



IMPLANTOLOGIE

DIE ZEITSCHRIFT FÜR DIE PRAXIS

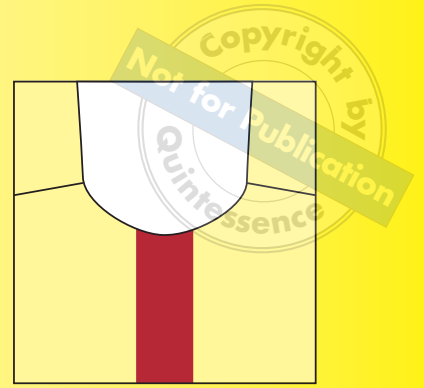
SPECIAL REPRINT

**Microscope-guided
external sinus floor
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a new minimally invasive
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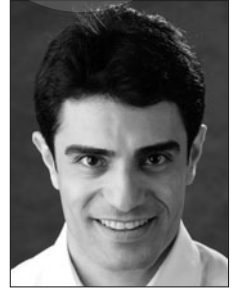
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Microscope-guided external sinus floor elevation (MGES) – a new minimally invasive surgical technique



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KEY WORDS *Sinus floor elevation, minimally invasive surgical technique, surgical microscope, microsurgery, implantation, perforation, Schneider's membrane*

Dental authors have considered the accidental perforation of Schneider's membrane the most serious complication of external sinus floor elevation. A sinus lift procedure with concurrent immediate implant placement (single-step procedure) has been judged equally risky in advanced atrophy of the alveolar ridge (categories SA3 and SA4 according to Misch). To reduce the incidence of membrane ruptures and to preserve the local vestibular alveolar bone, alternative surgical techniques have been introduced, notably the internal sinus lift according to Tatum and Summers, the balloon dilatation method according to Benner or the endoscopic technique according to Baumann and Ewers. The need for pressure-guided osteoelevation may diminish patient compliance. Missing or incomplete visual verification of the membrane elevation may reduce the scope of the clinical application of these methods. Using specially developed microsurgical instruments under optical magnification (surgical microscope or magnifying glass) and optimized illumination, the external access to the maxillary sinus can be kept small while at the same time significantly reducing the membrane perforation rate (1/20, 5%). This protects the vestibular alveolar bone, increasing the primary stability of concurrently placed implants, improving the supply of nutrients to the subantral bone graft, and reducing the postoperative complication rate. These results were obtained in a prospective in-office study on 17 patients on which 20 microscope-guided single-step external sinus floor elevation procedures were performed.

■ Introduction

Sinus floor elevation was first described by Boyne¹ in the late 1970s. It has meanwhile become a scientifically recognized routine procedure.² In clinical trials, the osseointegration of endosseous implants within the augmented sinus floor has been found to be exceptionally safe, at success rates of 78%–100%.^{3–5} However, the majority of dental authors have considered the accidental perforation of Schneider's membrane the most serious complication during a

classic external sinus floor elevation procedure. Depending on the extent of the perforation, the surgeon may be forced to abandon the operation, or the patient may suffer from postoperative complications such as sinusitis or implant loss due to peri-implantitis. Reports about the incidence of membrane perforations in sinus lift procedures vary between 12% and 44%.^{6–8}

Another surgical challenge during external sinus lift procedures with concurrent immediate implant placement (single-step procedure) is to achieve suffi-

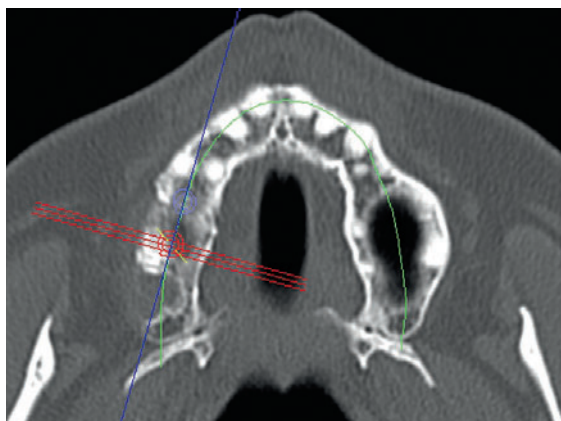


Fig. 1 Axial view of implant sites 15 and 16 using a CT scan and the coDiagnostiX® planning software.

