

## CHAPTER 15

# Flapless Crestal Sinus Augmentation: Hydraulic Technique

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### Introduction

The optimization of maxillary sinus floor elevation protocols to achieve high implant success rates, minimize morbidity, shorten treatment periods, and allow for simultaneous implant placement is a constant challenge for clinicians. The author describes a flapless crestal sinus floor augmentation procedure using a hydraulic sinus elevation system. The minimally invasive flapless procedure significantly decreases post-operative discomfort and complications versus conventional open-flap surgery [1, 2]. In flapless crestal sinus augmentation surgery, both transcristal osteotomy and sinus membrane elevation are performed via the implant osteotomy site without visual or tactile control [3]. For this reason, computer-guided surgery is mandatory, not just to guide drilling for implant placement but also to control the drill depth to the bony sinus floor when entering the bony sinus floor [4, 5]. To achieve high success rates in the flapless crestal sinus augmentation procedure, membrane integrity is a primary condition for success. In order to safely maintain membrane integrity, it is necessary to improve the techniques and instruments. This chapter addresses the techniques and instruments for successful flapless crestal sinus floor augmentation, using a hydraulic sinus elevation system combined with computer-guided implant surgery.

### Surgical instruments

- 1 Osteotomy drill
- 2 Dome-shaped crestal approach bur
- 3 Hydraulic membrane lifter
- 4 Bone plugger, sinus curette
- 5 Stopper
- 6 Digital surgical guide

#### 1. Osteotomy drill

This drill is used to drill to 1 mm short of the sinus floor. It comes with various lengths and diameters with a stop feature. The surgical guide guides the drill's depth, direction, and position.

#### 2. Dome-shaped crestal approach bur

This bur is used to eliminate the remaining bone below the sinus floor (Figure 15.1). The bur has a round tip and vertical stop. The tip

of the drill is characterized by a smooth cutting blade. This shape helps to avoid direct damage even if it comes in direct contact with the sinus membrane. The dome shape also makes it safe to use in either flat or steep bone walls. The bur also has a stop feature to control the drill depth through the surgical guide. To help control the drill depth precisely, a number of different stopper lengths are available. Using the stop feature and the stoppers, the drill depth can be controlled within a 1 mm range. The dome-shaped crestal approach bur has a 3.2 mm diameter, which is smaller than the diameter of implants placed in the maxillary premolar ( $\text{Ø}4.0$  mm) and molar ( $\text{Ø}5.0$  mm).

#### 3. Hydraulic membrane lifter

This is for injecting liquid into the maxillary sinus. It is comprised of a syringe, tube, and a nozzle (Figure 15.2). The tip of the nozzle has a feature that can completely close the opening to the drill hole. Thus, it has a conical-shaped sealing part and an extension part that is inserted into the drill hole. The other end of the nozzle is connected with the tube, which is then connected to a saline-filled syringe. The nozzle also has a handle feature (Figure 15.3). The handle not only helps the nozzle to be positioned into the hole and secured in place but it also helps the nozzle to pressurize the opening area. The syringe should be a 5 ml disposable syringe. A 1 ml syringe is too small to apply sufficient pressure. In addition, if the extension part of the syringe that connects the tube to the syringe is too short, the tube can be easily separated when applying pressure. Therefore, if possible, use a syringe with an elongated connection part.

#### 4. Bone plugger, sinus curette

A bone plugger is used to insert the bone-grafting material into the sinus cavity through the drill hole. A sinus curette is then used to disperse this bone-grafting material in the sinus cavity (Figure 15.4). They have a stop feature to control the depth of insertion into the sinus cavity. Their diameters are  $\text{Ø}2.6$  mm, which will allow entry into the  $\text{Ø}3.2$  mm hole created by the 3.2 mm diameter, dome-shaped crestal approach bur. The head of the sinus curette has a dome shape.

#### 5. Stopper

The stopper is designed to be able to connect to the crestal approach bur, bone plugger, or sinus curette. It also comes in varying lengths,

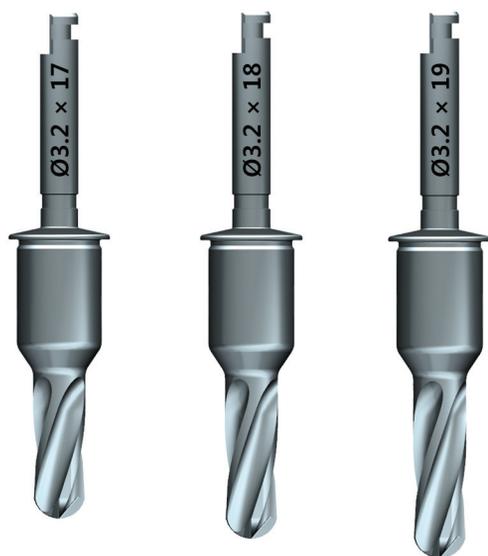


Figure 15.1 Dome-shaped crestal approach burs.

which can help control the depth of insertion into the sinus cavity within a 1 mm range (Figure 15.5).

