Flapless Sinus Floor Augmentation Using Endoscopy Combined with CT Scan–Designed Surgical Templates: Method and Report of 6 Consecutive Cases

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Purpose: *Sinus floor augmentation has become a routine procedure with predictable results. Flapless implant placement is recommended for a series of indications with sufficient bone volume. Flapless surgery in the atrophic maxilla is presented as a refinement of the endoscopic subantroscopic laterobasal sinus floor augmentation (SALSA) technique.* ***Materials and Methods:*** *Based on computerized tomography (CT) scans, the site of sinus trephination and implant positions are planned using a commercially available planning program, and surgical templates are fabricated according to the data of the treatment plan. Subantral space is augmented using the SALSA technique without raising a mucoperiosteal flap. Implants are placed transgingivally without raising a mucoperiosteal flap, with endoscopic control of the cover screw at the bone level.* ***Results:*** *In a case series of 6 patients, 21 implants were placed and augmented simultaneously. The mean augmentation height was 10.7 mm (range, 5.7 to 16.6 mm); the mean residual bone height was 5.1 mm (range, 1.9 to 12.1 mm). Complications such as insufficient primary stability and sinus membrane perforation were treated without changing to an open surgical approach.* ***Discussion and Conclusion:*** *Flapless sinus augmentation (FSA) can reduce the surgical trauma significantly. The procedure has high acceptance by the patient and less postoperative discomfort. FSA enlarges the spectrum of minimally invasive surgery and may offer better vascularization and less alveolar resorption.* INT J ORAL MAXILLOFAC IMPLANTS 2005;20:891–897

Key words: *endoscopy, minimally invasive surgery, sinus augmentation, 3-dimensional surgical templates*

Flapless placement of dental implants in the maxilla has been determined to be a feasible treatment protocol when precisely planned surgical guides and prefabricated provisional restorations are used.[1,2] Flapless implant surgery has been primarily applied in the anterior esthetic zone in extraction sockets to optimize esthetic results.[3,4] This procedure has many advantages for the patient and the surgeon: it is less time consuming, there is minimal bleeding, and there is no need for sutures. It may be a predictable procedure if patient selection is adequate and surgical technique is appropriate. Flapless implant placement may be performed in extraction sockets with immediate provisionalization[4] or via a single-stage punch technique.[5] Flapless implant placement is usually performed to assist immediate loading,[6] but it has also been used for various indications in partially and completely edentulous patients.[1]

Precision of implant site preparation has recently been improved significantly using 3-dimensional (3-D) planning based on computerized tomography (CT). This has been demonstrated in animal trials [7] as well as in clinical studies.[8,9] Computer-assisted placement may be performed using a CT scan–based planning system with a drill guide created by stereolithography.[10] The CT scan–based template may then be transformed into a temporary fixed prosthesis for immediate loading. Computer assisted implant placement can be very useful in anatomically complex situations [11] and after ablative tumor surgery[12];

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the benefits of a 3D approach in both implant placement and restoration are evident in such cases.[13]

The accuracy of drilling guides evaluated by van Steenberghe and associates[14] revealed that the use of surgical drilling guides should be encouraged for zygomatic implant placement because of the intricacies of the region. Data from 3D planning software for oral implants can be transferred to the surgical field by means of a drilling template in cadavers and patients with a nearly perfect match between the positions and axes of the placed implants and those planned.[15]

Since the development of an endoscopic approach to visualize transalveolar sinus floor augmentation,[16] endoscopy has been used to evaluate the outcome of sinus floor augmentation.[17,18] Baumann and Evers[19] performed sinus floor elevations with endoscopic control using a crestal approach and reported sufficient bone heights when applying the minimally invasive method. However, they noted that, as bone had to be inserted through the implant site, the technique was restricted to the area surrounding the implant bed.