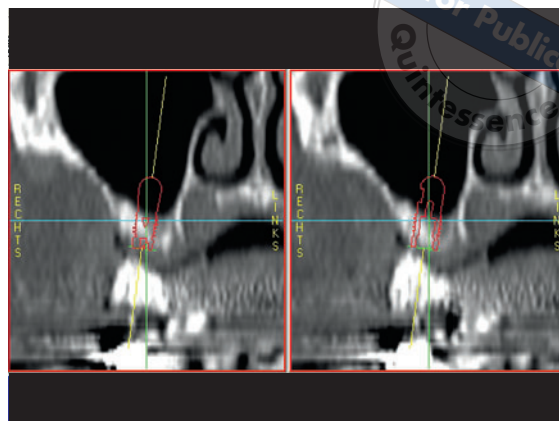


Fig. 2 Transversal view of implant sites 15 and 16 using a CT scan and the coDiagnostiX® planning software.

cient primary stability in advanced atrophy of the alveolar ridge (residual bone height of 0–5 mm; categories SA3 and SA4 according to Carl E. Misch). Alternative surgical techniques to classical external sinus lift were introduced, notably the internal sinus lift according to Tatum⁹ and transalveolar bone augmentation according to Summers.^{10,11} These two have also found clinical acceptance, whereas the balloon dilation method according to Benner¹² or the endoscopic technique according to Baumann and Ewers¹³ have not been equally popular because of their technical and logistical complexities.

■ Materials and methods

Between October 2005 and June 2007, 20 sinuses of 17 patients were surgically treated according to the method described here within the framework of an in-office study, and 38 implants were inserted in single-step procedures.

The medical history of all patients was without significant findings. The patients were between 32 and 68 years old; all were non-smokers. Out of the seventeen patients, eleven were female and six were male. Eight patients received pre-implantological periodontal treatment. In eleven patients, fresh extraction sockets were treated according to the socket preservation technique using Bio-Oss® granules (Geistlich, Wolhusen, Switzerland) and Stypro® resorbable hemostatic sponge material (Curasan, Kleinostheim, Germany).

Radiological diagnostics included OPGs and intraoral radiographs in nine patients and CT scans and OPG in eight patients. The data of patients examined by computed tomography were analyzed three dimensionally using the coDiagnostiX® implant planning software (IVS Solutions, Chemnitz, Germany) (Figures 1 and 2). The results of the 3D analyses were used to create intraoperative drilling stents.

The baseline bone situation showed advanced atrophies of the alveolar ridge in all cases, with residual crestal bone heights of 0 to 8 mm (categories SA3 and SA4 according to Misch) (Figure 2, Table 1).

All sinus lift operations were performed under the OPMI Proergo surgical microscope (Zeiss, Oberkochen, Germany) (Figure 3) using newly developed microsurgical sinus lift instruments (Helmut Zepf Medizintechnik/DCV, Seitingen, Germany).

The surgical protocol was the same for all patients. Where more than two implants were to be inserted simultaneously, an additional fenestration was made for maximum intraoperative visibility.

All patients received Camlog implants (Screw line and Root line; Camlog Biotechnologies, Wimsheim, Germany) with diameters between 3.8 and 5.0 mm and lengths between 9 and 13 mm. No additional lateral augmentation was performed. The bone-augmentation material used was a mixture of autologous bone (Crista zygomaticoalveolaris) and Bio-Oss® granules.

Once the augmentation was completed, all sinus lift windows were covered with multiple layers of Bio-Gide® membrane (Geistlich, Wolhusen, Switzer-

Table 1 Mean preoperative residual bone height at the various implants sites within the study group

Implant site(s)	Mean residual bone height [mm]	Bone quality class according to Misch
24, 25, 26	5.5	SA 3
15, 16	7.0	SA 3
15, 16	3.5	SA 4
25	3.5	SA 4
16	4.0	SA 4
14, 15, 16	4.5	SA 4
24, 25	3.0	SA 4
14, 15	3.0	SA 4
25, 26	5.5	SA 3
26	6.0	SA 3
14, 15, 16	2.5	SA 4
15, 16, 17	3.0	SA 4
26, 27	3.5	SA 4
26	3.0	SA 4
16	5.0	SA 3
14, 15	8.0	SA 3
26	4.0	SA 4
25, 26	3.5	SA 4
15, 16	2.5	SA 4
25, 26	3.0	SA 4

land) to provide for guided bone regeneration (GBR). No additional pin fixation was performed.

Patients were concomitantly medicated as follows:

1. Clindamycin 300 mg, three times daily from the first preoperative day to the third post operative day;
2. Prednisolone 10 mg (Acis, Oberhaching, Germany), 20 mg on the first preoperative day and 10 mg daily from day of the operation to the third postoperative day;
3. Novalglin drops (Aventis, Frankfurt, Germany) postoperatively as needed, 15 to 20 drops at eight-hour intervals.

All patients were instructed not to engage in sports and to refrain from wearing their dentures for up to one week postoperatively. The first postoperative control was two days after the procedure; the sutures were removed on the tenth day postoperatively.



Fig. 3 Clinical use of the OPMI Proergo surgical microscope by Zeiss.

■ Properties of the newly developed microsurgical sinus lift instruments

The shape of these instruments is based on that of the proven conventional sinus lift instruments by Helmut Zepf Medizintechnik (Seitingen, Germany). Over a period of approximately 2 years and based on studies performed during 32 microscope-guided external sinus lift procedures, the instrument angles were adapted to match the specific working and lighting conditions under the surgical microscope. Special regard was taken to ergonomics and the safe preparation of the sinus membrane. In addition, the following modifications were made:

1. To minimize the diameter of the sinus lift window (approximately 5 mm) without compromising the maneuverability of the instruments, the working ends of the instruments were reduced in size by approximately 60%.
2. All working ends were sharpened in order to be able to achieve initial fracturing of the paper-thin bone layer following preparation of the sinus lift window without having to exert excessive pressure.
3. The surfaces of all instruments were roughened to avoid distracting light reflection to the surgical microscope or halogen-lit magnifying glass.