#### 6. Digital surgical guide

The surgical guide guides the depth and direction of the osteotomy drill, crestal approach bur, and the implant. Therefore, a highly accurate and precise surgical guide must be used – the recommended vertical error value should be less than 0.5 mm. From the author's experiments, an average vertical error value of 0.44 mm was achieved if the surgical guide was digitally designed using both the cone beam computed tomography (CBCT) image and the oral

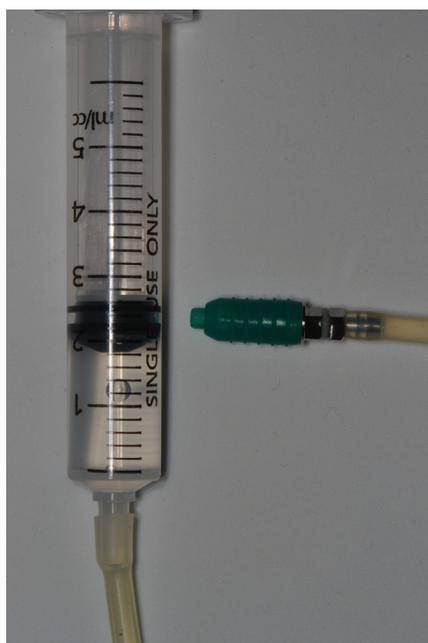


Figure 15.2 Hydraulic membrane lifter.

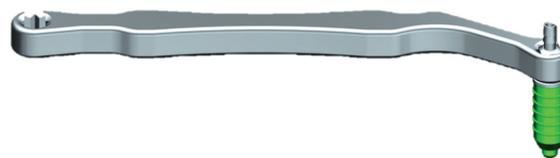


Figure 15.3 Nozzle with handle.



Figure 15.4 Bone plugger and sinus curette.



Figure 15.5 Stoppers.

scan image taken by TRIOS (3Shape, Copenhagen, Denmark) and produced using a 3D printer. The error from the digital surgical guide might have resulted from each step of the surgical guide production, including the digital impression step, the fusion of the surface scan image with the CBCT scan image, and the 3D printing process. The error value increases if the surgical guide is made with the use of stone models from alginate impressions instead of digital impressions. If the vertical error value of the surgical guide is greater than 1 mm, the risk of membrane perforation increases.

### Technique

#### Pre-operative protocol

The best location to penetrate the bony sinus floor is determined with the help of CBCT images of the maxillary sinus while taking into consideration both the position of the final prosthesis and the anatomy of the maxillary sinus, such as the shapes of the sinus walls as well as the presence of the septum. This location will be where the implant is placed. Once the location has been determined, the drilling depth is calculated. This is important so as to avoid causing membrane perforation while drilling. Cross-sectional CBCT images can help define the length of the osteotomy up to the sinus floor. A panoramic 2D image or dental X-rays are not appropriate for this purpose as they are not precise enough. In contrast, a CBCT image can show the anatomy of the maxillary sinus with great precision in three dimensions. CBCT scans and oral digital impressions are used to perform three-dimensional implant planning and to create a

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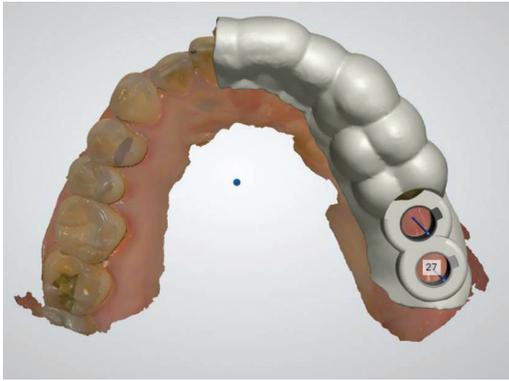


Figure 15.6 Digital surgical guide designed.

customized surgical guide (Figure 15.6). If immediate restoration is being performed, the customized abutment and provisional restoration is designed and then made using the computer-aided design/computer-aided manufacturing (CAD/CAM) milling machine. When designing the customized abutment and crown, one must consider factors such as the soft tissue profile around the proposed location of the implant and the relationship between the implant with its adjacent and opposite teeth using dental design software (Dental System, 3Shape, Copenhagen, Denmark). The surgical guide, prefabricated customized abutment and crown are prepared before implant surgery.

