with a bias in groups 1 and 2, the effect of nicotine on the perforation rate could not be accurately determined. Additional investigations would be required to evaluate the effect of smoking.

What the results clearly show is that osteomucosal layer perforation should be carefully avoided during internal SFE procedures, as all cases of sinus-related complications and implant loss noted in this study were preceded by a visually verified perforation. Additional factors that had a striking role in the cases of perforation included bone density and horizontal ridge dimension. Harder bone structures and narrower ridges were associated with an increasingly higher risk of damaging the osteomucosal layer. Based on the above-described results and conclusions about the recommended height of sinus floor elevation (not exceeding 4 mm), and given the presence of an appropriate horizontal ridge dimension, a ridge height of 5 to 8 mm is required preoperatively, considering that implants 8 to 11 mm in length are usually inserted in posterior segments. This range applies to ideal situations in which 1 mm of elevation height is reserved for the grafting material above the implant apex.

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