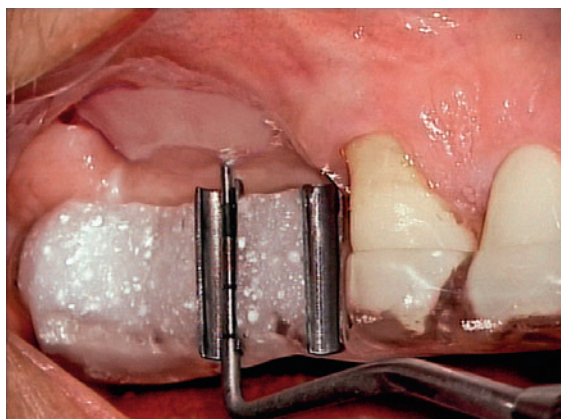


Fig. 4 Mucosal marks for the future implant sites 15 and 16 using a coDiagnostiX® drilling stent in a case with advanced loss of alveolar bone height.

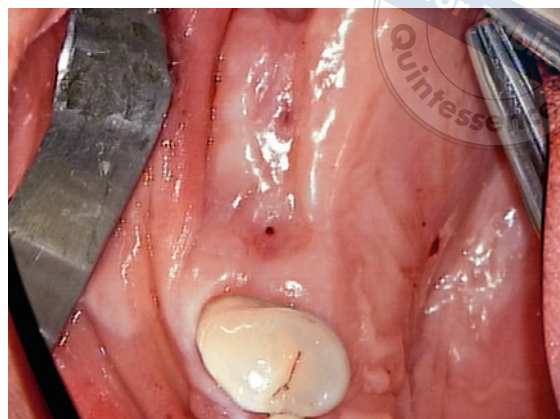


Fig. 5 Mucosal marks for the future implant sites 15 and 16 in a case with well-preserved alveolar bone width following socket preservation.

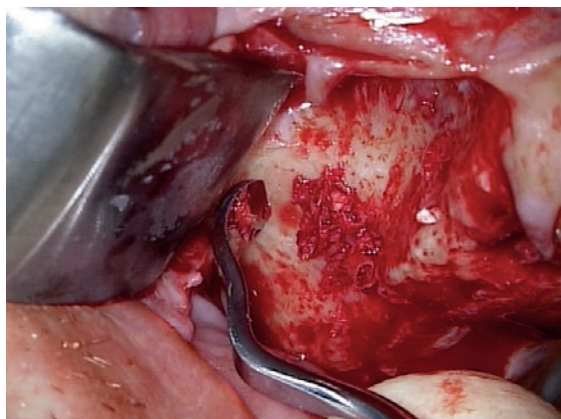


Fig. 6 Harvesting autologous bone chips in the region of the future sinus lift window.

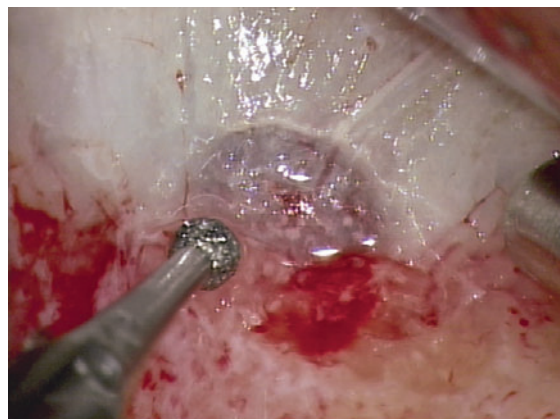


Fig. 7 Preparation of the window using a 1.4 mm rotating spherical diamond under $\times 15$ magnification until the first antral set periosteal blood vessels are seen.

■ Surgical procedure

Following the administration of a local anesthetic (Ultracain D-S forte; Sanofi-Aventis, Berlin, Germany), the operation is begun by inserting the implant drilling stents, followed by marking the implant positions on the crestal mucosa using a periodontal probe (Figures 4 and 5). The subsequent incision is made crestopalatally with trapezoid mesiodistal relief, taking care to protect the papillae of the adjacent teeth. A split flap is prepared in the crestal area, leaving the crestal periosteal tissue in place. The split flap then becomes a full flap to the vestibular of the crestobuccal bone margin. A mucosal punch 5 mm in diameter is used to remove the connective and periosteal tissue layer around the crestal implant-position marker.

Autologous bone chips are harvested from the facial sinus wall in the region of the three-dimensionally positioned sinus lift window (Figure 6). The bone chips are stored safely for later use in the augmentation procedure.