### Surgical protocol

- 1 Drill osteotomy.** Under local anesthesia with 2% lidocaine, the stereolithographic surgical guide is placed in the mouth and checked for proper seating. The guide should be positioned accurately and securely. Accurate positioning of the guide is extremely important for precise implant placement because minor deviations can lead to errors in drilling and implant placement. The tissue punch is the first drill in sequence. The soft tissue of the proposed implant site is punched through the guide with a 3 mm soft tissue punch. After punching the soft tissue, the crestal bone is flattened with a bone-flattening drill. After flattening the bone surface, implant osteotomy is prepared up to 1 mm short of the sinus floor (Figure 15.7). The drilling is performed using sequential drills with increasing diameters through the guide. The implant osteotomy is prepared to the appropriate final diameter according to the drill sequence. The drilling depth is controlled by the drill stop in the shank that corresponds to the sum of the implant length, the gap between the guiding sleeve and the implant, and the guiding sleeve height (Figure 15.8). The drill stop precludes the drill from going deeper than intended. The final drill diameter should be approximately 0.7–1.0 mm smaller than that of the implant. For example, if a 5.0 mm implant is to be placed, use up to a 4.3 mm drill.
- 2 Penetrating the bony sinus floor.** After drilling to 1 mm short of the sinus floor, a 3.2 mm diameter, dome-shaped crestal approach bur is used to eliminate the remaining bone below the sinus floor (Figure 15.9). After removing the remaining 1 mm, the bur is advanced into the sinus cavity using a bur with a stop, which allows it to drill down another 1 mm and expand the opening on the sinus floor. The bur is used at a speed of <10 rpm. During drilling, an upward force is applied to drill into the bony sinus floor, thus pushing the drill 1 mm beyond the sinus floor, which is

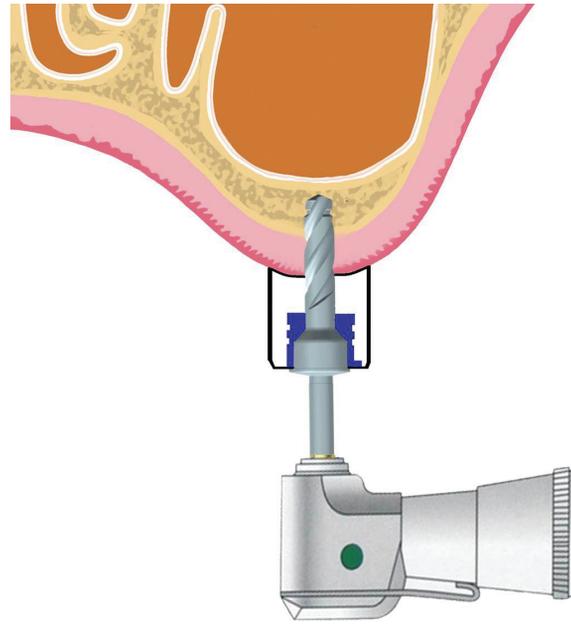


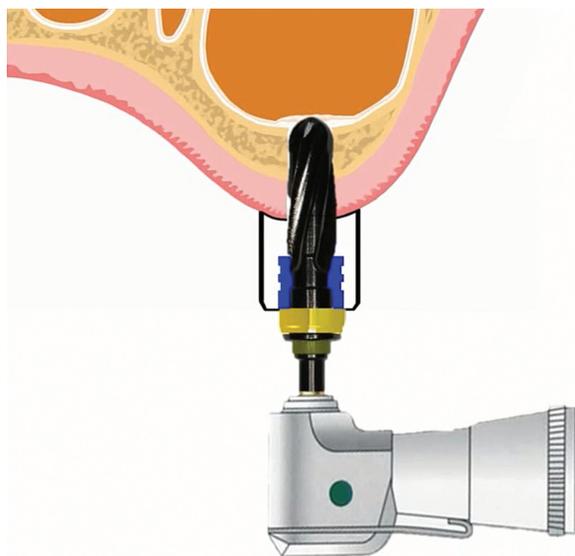
Figure 15.7 Drilling to 1 mm short of the sinus floor.



Figure 15.8 Drilling through the surgical guide.

controlled with drill stops and surgical guides. The bony sinus floor is perforated rather than fractured. Low-speed drilling leads to decreased friction between the bur and the membrane, when the bur comes into contact with the membrane. As a result, this technique reduces the risk of impinging on the sinus membrane, which is attributable to the risk of subsequent membrane perforation. If the bur has no stop, stopping the drill manually at the moment the last bone layer is penetrated will occur too late and the drill will still push forward and get abruptly drawn into the sinus cavity. This explains why this maneuver risks perforating the sinus membrane. The dome shape of the crestal burs, the low-speed drilling with upward force, and the perfect drilling depth control might be crucial to remove the cortical bone of the sinus floor.

- 3 Membrane elevation.** After puncturing the sinus floor, the most reliable method should be used to elevate the Schneiderian membrane without injuring it. The most reliable method is to elevate the sinus membrane using *hydrostatic pressure* because the pressure exerted is uniformly distributed across the sinus



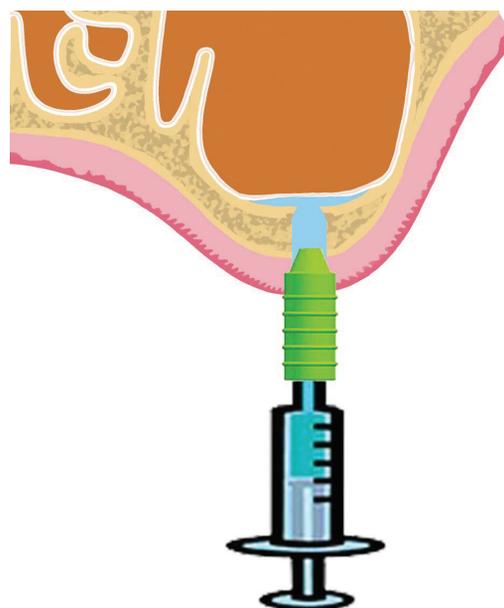
**Figure 15.9** Dome-shaped crestal approach drill eliminating the remaining bone below the sinus floor.

membrane to minimize membrane tearing during membrane elevation [6, 7]. Compared to other techniques, the hydraulic pressure generated by injecting saline into the drill hole offers the most uniform distribution of forces, resulting in uniform elevation of the sinus membrane [8]. This is supported by finite element analyses conducted by Pommer et al., which confirmed that the pressure was uniformly distributed across the elevated membrane [9].