The disadvantages of the endoscopic approach have been overcome with the development of the subantroscopic laterobasal sinus floor augmentation (SALSA).[20] The 5-year results of the subantroscopic approach include a cumulative success rate of 94%, and SALSA appears to be a predictable technique appropriate for achieving adequate augmentation height even in cases of severe maxillary atrophy. Recently, the SALSA technique has been used in combination with 3D navigated cavity preparation.[21] In the case reported, endoscopic observation of the break-through of the drilling instrument served as a control for online navigation, and the precision of the technique was demonstrated to be within the observable range of < 1 mm.

Endoscopic observation of implant cavities[22] and the periodontal sulcus[23] allows precise examination of structures below the gingival level and therefore enables the surgeon to identify possible risk factors during site preparation and after implant placement. The combination of advanced endoscopically assisted SALSA techniques with 3D navigation may allow precise preoperative location of the area to be augmented and precise transgingival implant placement in the sinus floor. This precision may eliminate the need for exposure of the maxilla and elevation of a mucoperiosteal flap. The aim of this report was to present flapless sinus floor augmentation in detail as a new option toward an optimized minimally invasive approach for implant surgery in the atrophic maxilla.

MATERIALS AND METHODS

Planning

Primary planning is based on clinical findings and the orthopantomogram. It is followed by fabrication of a removable resin planning prosthesis with radiopaque crowns placed in the desired definitive restorative position. Fabrication of the planning prosthesis involves the placement of a reference body for artifact definition and correction. High-resolution spiral CT scans are made with the planning prosthesis in situ. Data are obtained by the radiologist and stored on a CD for further processing in DICOM format. Virtual implant planning is carried out using the planning program med3D (med3D, Heidelberg, Germany). The program allows the viewing of multiple 2D and 3D reformats of the maxilla and the mandible. Planning consists of stepwise analysis of the bony implant site mainly using cross-sectional and panoramic reformats of the alveolus and the corresponding sinus floor. Figure 1a demonstrates planning of the trephination of the sinus wall in a cross-sectional view at the maxillary right second premolar site using a virtual cylinder implant as a marker for the keyhole approach. Figure 1b shows the planned placement of 2 Friadent Xive implants (Friadent, Mannheim, Germany) at the sites of the maxillary right first and second molars. Augmentation according to the SALSA technique was planned to provide at least 3 mm of augmented material around the implants in all dimensions. Fig 1c displays the cross-sectional view of the implant and the augmentation.

As a result of the planning, a detailed drilling format indicates the position, axis, length, and diameter of the implants and the position of the keyhole approach to the subantral space. The data are transferred to a surgical template with a positioning device in the dental laboratory (Steinhage Dentallabor, Wolfenbüttel, Germany). Precision titanium tubes fixed with light polymerizing resin on the template serve as guides for the minimally invasive approach to the subantral space and for the transgingival approach to the implant sites. A surgical plan is printed out, giving the surgeon information on the placement depth, the distance between the guide tube and the bone surface, and the implants to be placed. The surgical guide then can be sterilized and stored until needed. Surgery is carried out with the same instruments used for conventional implant placement.

Surgery

Surgery follows the protocol reported by Engelke and associates[20] for SALSA. Local anesthesia is obtained by injections at the infraorbital and major

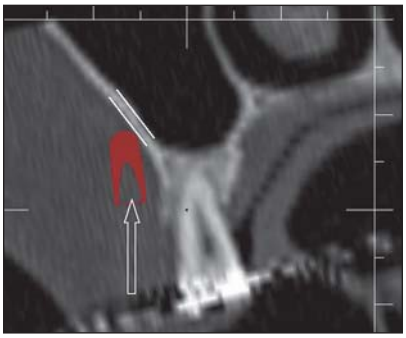


Fig 1a Keyhole approach to the sinus *(arrow)* planned (cross-sectional view).

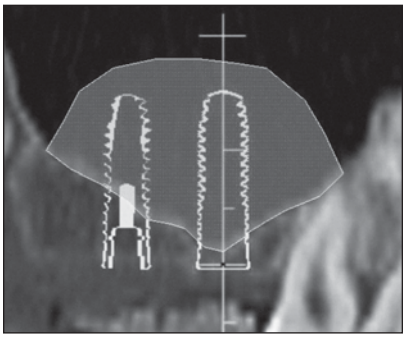


Fig 1b Treatment planned for implant placement and augmentation (panoramic view).