The following steps are then performed under a surgical microscope at $\times 7$ to $\times 16$ magnification (optical magnification using a magnifying glass is the second-choice alternative):

1. The sinus lift window (approximately 5 mm in diameter) is prepared using a 1.4 mm rotating spherical diamond (Figure 7). No bone "island" is left in the central region of the window.
2. The window is further prepared until the first antral/subperiosteal blood vessels are reached (Figure 7). At this point, the thickness of the residual bone layer will generally be so low that

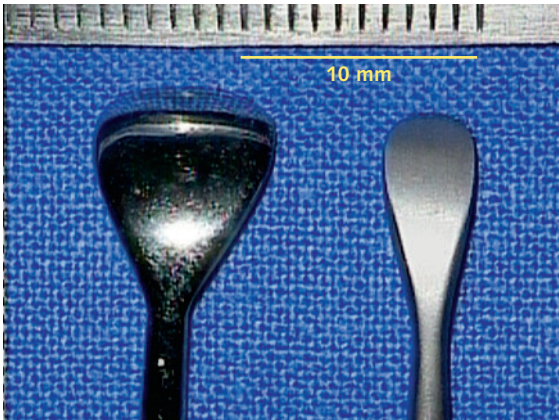


Fig. 8 Comparison of instrument working ends: Microsurgical sinus lift instrument (right) and classical sinus lift instrument (left).

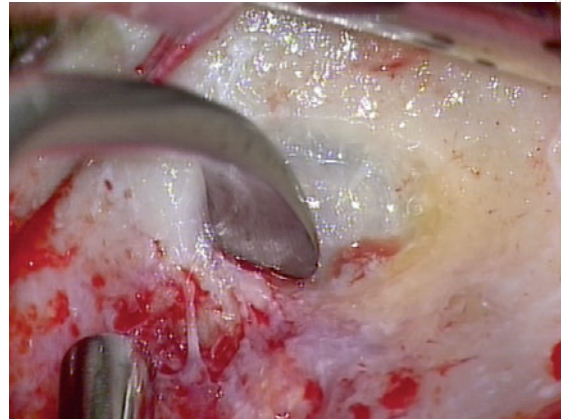


Fig. 9 Initial fracturing of the paper-thin bone layer using microsurgical sinus lift instruments #1 and #2 under $\times 14$ magnification.

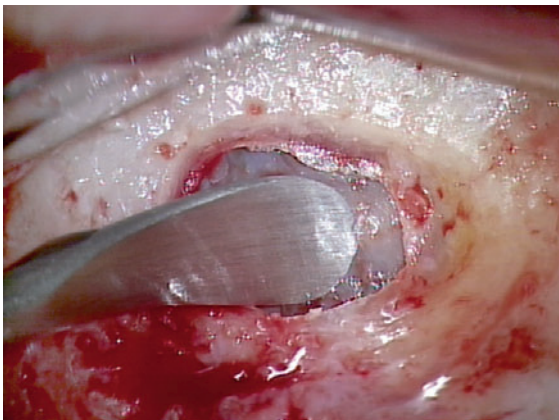


Fig. 10 Circular membrane loosening using microsurgical sinus lift instruments #1 and #2 under $\times 14$ magnification.

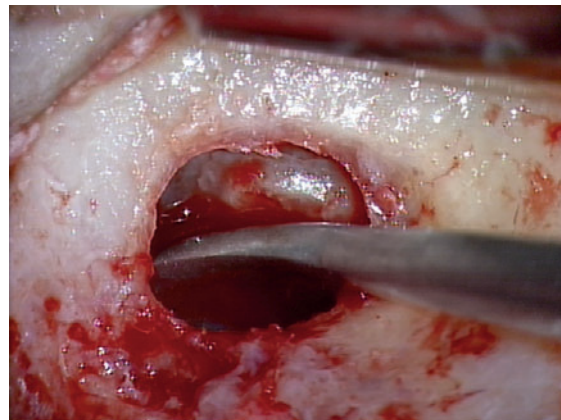


Fig. 11 Complete membrane elevation using microsurgical sinus lift instruments #3 to #6 under $\times 14$ magnification.

- it can be fractured for access to the subantral space.
3. It is attempted to fracture the paper-thin bone layer using the microsurgical sinus lift instruments #1 and #2 (Figure 8 und 9). If the bone cannot be fractured at this stage, more rotating antral bone preparation is required. One should never increase the pressure on the instrument instead, because this might result in a perforation of the sinus membrane.
 4. The membrane is initially lifted with a circular movement around the window to approximately 1 to 2 mm (Figure 10).
 5. Additional membrane elevation is performed caudally (instruments #3 and #4), dorsally (instruments #4 and #5) and ventrally (instrument #6).
 6. Optimally, Schneider's membrane will move synchronously with the patient's breath once the preparation has been completed. This indicates that the membrane is positioned far enough cranially to avoid trauma during the following implantation step (Figures 11 to 13).