Membrane elevation is completed without the surgical guide. First, the hydraulic membrane lifter's nozzle is connected with the handle, and then the nozzle is positioned in the opening of the drill hole and secured in place. Next, 0.8 ml of saline is slowly injected to separate the sinus membrane from the bony sinus floor and to push the membrane upward (Figure 15.10). Approximately the first 0.3–0.4 ml will go into the drill hole without feeling pressure. As the saline enters the hole and touches the sinus membrane, the membrane is elevated with feeling pressure; however, as soon as the membrane is elevated, the pressure is decreased. It is important not to inject too much saline as the



**Figure 15.10** Nozzle positioned into the transcristal osteotomy canal and secured in place.



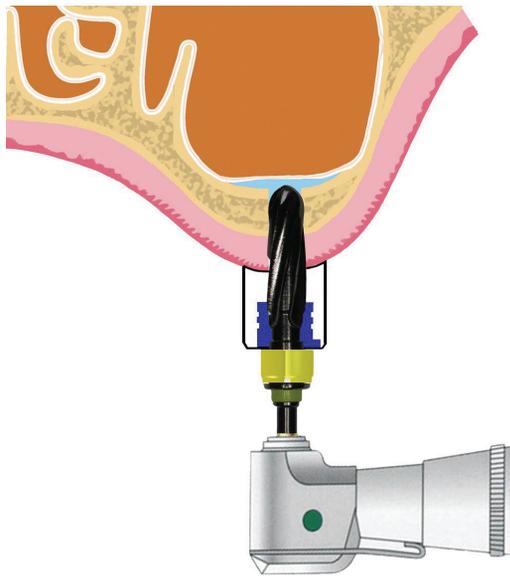
**Figure 15.11** Saline injected to separate the sinus membrane from the bony sinus floor.

pressure decreases as this can elevate the sinus membrane too much. Therefore, saline should be slowly injected 0.1 ml at a time (Figure 15.11). If the sinus floor has not been fully penetrated, the pressure can be felt after injecting 0.3–0.4 ml of saline but no more saline can be injected, in which case another attempt should be made to reinject saline after drilling an additional 1 mm into the sinus cavity using the 3.2 mm diameter, dome-shaped crestal approach bur.

4 Membrane integrity test. The most reliable way to test membrane integrity is the aspiration technique. The membrane integrity is evaluated by drawing the saline back through the drill hole. The volume of saline that was injected is fully retrieved, suggesting that the membrane remains intact. Directly viewing the sinus membrane, using the Valsalva maneuver (light forceful attempted exhalation against a close nasal airway, for example), and probing or irrigation does not guarantee preservation of the sinus membrane. In the author's view, retrieving and measuring the injected saline back through the drill hole is the best test to guarantee membrane integrity.

Sinus membrane perforation is tested immediately after elevating the sinus membrane. Once 0.8 ml of saline is injected to elevate the sinus membrane, the same syringe is used to withdraw the saline. If all the saline that was just injected is withdrawn back up and the syringe shows negative pressure, then the membrane has not been perforated. There will be some blood and bubbles that get aspirated with the saline because the air that was in the hole can be pushed in with the saline and some bleeding can occur as the membrane is separated from the bone. The sinus membrane is perforated if only part of the saline is sucked back up and the syringe is unable to achieve negative air pressure. If this is the case, do not place bone-grafting material into the sinus cavity. It is possible that mucus can penetrate the graft through the perforation site and negatively affect bone formation after surgery. In addition, bone graft material can escape into the sinus cavity through the perforated area causing sinus inflammation.

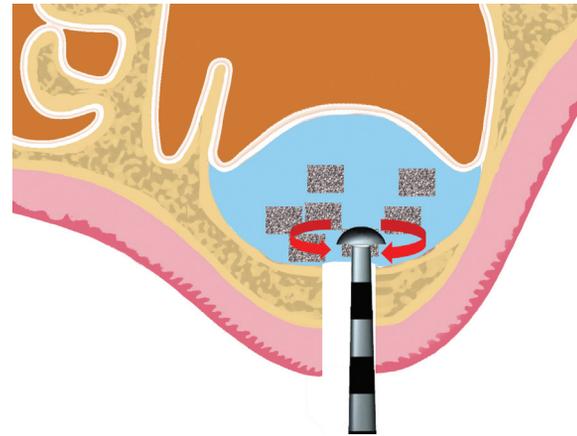
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**Figure 15.12** Dome-shaped crestal approach drill pushed 1 mm beyond the sinus floor.