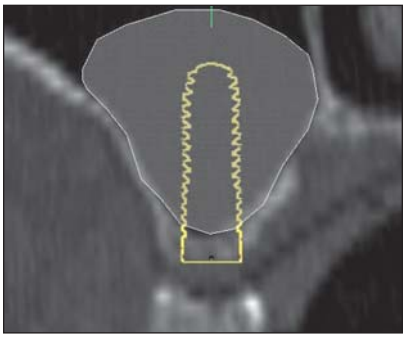
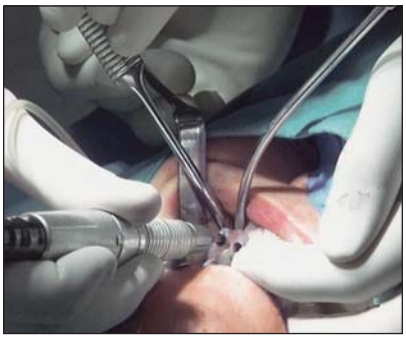


Fig 1c Cross-sectional view of the implant and augmentation planned at the site of the right first molar.

Figs 2a to 2c *Dentification of the approach to the subantral space using the surgical guide.*



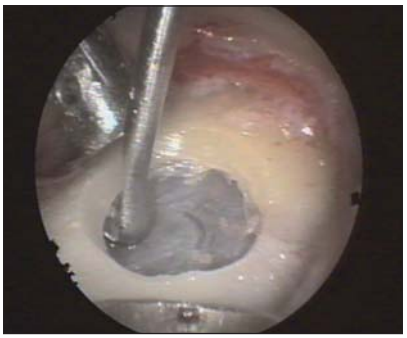


Fig 2a The 3D template. The position of the sinus approach is marked with a round bur guided by the lateral titanium tube.

Fig 2b Localization of the sinus approach using the 3D template.

Fig 2c Keyhole approach for opening of the subantral space.

palatine foramen with additional local infiltration. To identify the entrance to the subantral space, puncture of the mucous membrane is carried out through the surgical guide as planned (Fig 2). A 1-cm vertical incision is then made to expose the sinus wall for the trephination. The position of the sinus approach is marked with a round bur guided by the titanium tube. The subantral space is then opened with 4-mm diamond round burs (Fig 2). The bony access to the subantral space has a diameter of 5 mm to allow the introduction of 2.7-mm endoscopes and 4-mm mucosal elevators. In case of large septae, a second trephination is performed distal to the location of the septum. The schneiderian membrane is elevated with the elevators as described by Engelke and colleagues.[16] The creation of subantral space requires continuous bone contact during elevation of the sinus mucoperiosteum. Fig 3 shows the endoscopic control of the initial preparation (keyhole approach) and control of the subantral space after it has been extended sufficiently. If delicate structures are encountered or the sinus is perforated, the mucoperiosteum may be reinforced with a resorbable membrane.

The surgical guide is then reinserted, and the implant sites are located using a 1.5-mm pilot drill (Fig 4). After the implant sites have been marked, the oral mucosa is incised locally, undermining subperiosteally the tissue 3 mm around the implant site without raising a mucoperiosteal flap. The implant cavities are subsequently enlarged as indicated by the surgical template (Fig 5) using the intermediate drills and the corresponding final drill for the implant system, as recommended by the manufacturer. Implant sites may be checked internally for bone structure with support immersion endoscopy (SIE). Subantroscopic examination is carried out to verify whether the internal orifice of the implant cavity has been located within the subantral space. Augmentation with tricalcium phosphate (Cerasorb; Curasan, Kleinostheim, Germany) mixed with a variable amount of autogenous bone from the implant cavity and the patient's blood is then carried out. The aug-