This is followed by the preparation of the implant bed. Additional bone condensation is performed in cases where the alveolar ridge exhibits insufficient bone density (D3 und D4) following socket preservation in order to improve primary implant stability. The initial augmentation is performed in the median region of the subantral space using a mixture of autologous bone chips and Bio-Oss® granules (Figure 14), followed by implant insertion in a position of primary stability and additional augmentation of the re-

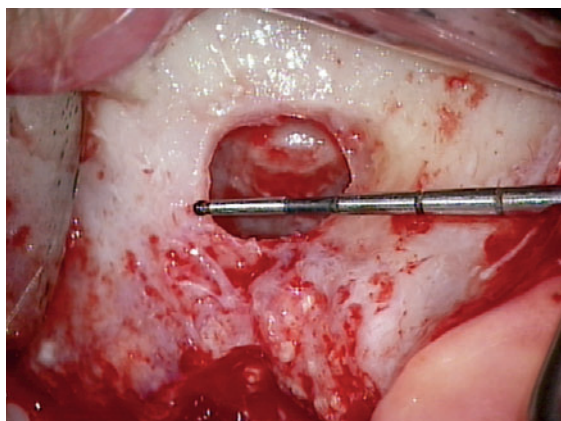


Fig. 12 Sinus lift window approximately 5 mm in diameter on completion of the non-traumatic membrane elevation.

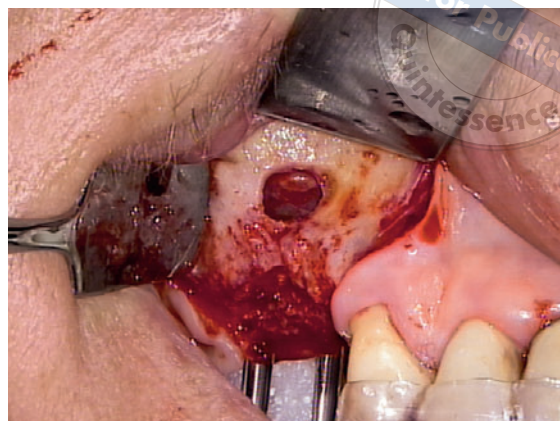


Fig. 13 Situation prior to implant bed preparation at sites 15 and 16.

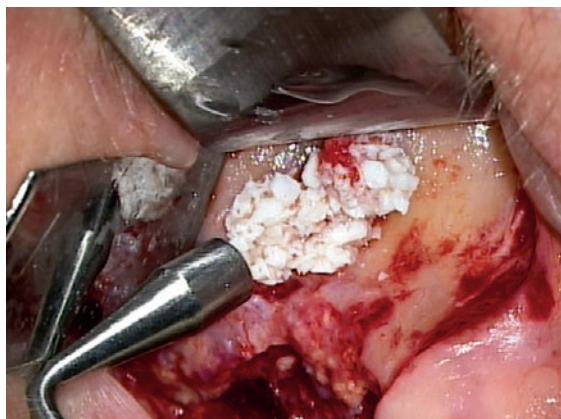


Fig. 14 Augmentation of the median aspect of the sub-antral space using a mixture of autologous bone and Bio-Oss® granulate.

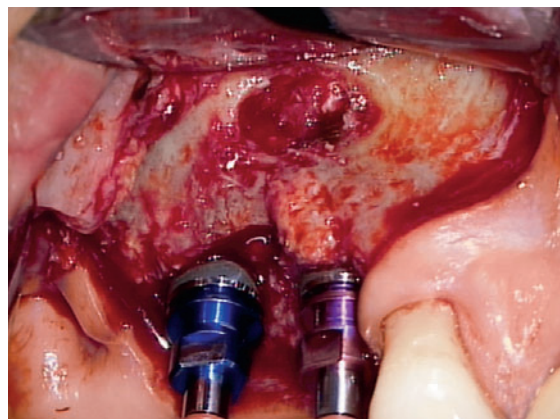


Fig. 15 Situation following primary stable insertion of two Camlog Screw-Line implants at sites 15 and 16 with maximum conservation of the vestibular alveolar ridge.

maining subantral space (Figures 15 and 16). The special applicator and the condensing instrument of the microsurgical sinus lift instrument set were developed specifically for this purpose. To access remote areas, the corresponding sinus lift instruments can be employed again.

Once the subantral space has been completely augmented, the window is covered with multiple layers of a contoured Bio-Gide® membrane for guided bone regeneration (Figures 17 to 19). The flap is then sutured into place, making sure to avoid tension (performing periosteal separation if required) and to prevent the entry of saliva, using Seralon suturing material 4-0 and 5-0 (Serag-Wiessner, Naila, Germany) (Figure 20). The operation concludes with a postoperative radiological check (OPG and/or conventional intraoral x-ray) (Figure 21).

■ Results

By taking measures for socket preservation after tooth extraction as described above, using Bio-Oss® granulate and Stypro® resorbable hemostatic sponge material, the three-dimensional morphology of the alveolar limbus could be largely preserved prior to implant placement (Figures 22 to 24). The crestal keratinized soft-tissue profile obtained after socket preservation proved particularly useful at the time of implant placement (Figure 5).