If the membrane is perforated during the membrane elevation procedure, the surgery should be reattempted after about two months. During the reattempt, the surgery is tried from a different area, away from the sinus membrane that was damaged in order to improve the success rate.

- 5 Expanding the opening hole of the sinus floor. Prior to inserting the grafting material into the maxillary sinus, the opening hole of the sinus floor into the sinus cavity is expanded. The surgical guide is replaced in the mouth and using the 3.2 mm diameter, dome-shaped crestal approach bur, the hole is expanded by advancing it an additional 1 mm into the sinus cavity (Figure 15.12). The bur should be advanced precisely 1 mm into the sinus cavity using the surgical guide and stop on the bur. After that, the surgical guide is removed and the bone plugger is inserted to check for the presence of any other bony barriers inside the hole – ensuring that the opening is completely clear. The bone plugger should be restricted to not insert into the sinus cavity further than the additional 1 mm using a stopper.
- 6 Grafting procedure. The bone grafting procedure is performed without the aid of a surgical guide. If a Bio-Oss collagen sponge (Geistlich Pharma AG, Wolhusen, Switzerland) is used as the graft material, a 1 cm<sup>3</sup> portion of the sponge is cut into nine pieces and then inserted into the sinus cavity through the drill hole using the bone plugger. When inserted into the sinus cavity, the grafting material has a tendency to remain pushed upwards. Therefore, it is necessary to spread the material in the sinus cavity. Whenever approximately 0.2–0.3 ml of grafting material is inserted, it is dispersed using a sinus curette by rotating the sinus curette in the sinus cavity, both clockwise and counterclockwise, drawing the largest circle possible (Figure 15.13). The amount of grafting material inserted is determined by the height of membrane elevation. When attempting to elevate the membrane by 3 mm, insert 0.3 ml; to elevate by 5 mm, insert 0.5 ml; to elevate by 7 mm, insert 0.7 ml. If only the grafting material is inserted into the sinus cavity without placing implants, an additional 0.3 ml is inserted. For example, when attempting to elevate by 7 mm, 1 ml of graft material is inserted.

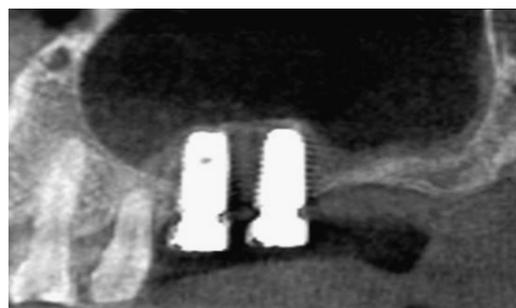


**Figure 15.13** Sinus curette used to spread the graft material.

- 7 Implant placement. Simultaneous implant placement is conducted. Before implant placement, final drilling is performed 1 mm beyond the sinus floor through the surgical guide to enlarge the sinus floor. Implants are then placed in the formed socket through the guide. It is recommended that implants be placed simultaneously with the grafting procedure because the implant will help disperse the grafting material as well as help keep the membrane elevated. However, if the vertical height of the residual bone is less than 2 mm and the implant has no primary stability, only the bone-grafting material is inserted into the sinus cavity without placing implants. Implant stability is evaluated by resistance of the implant during insertion and via measurement of the implant's insertion torque.
- 8 Immediate restoration or installing a healing abutment. Immediate restoration is performed using the customized abutment and preliminary restoration that was prefabricated pre-surgery if the following conditions have been met: for a single implant, immediate restoration is performed if the primary stability is greater than 30 N cm. For the implant that is splinted with neighboring implants, immediate restoration is performed if the primary stability is greater than 20 N cm. The restoration process must follow the immediate non-functional loading concept by adjusting the crown to avoid contact with the opposing teeth (Figure 15.14). Patients are asked to refrain from using the



**Figure 15.14** Immediate restoration with prefabricated resin temporary crowns. The occlusion and articulation of the crowns were adjusted out of contact with the opposing teeth.



**Figure 15.15** CBCT scan taken immediately after surgery.

restored teeth for 3–4 months. A cover screw or healing abutment is installed if the implant is unable to secure the primary stabilization.

- 9 Radiographic evaluation. Patients are scanned post-operatively with the CBCT unit to inspect and identify any sinus membrane perforations (Figure 15.15).

### Advantages

Compared to a lateral approach, the flapless crestal approach offers many advantages. Pain, discomfort, and healing time are greatly reduced because of the absence of trauma resulting from the large sinus floor incisions that are used in lateral sinus elevation surgeries [10–13]. The flapless crestal approach preserves the integrity of the bony sinus structure, except at the implant site. In addition, this is a flapless procedure, which is the result of using punch incisions and simultaneous implant placement with the transmucosal components. The flapless crestal approach eliminates the need for a second surgical procedure to connect the transmucosal components, thereby reducing chair time [6, 14]. The esthetic results are also improved compared to the lateral approach [10]. Based on the author's experience, the average operative time for the flapless crestal approach was  $17 \pm 15$  minutes. The surgical procedure substantially decreased the length of surgery compared to the previous crestal approaches. Some possible reasons for this shortened operative time might be due to using drills with stops, using surgical guides, the effective membrane elevation system, eliminating the need for sutures, and avoiding soft tissue elevation. In addition to a shorter operative time, the approach is successful in anatomically difficult sinus structures. During sinus lift surgery,

problems are not encountered in the presence of antral septa or when drilling along a steep bone wall. Therefore, this procedure can be highly successful in patients with septated maxillary sinuses.