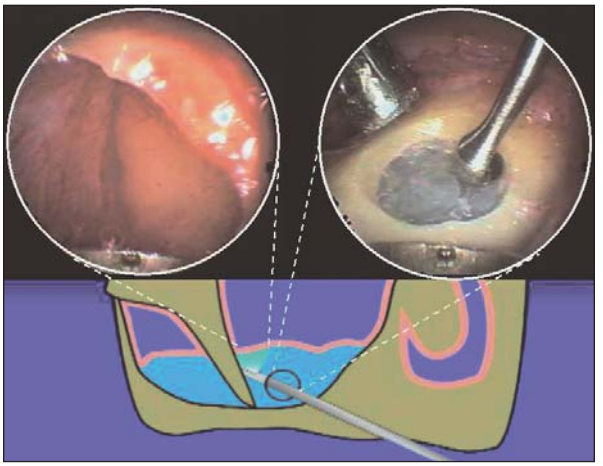


Fig 3 Endoscopic control of the entrance and roof of the subantral space.

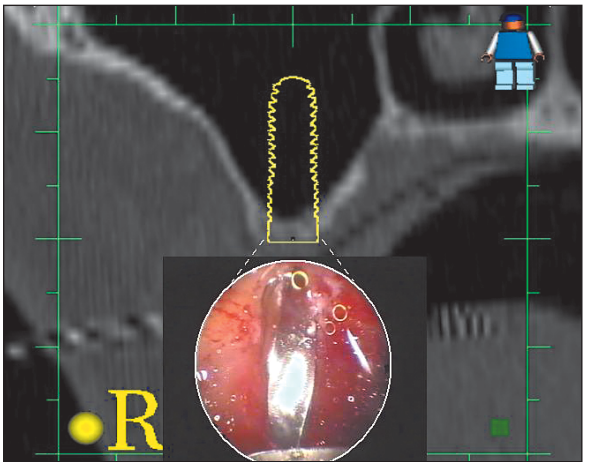


Fig 4 Planned implant position and endoscopic control of the drilling instrument in the subantral space. The Lego man (Lego, Billund, Denmark) in the corner indicates the plane of the reformat, in this case, the frontal plane.

mentation procedure starts with the filling of the most distal aspect of the subantral space, followed by implant placement and stepwise augmentation. Subantroscopic control is performed to verify complete filling of the space created around the implants with augmentation material (Fig 6).

The implants are placed transgingivally with external irrigation. After implant placement, the remaining subantral space adjacent to the access trephination is filled. The vestibular incision is then sutured. Before the crestal incisions are closed, cover screws are placed on the implants. Support immersion endoscopy is used to verify tight closure of the cover screw without the interposition of soft tissue. Postoperative treatment follows the protocol of the SALSA technique.

RESULTS

The first clinical results of the technique presented here are displayed in Table 1. A total of 21 titanium screw-type implants—18 Friadent Xive and 3 Semados (Bego, Bremen, Germany)—ranging in length from 13 to 15 mm and diameter from 3.4 to 4.5 mm were placed in 6 patients using flapless sinus floor augmentation. In all cases, the implants could be placed in the planned sites transgingivally without raising a mucoperiosteal flap in the resting bone and the subantral space with simultaneous augmentation. The residual bone height ranged from 1.9 to 12.1 mm (mean 5.1 mm), and augmentation height varied from 5.7 to 16.6 mm (mean 10.7 mm). Perforation of the schneiderian membrane occurred in 1 case; it was closed with a polyglactin mesh (Vicryl; Johnson & Johnson/Ethicon, Norderstedt, Germany) using the underlay technique. Another case with residual bone height of 1.9 mm required the use of "satellite" implants to obtain sufficient primary stability. Satellite implants (1.7 mm bone screws; Mondeal, Tuttlingen, Germany) were placed with local mobilization of the gingiva adjacent to the implant. Another implant did not achieve appropriate primary stability when placed according to the drilling plan and had to be replaced by one with a wider diameter. One implant placed in 3.8 mm of residual bone exhibited slight distal deviation of the implant axis from the position planned. Healing in all cases was uneventful; no bleeding, no inflammation, and no loss of implants was observed during the healing period. Figure 7 shows a typical postoperative radiograph.