General and local postoperative healing was generally uneventful in all patients, both following extraction and socket preservation and following sinus floor augmentation and implant insertion.

There was only one case of membrane perforation (1/20, 5%), in the mesio-caudal region of the

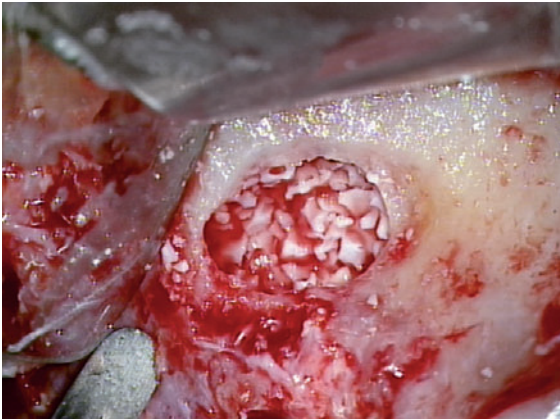


Fig. 16 Situation following complete augmentation of the subantral space subsequent to implant insertion.

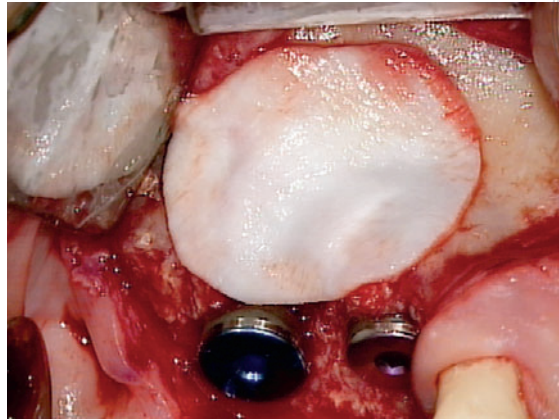


Fig. 17 Stable positioning of the Bio-Gide® membrane over the sinus lift window.

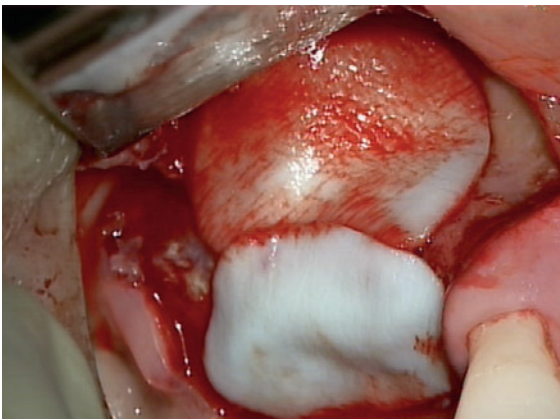


Fig. 18 Application of an additional Bio-Gide® membrane to cover the crystal bone region.

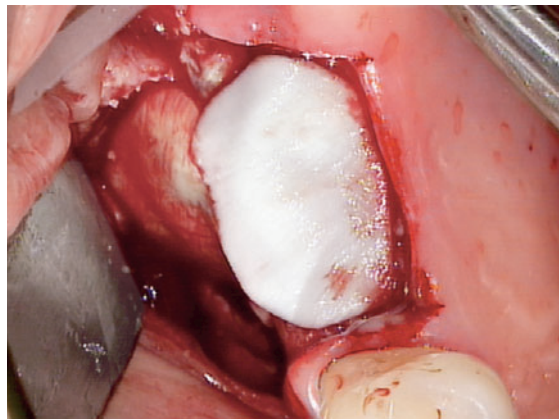


Fig. 19 Coronal view prior to plastic wound closure.

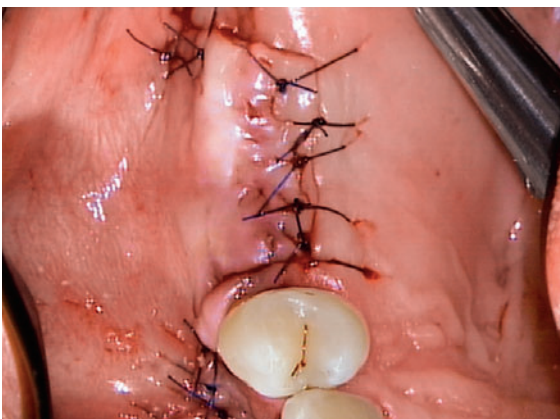


Fig. 20 Coronal view after plastic wound closure using an atraumatic Seralon® suture with needle, sizes 4-0 and 5-0.