### In patients with antral septum

The presence of an antral septum in the sinus cavity poses additional difficulties for a lateral approach. As a result, the lateral approach requires greater skill of the surgeon and longer operative time. Even surgeons with a lot of experience often cause sinus membrane perforation; however, with the aid of a surgical guide and hydraulic pressure, the flapless crestal approach makes the procedure simpler and faster (Figure 15.16a to c). The septum can actually be utilized to aid in shaping the grafting material in the maxillary sinus (Figure 15.17a and b). One of the reasons for the high success rate in patients with septated maxillary sinuses is that the dome-shaped crestal approach bur, which is used to drill through the sinus floor, can be safely used in steep bone walls as well (Figure 15.18). Due to its round shape, the drill works whether the surface is flat or not. Bone in the septum area tends to be hard, which can help implants achieve primary stability. If the pre-surgery CBCT scan reveals the presence of a septum, the surgeon must take this into consideration in determining the appropriate position and depth of initial drilling. When drilling through a steep sinus wall, depending on the angle, the surgeon may need to drill an additional 1 mm compared to when drilling through a flat wall.

### In patients with severely atrophic maxillae

Even in patients with severely atrophic maxillae (1 to 2 mm of residual bone), the implants can be successfully inserted at the same time as maxillary sinus elevation (Figure 15.19a and b) [15]. Typically in these situations, the maxillary sinus floor wall has hardened the cortical bone remaining. To successfully place implants in 1 to 2 mm of bone in the posterior maxilla, the residual bone quality should be effectively used to achieve primary implant stability. The drilling and implant placement is performed without shaking the axis with the aid of a surgical guide. Tapered implants are used. The osteotomy for implant placement is enlarged to 0.7–1.0 mm narrower than the anticipated implant diameter.

### Grafting material

It is difficult to create a desirable shape of the grafting material in the sinus cavity through the flapless crestal approach because the material is inserted without the ability to see inside the sinus cavity. The goal of the grafting procedure using the flapless crestal approach is to simply maintain the space created by the sinus



**Figure 15.16** A case with antral septa: (a) before, (b) immediately, and (c) 6 months after surgery.

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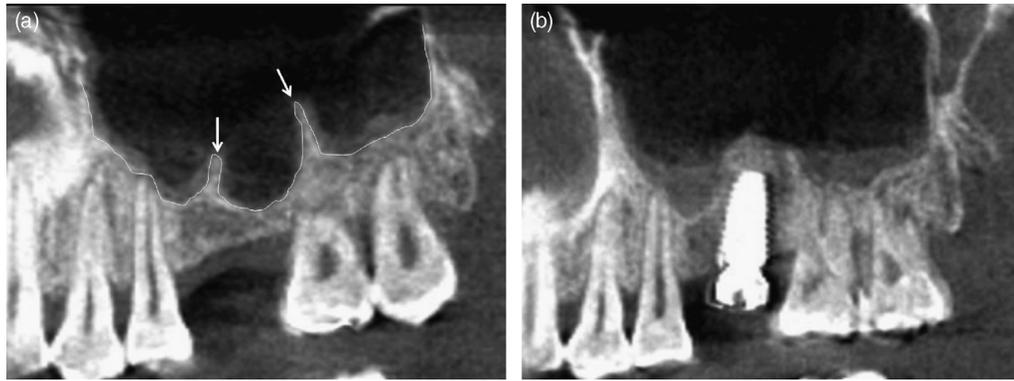


Figure 15.17 A case with antral septa: (a) before and (b) 6 months after surgery.

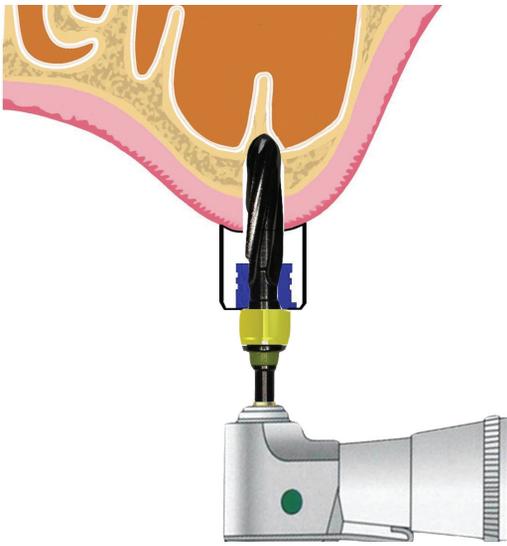


Figure 15.18 Dome-shaped crestal approach bur under the septum.