Patients reported only moderate postoperative swelling and did not complain of major postoperative discomfort. At the time of examination all implants were exposed and loaded. Healing time before exposure was 7 to 12 months, depending on original bone height. Twenty of 21 implants osseointegrated; 1 implant had to be removed during exposure because of failure to osseointegrate.

DISCUSSION

Since the description of endoscopically controlled sinus floor augmentation,[16] limitations of and possibilities for the transalveolar approach have been reported by 2 workgroups.[19,24] Baumann and Ewers[19] suggested that protection of intraosseous vessels and reduced postoperative morbidity were advantages of the transalveolar technique but also discussed the limitation of bone augmentation to the area surrounding the implant bed. Nkenke and

Figs 5a to 5c *Localization of implant cavities using the surgical guide.*

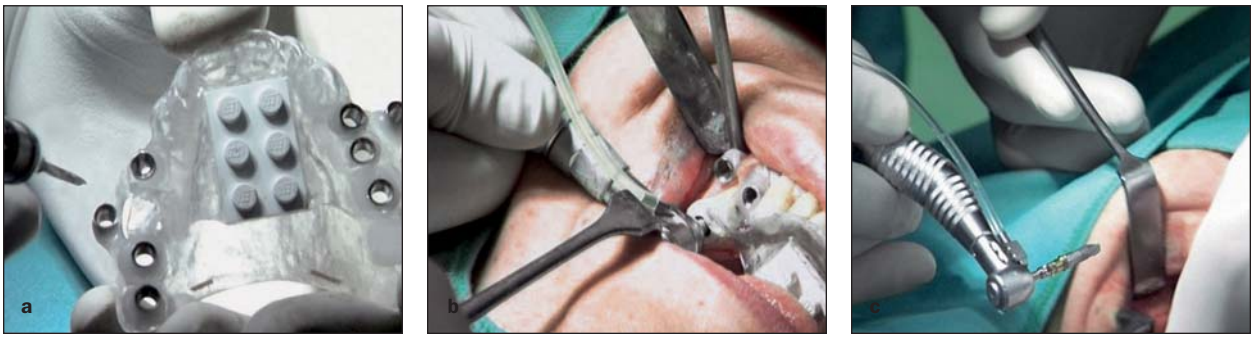


Fig 5a to 5c *(a)* View of the 3D template, which provides tubes for localization of the implant site and sinus approach. The Lego block was embedded in the template for CT imaging and as a means to attach the template to the 3D drilling device. *(b)* Implant site preparation using the 3D template. *(c)* Implant placement.

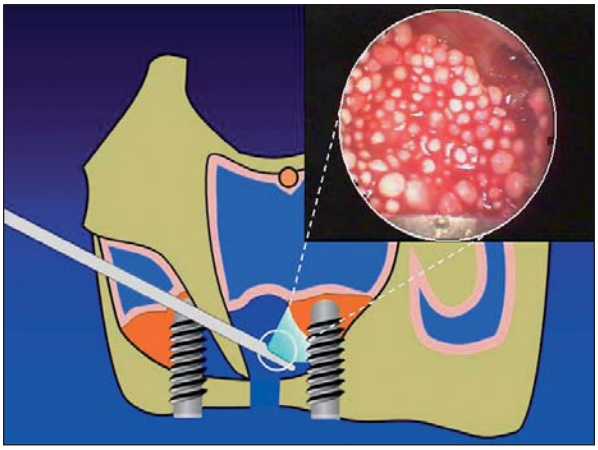


Fig 6 Endoscopic examination of the subantral augmentation.