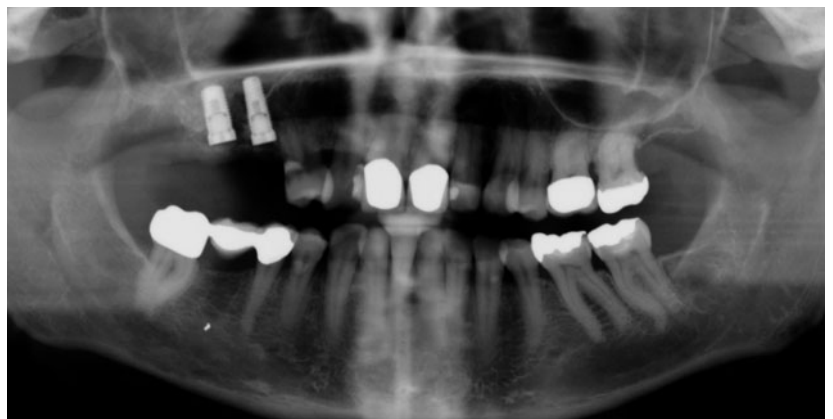


Fig. 21 Postoperative radiograph.

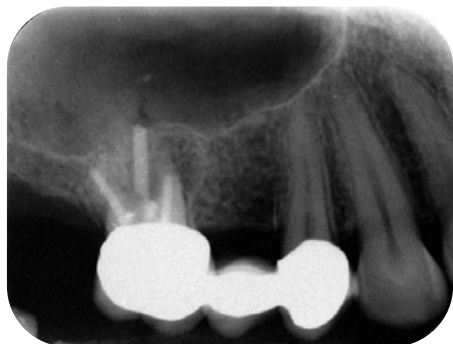


Fig. 22 Radiograph prior to the extraction of tooth 16.



Fig. 23 Radiograph directly after the extraction of tooth 16 and socket preservation.

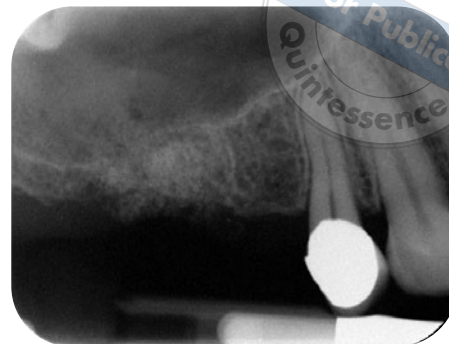


Fig. 24 Radiograph three months after the extraction of tooth 16 and socket preservation.

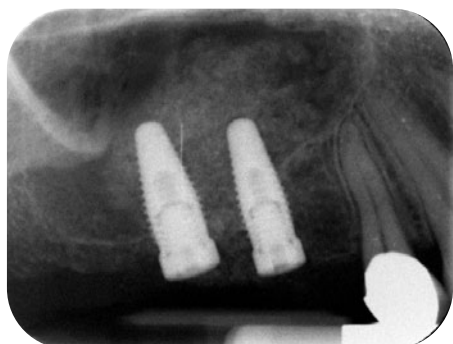


Fig. 25 Radiograph nine months after the implantation and microscope-guided external sinus floor elevation at sites 15 and 16.



Fig. 26 Radiograph six weeks after the exposure of implants 15 and 16.

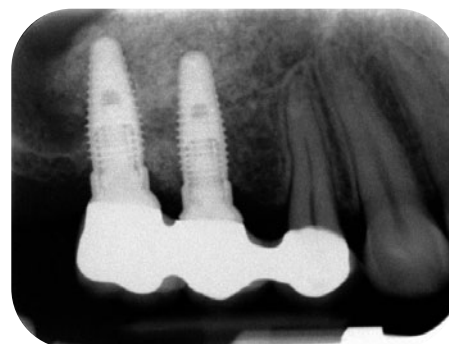


Fig. 27 Radiograph one year after insertion of the prosthetic superstructure.

sinus window; it could be resealed safely by application of a contoured Bio-Gide® membrane. The operation could be continued and completed according to protocol.

Without the concurrent implantation, the sinus lift procedures took between 30 and 60 minutes. The longest operations were those where more than two implants were inserted at the same time, and two sinus windows were prepared. Once the operator has gained a certain routine, one sinus floor elevation (with one window) plus the insertion of one or two implants takes no more than 40 minutes.

Primary stability (25 to 35 Ncm) was achieved in all but six implants, where primary stability was 15 to 20 Ncm.

A nine-month healing period was provided for these latter implants, while the healing period for all other implants was five to six months. All implants were allowed to heal subgingivally.

There were no significant findings during the radiological controls performed to date – immediately postoperatively, prior to exposure (Figure 25), six

weeks after exposure (Figure 26), immediately prior to insertion of the prosthetic superstructure, six months later, and one year later (Figure 27).

Of the 38 implants inserted, 27 have been exposed to date and restored following complete osseointegration. Osseointegration and implant stability were checked by resonance frequency analysis (RSA) using the Ostell® unit (Integration Diagnostics, Göteborg, Sweden). The osseointegration of the implants was examined radiologically by OPGs or conventional intraoral radiographs at the relevant stages (Figures 25 and 27).

The remaining implants are still in the healing phase at the time of this writing.