membrane elevation. In other words, the goal is to keep the sinus membrane elevated to encourage new bone formation underneath the membrane. The elevated sinus membrane can act like a tent while enabling blood flow and taking advantage of the bone's regeneration ability. The environment of the sinus cavity below

the lifted sinus membrane after sinus membrane elevation is quite beneficial for bone formation [16, 17]. This is in part because the cavity is surrounded by bone and the primary source of revascularization of the graft originates from the adjacent bony walls. In addition, the sinus membrane has an intensely vascular network and contains mesenchymal progenitor cells committed to the osteogenic lineage [18]. The periosteum of the lifted sinus membrane is another source of bone-forming cells. Accordingly, new bone formation in the newly created space can be induced by only elevating the sinus membrane, provided that the space is well maintained. When the implant is placed along with grating material, both the implant and the graft material can help maintain the elevated sinus membrane. The graft material for the flapless crestal approach must be selected on the basis of its ability to maintain space, its ability to be inserted through a small opening, and its ease of dispersion inside the sinus cavity.

The graft material can be in particle, gel, or sponge form. The *particle type* can be pushed into the sinus cavity through the drill hole using a bone carrier; however, this type can be ineffective and more time-consuming as the small opening makes it difficult for the particles to be pushed in. The advantage of the *gel type* is that it can be injected into the sinus cavity through the drill hole using a syringe; however, its disadvantage is that if there is space inside the sinus cavity, the gel can shift around. In particular, in a laid-down position, the gel moves towards the back. If a thermosensitive gel is used instead, the gel may be able to solidify inside the sinus cavity and hold its shape. If the gel and particle types are mixed together,

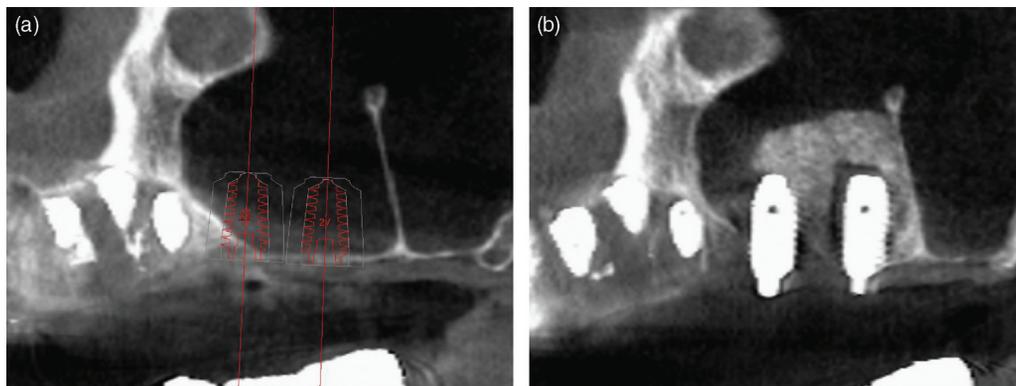
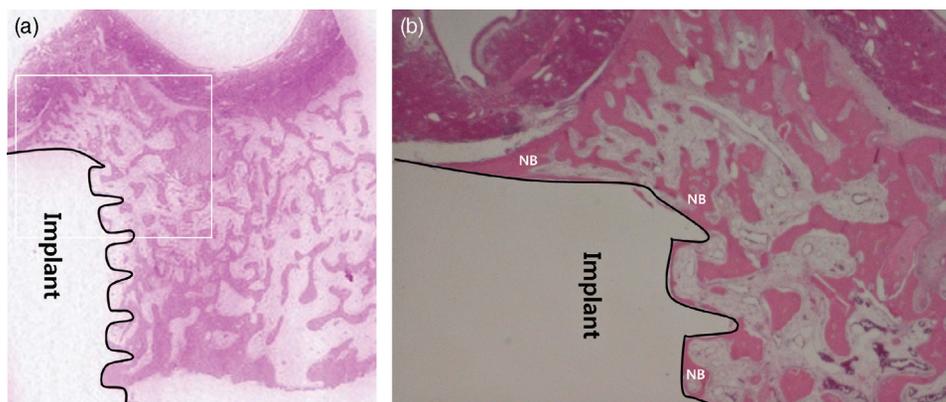


Figure 15.19 Cone beam computed tomography (CBCT) scans of the severely atrophic ridge with 1 mm of residual bone (a) before and (b) after surgery.