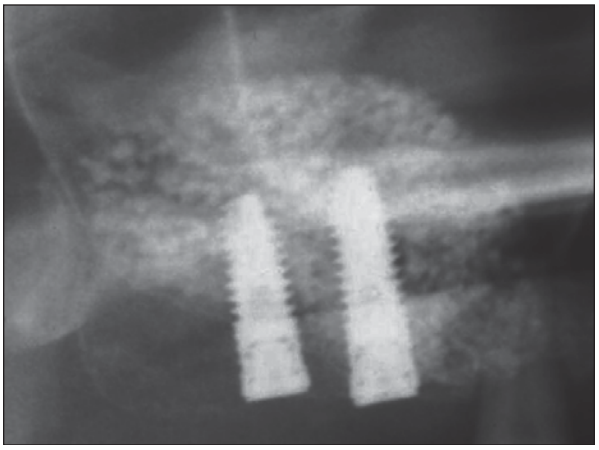


Fig 7 Radiographic result after flapless sinus floor augmentation.

Table 1 Clinical Results of Flapless Sinus Floor Augmentation

Age	Sex	Implant position	Implant length/diameter planned	Implant length/diameter placed	Implant type	Primary stability	Gap at cover screw	Residual bone height	Augmentation height	Complications/ additional surgery
42	F	16	15/3.8	15/3.8	Xive Friadent	+	No	2.6	16.6	Schneiderian membrane
		17	15/3.8	13/3.8	Xive Friadent	+	No	5.1	14.2	perforation closed
64	M	14	15/3.8	15/3.8	Xive Friadent	+	No	4.3	10.0	
		15	15/3.8	13/3.8	Xive Friadent	–	No	1.9	11.5	Microfixation with
		16	15/3.8	13/3.8	Xive Friadent	+	No	4.6	9.9	satellite implants
		24	15/3.8	15/3.8	Xive Friadent	+	No	12.1	5.7	
		25	15/3.8	15/3.8	Xive Friadent	+	No	5.0	11.4	
		26	15/3.8	13/3.8	Xive Friadent	+	No	4.6	13.0	
69	F	14	15/3.8	15/3.8	Xive Friadent	+	No	5.0	10.0	
		15	15/3.8	15/3.8	Xive Friadent	+	No	5.7	10.7	
		16	15/3.8	15/3.8	Xive Friadent	+	No	5.0	10.0	
53	F	15	15/3.8	15/3.8	Xive Friadent	+	No	5.7	11.4	
		16	15/3.8	15/3.8	Xive Friadent	+	No	5.0	10.0	
62	M	15	15/3.75	15/3.75	Semados	+	No	9.0	6.8	
		16	15/3.75	15/3.75	Semados	+	No	3.8	11.3	Wide-diameter
		17	15/3.75	13/4.5	Semados	-	No	4.1	11.4	implant necessary
63	F	15	15/3.4	15/3.4	Xive Friadent	+	No	7.5	7.5	
		16	15/3.8	15/3.8	Xive Friadent	+	No	2.3	14.3	Not osseointegrated
		17	13/3.8	13/3.8	Xive Friadent	+	No	5.3	6.8	
		25	15/3.8	15/3.8	Xive Friadent	+	No	3.0	12.8	
		26	13/3.8	13/3.8	Xive Friadent	+	No	4.5	9.0	

colleagues[24] reported on the placement of 22 implants with endoscopically controlled osteotome sinus floor augmentation and concluded that this technique should be confined to scientific trials. Neither workgroup used the SALSA technique, which according to Engelke and coworkers[20] was applied routinely in a study with 211 implants with up to 5 years of observation time. Additionally, endoscopy has been used as a diagnostic tool to evaluate the outcome of sinus floor surgery.[17,18] Recently the authors' workgroup reported on the combined use of an online 3D navigation system and the SALSA approach.[21] Based on their report, a new concept has been developed to optimize the endoscopic sinus floor augmentation.