■ Discussion

The sinus floor elevation or sinus lift procedure is a scientifically documented method for the vertical reconstruction of the posterior mandibular ridge. The choice of surgical method is determined primarily by



the degree to which the alveolar ridge has atrophied.^{14,15}

Clinically relevant procedures used today include the classic internal sinus lift according to Tatum and Summers.⁹⁻¹¹ The single-step protocol (simultaneous sinus lift and implantation) is superior to the staged approach (sinus lift and implantation in two different surgical sessions), especially with regard to patient comfort and treatment duration. Advanced atrophy of the alveolar ridge (residual bone height of 0 to 8 mm; categories SA3 and SA4 according to Misch) is often an indication for a staged approach.^{16,17} But especially in Misch SA3 and SA4 cases, external sinus floor augmentation may result in serious complications – one being accidental membrane perforation (12% to 44% of all cases) and the other a lack of primary stability of the implant placed in a single-step procedure. This may result in a significantly poorer prognosis for the entire treatment due to aborted sinus lift procedures, postoperative consequences such as sinusitis and peri-implantitis, lack of osseointegration, and even implant loss.

Alternative procedures such as the internal sinus lift according to Tatum or transalveolar antral bone augmentation according to Summers are clinically established but not tolerated by all patients because of the pressure-guided technique used. Because of their logistical complexities and technical risks, other surgical approaches using endoscopes and balloon dilatation have not yet moved beyond the experimental stage.

The objective of the present study was the clinical evaluation of microscopically guided external sinus floor elevation for practicality in patients with advanced atrophy of the alveolar ridge (categories SA3 and SA4 according to Misch). Specifically, the study aimed to examine whether the high incidence of membrane perforations and the low primary stability of simultaneously placed implants in these difficult situations could be improved by following the surgical protocol presented here, under clinically acceptable conditions, with a view to avoiding a staged approach wherever possible.

The following technical prerequisites must be met for this minimally invasive external sinus floor elevation as presented here:

1. Optical magnification and optimum site illumination (surgical microscope or magnifying glass with external illumination),
2. Spherical diamonds with diameters between 1.4 and 1.6 mm,
3. Microsurgical sinus lift instruments.

Supplementing conventional radiographs with preoperative 3D implant diagnostics and treatment planning by computed tomography is recommended. In addition to preprosthetic advantages, an optimized selection of implant length and diameter, and exact three-dimensional implant positioning for maximum conservation of anatomically delicate structures,¹⁸ this also allows the identification of the best strategic location for the sinus lift window position.

Our clinical experience has shown that in approximately 10% of the cases, accidental soft-tissue findings of importance for the sinus lift procedure are recognized by CT where conventional x-rays failed to show them.

As in endodontics, optical magnification and optimum site illumination are prerequisites for success in sinus floor microsurgical procedures.

The rotating preparation of the fenestration using a spherical diamond 1.4 to 1.6 mm facilitates a controlled fenestration diameter of approximately 5 mm while allowing for preparation narrow grooves in the bone. Microscopically guided bone preparation allows stringent visual control as the sinus is approached. When the shade of the tissue becomes darker and the delicate subantral blood vessels (visible under the microscope) are reached, this indicates that the use of the rotating osteotomy instruments should be discontinued in favor of careful and incremental manual instrumentation as the subantral space is reached. The microsurgical instruments allow Schneider's membrane to be safely elevated through the sinus window, which will be approximately 5 mm in diameter.

At the time of elevation, excess local tension on the membrane cannot only be felt but also seen, with the result that perforation can be avoided by continuing the elevation process at a different position within the subantral space.

Local, coarse, usually inflammatory fibrous processes between the membrane and the bony si-

nus floor are easier to recognize under the microscope and can be severed without problem by the special sharpened working ends of the appropriate instruments. This is assisted by the special microsurgical evacuator with replaceable titanium attachment (2 mm diameter), which is also part of the instrument set. Overall, the surgical technique presented here not only reduces the incidence of membrane perforations, but it also lowers the risk of microruptures of the sinus mucosa during the sinus lift procedure. Minimally traumatic elevation of Schneider's membrane facilitates an improved cranial supply of nutrients (through the periosteal tissue) and mechanical stabilization of the subantral bone graft.

Visibly evident bone preservation in the region of the vestibular alveolar ridge and the additional transalveolar bone condensation (Camlog osteotome set) allows concurrent implantation even in the presence of residual alveolar ridge heights of between 2 and 8 mm, resulting in a more favorable lateral supply of nutrients to the graft.

Our experience to date has shown that postoperative healing following the procedure presented here is associated with considerably fewer complications than the classical external sinus lift with a large-sized window. Patients particularly appreciate the absence of the pressure-guided technique in the maxilla (internal sinus lift). At the same time, the amount of primary implant stability that can be achieved in this single-step procedure despite advanced alveolar ridge loss is another factor that motivates patients to favor this approach.

Given the proper technical equipment and a trained assistant, the microscopically guided external sinus floor elevation is a minimally invasive method that is easy to perform in clinical implantological practice.

The conspicuously high acceptance of this technique by patients coupled with a gain in intraoperative safety and better predictability easily justify the slight amount of extra time expended and the initial investment.

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