**Figure 15.20** CBCT scans taken (a) before, (b) immediately, and (c) six months after surgery.



**Figure 15.21** View of the specimen of Bio-Oss collagen sponge: (a) low ratio and (b) high ratio.

two things can happen. First, if the ratio of the particle type is greater than the gel type, the mixture might not be able to be injected using a syringe. Second, if the ratio of the particle type is less than the gel type, the mixture may be absorbed too easily. In contrast, if the *sponge type* material is inserted into the sinus cavity as a grafting material, the sponge can protect the membrane from the roughness of the graft material and may minimize membrane tearing during the grafting procedure. The sponge type material is soft and more elastic, which makes it easier to handle. It can be cut into a size that can easily be pushed through the hole and, when positioned, the sponge is able to maintain its space under the elevated sinus membrane. The Bio-Oss collagen sponge (Geistlich Pharma AG, Wolhusen, Switzerland) is a commonly used sponge-type grafting material. The Bio-Oss collagen sponge is made up of 90% calf cancellous bone and 10% pig collagen. Collagen sponge may not be suitable for maintaining the space because it can be absorbed quickly; however, the Bio-Oss collagen sponge is suitable because Bio-Oss bone particles are able to maintain their shape without being absorbed too quickly when inside the sinus cavity (Figure 15.20a to c). The author's animal experiment showed that when the Bio-Oss collagen sponge was used as the graft material for bone augmentation in the maxillary sinus, bone formation in the graft site was excellent and the mean osseointegration rate was more than 40% (Figure 15.21a and b).

## Conclusion

The first key factor for the success of flapless crestal sinus augmentation is penetrating the bony sinus floor using the dome-shaped crestal approach bur, a low-speed drilling with upward force and a

perfect drilling depth control. The second factor is that hydraulic pressure is used to safely elevate the sinus membrane and check for membrane integrity. The third factor is that a CBCT scan with high resolution, advanced surgical equipment, and a highly precise surgical guide are used for the surgery.

## References

- 1 Bassi MA, Lopez MA: Hydraulica sinus lift: a new method proposal. *J Osteol Biomat* 2010;1:93–101.
- 2 Engelke W, Capobianco M: Flapless sinus floor augmentation using endoscopy combined with CT scan-designed surgical templates: method and report of 6 consecutive cases. *Int J Oral Maxillofac Implants* 2005;20:891–897.
- 3 Toffler M: Minimally invasive sinus floor elevation procedures for simultaneous and staged implant placement. *N Y State Dent J* 2004;70:38–44.
- 4 Cassetta M, Stefanelli LV, Giansanti M, Calasso S: Accuracy of implant placement with a stereolithographic surgical template. *Int J Oral Maxillofac Implants* 2012;27:655–663.
- 5 D'haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H: Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. *Clin Implant Dent Relat Res* 2012;14:321–335.
- 6 Chen I, Cha J: An 8-year retrospective study: 1,100 patients receiving 1,557 implants using the minimally invasive hydraulic sinus condensing technique. *J Periodontol* 2005;76:482–491.
- 7 Kao DW, DeHaven HA: Controlled hydrostatic sinus elevation: a novel method of elevating the sinus membrane. *Implant Dent* 2011;20:425–429.
- 8 Watzek G. *The Percrestal Sinus Lift – From Illusion to Reality*. Quintessence Publishing, London, 2012, pp. 67–86.
- 9 Pommer B, Unger E, Sütö D, Hack N, Watzek G: Mechanical properties of the Schneiderian membrane *in vitro*. *Clin Oral Implants Res* 2009;20:633–637.
- 10 Fortin T, Bosson JL, Isidori M, Blanchet E: Effect of flapless surgery on pain experienced in implant placement using an image-guided system. *Int J Oral Maxillofac Implants* 2006;21:298–304.

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- 11 Nkenke E, Eitner S, Radespiel-Troeger M, Vairaktaris E, Neukam FW, Fenner M: Patient-centred outcomes comparing transmucosal implant placement with an open approach in the maxilla: a prospective, non-randomized pilot study. *Clin Oral Implants Res* 2007;**18**:197–203.
- 12 Bensaha T: Outcomes of flapless crestal maxillary sinus elevation under hydraulic pressure. *Int J Oral Maxillofac Implants* 2012;**27**:1223–1229.
- 13 Brodala N: Flapless surgery and its effect on dental implant outcomes. *Int J Oral Maxillofac Implants* 2009;**24**:118–125.
- 14 Kfir E, Goldstein M, Yerushalmi I: Minimally invasive antral membrane balloon elevation: results of a multicenter registry. *Clin Implant Dent Relat Res* 2009;**11**: e83–91.
- 15 Peleg M, Mazor Z, Chaushu G, Garg AK: Sinus floor augmentation with simultaneous implant placement in the severely atrophic maxilla. *Periodontol* 1998;**69**:1397–1403.
- 16 Lundgren S, Andersson S, Gualini F, Sennerby L: Bone reformation with sinus membrane elevation: a new surgical technique for maxillary sinus floor augmentation. *Clin Implant Dent Relat Res* 2004;**6**:165–173.
- 17 Palma VC, Magro-Filho O, Oliveira JA, Lundgren S, Salata LA, Sennerby L: Bone reformation and implant integration following maxillary sinus membrane elevation: an experimental study in primates. *Clin Implant Dent Relat Res* 2006;**8**:11–24.
- 18 Gruber R, Kandler B, Fürst G, Fischer MB, Watzek G: Porcine sinus mucosa holds cells that respond to bone morphogenetic protein BMP-6 and BMP-7 with increased osteogenic differentiation *in vitro*. *Clin Oral Implants Res* 2004;**15**:575–580.