Because of the exact preoperative CT localization of the bony approach to the subantral space, the soft tissue approach guided by the surgical template is reduced to a 1-cm incision formerly needed for antroscopy only. The implant sites are exposed by incisions only 5 mm in length, which allows unimpeded entrance of the drilling instruments into the alveolar bone. Further undermining is not intended to preserve the periosteal attachment to the coronal alveolus and the sinus wall. Additionally, the 3D planning of surgery facilitates the identification of critical anatomic structures, ie, septa or irregularities of the sinus walls, thus facilitating the surgical procedure. The technical difficulties encountered by Nkenke and coworkers[24] using an endoscopically controlled osteotome technique may be have been the result of *(1)* missing precise preoperative anatomic information and/or *(2)* the limitations of the transalveolar approach for creation of the subantral space. The latter is in accordance with the observations of Baumann and Ewers.[19] In contrast, laterobasal tunnel preparation according to the SALSA technique allows straight guidance of the instruments and therefore direct endoscopically assisted surgery, not merely an endoscopic examination of conventional transalveolar preparation with osteotomes. Using the flapless SALSA technique, perforations of the mucoperiosteum encountered during elevation can be treated with the application of resorbable membranes without enlarging the access trephination and without flap elevation.

Precise surgical templates not only facilitate the access to the sinus but also are essential to allow the placement of implants into the subantral space transgingivally. Navigation systems using computer-navigated handpieces require the surgeon's orientation via observation on a monitor screen. The laboratory fabricated template seems to be more convenient for the surgeon with respect to avoiding difficulties with online handling of the navigation system.

The individual learning curve of the surgeon in mastering endoscopic techniques and online navigation must be taken into account when judging the results of these techniques. Therefore, at Georg-August University, all oral surgeons are trained in endoscopic procedures on phantoms[25] before performing sinus floor elevations in patients.

Within the concept of flapless sinus floor elevation, a clear separation of tasks can be described. Bone and soft tissue surgery are planned 3-dimensionally based on CT scan data. Location of incisions and all steps of bone surgery are guided by the template. The soft tissue surgery is performed with endoscopic assistance or control. The 2 components of the clinical procedure, endoscopy and template-based navigation, are mutually complementary.

There is evidence in the literature[9–12,14,15] that 3-dimensionally planned and navigation-guided implant placement may allow the placement of implants exactly in the prosthetically defined position and may improve the quality of surgery while avoiding complications. In case of flapless sinus floor augmentation, the use of 3D planning is valuable. The clinical cases gave evidence of the feasibility of the combination of the 2 methods, which permitted the majority of implants to be placed as planned. Nevertheless, the primary stability of implants in severely atrophic sites may be difficult to achieve. Therefore, a larger diameter implant or, if necessary, satellite implants[26] may be used; alternatively, secondary implantation may be chosen.

Results of the cases presented show that the augmentation height gained may exceed that usually provided by transalveolar procedures. When preparing the subantral space, generally no intrinsic limitation of the procedure was evident concerning the volume of augmentation. Alloplastic material as well as autogeneous bone may be used to fill the subantral space; the only limitation is that the size of the approach does not allow the insertion of a bone block.

Crestal mini-incisions and local undermining at the implant sites were performed without flap elevation when placing the implants. The amount of undermining at the implant site did not exceed 6 mm and therefore fell within the range of a large-diameter implant. Mucoperiosteal flap surgery has provoked regional accelerated bone resorption in animal trials[27] and that a coronal approach exhibits an extensive resorptive phase compared with an apical approach.[28] Therefore, flapless surgery may be advantageous in discouraging alveolar bone resorption. Additionally, preservation of the external periosteum implies the preservation of vascularization of the osseous sinus floor, which may contribute to optimization of bone regeneration.

To date, lack of visual control of cover screws when placed below the gingival level has been a disadvantage of placing implants transgingivally. Using support immersion endoscopy[22] a clear view of the implant and its cover screw can be obtained, eliminating the need for radiographic examination. The SALSA technique has been used for more than 7 years with predictable late results; it has not restricted the amount of augmentation possible. Within the limited number of observations during the present case series, refinement of the technique with 3D planned templates allows a flapless approach.

CONCLUSION

Flapless sinus floor augmentation offers several advantages. Surgical trauma for the procedure does not exceed that observed with antroscopy. Operation time is comparable with that for conventional SALSA. Endoscopically assisted complication strategies are provided. CT planning cross-checked endoscopically results in a high degree of safety. Augmentation volume is not limited by the technique. Implant position is precisely defined. The procedure has a high patient acceptance rate.

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