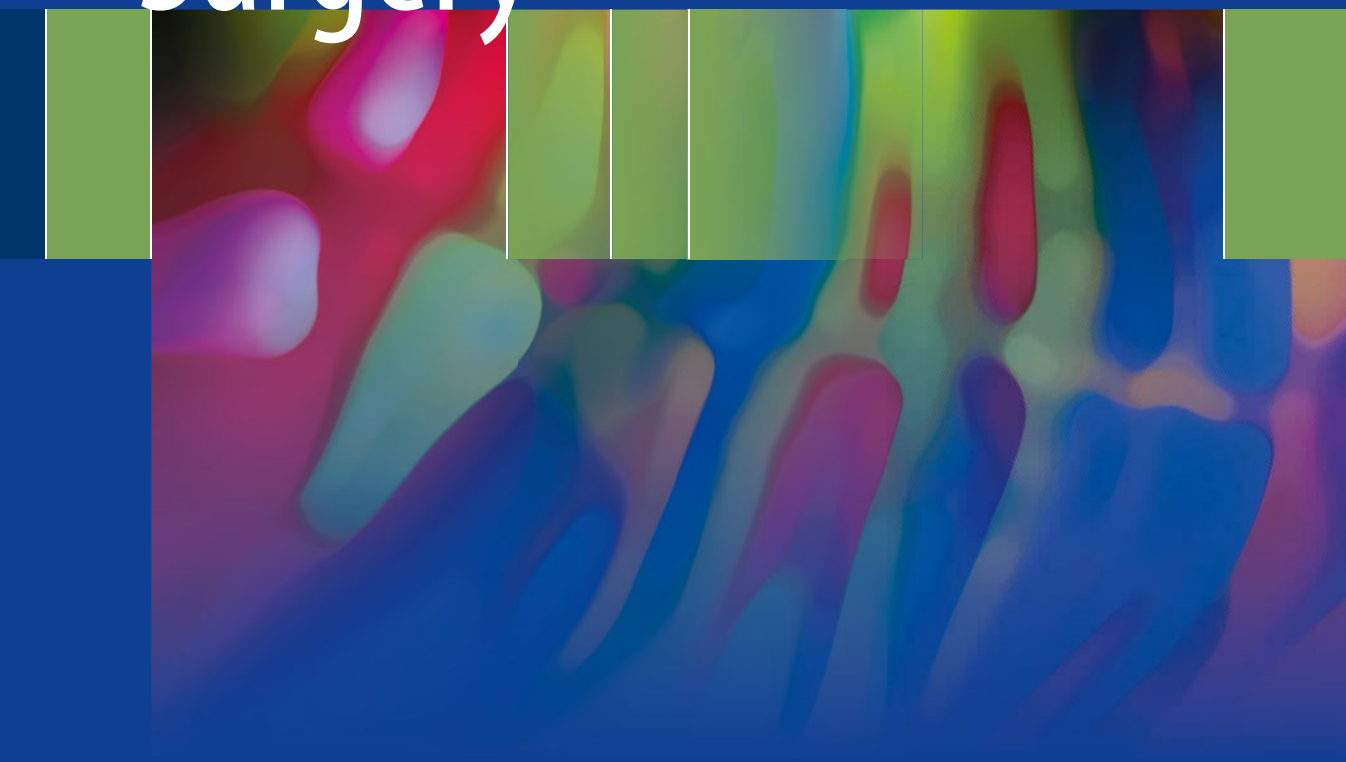
Oded Nahlieli
Editor

Minimally Invasive Oral and Maxillofacial Surgery



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Minimally Invasive Implant Surgery with and Without Sinus Floor Elevation

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Oded Nahlieli and Awfa Abu-Nimer

Abstract

The minimally invasive (MI) implant surgery is based on two innovations: the endoscopic approach to the implantation procedure and the endoscopy-friendly smart implant. The proper changes in the construction of the dental implant may solve three problems, i.e., (1) to reduce risk of complications; (2) to improve the maxillary sinus lifting procedure; and (3) to secure proper management of inflammatory diseases, bone loss, and low-density bone. Having these three problems in mind, we developed the dynamic implant valve approach (DIVA) for the dental implant procedures that uses an implant with an inner sealing screw (Upheal Dental Ltd. Netanya, Israel). This innovation was combined to the previously used endoscopic assistance during the dental implant placements and revolutionized the maxillary sinus lifting procedure itself. The innovation was put to test more than 7 years ago, and this chapter describes the results that we obtained and provides general instructions to use DIVA in the dental implantology.

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10.1 Introduction

Implantation techniques in dentistry have gradually developed from blind drilling and insertion procedures to the computerized guided surgery (stereolithographic stents). Later on, navigation equipment was introduced to assist in accurate and precise implant placement, so overcoming the shortcomings of the blind technique. An intraoperative examination of implant sites was presented in the 2000s. Initially, the examination of implant cavities was performed with immersion endoscopy. In 2006, a micro-endoscope (Visio Scope) was intro-

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duced for multidisciplinary use in dentistry, including dental implantology. It was just a next logical step after introduction of the root canal endoscopy. The second logical step was to design an endoscopy-friendly implant that also was introduced. The main goal of the endoscopic assisted dental implantation is to increase the longevity of oral implants by securing proper implant placement into bone of sufficient density. For the planning of surgery, bone conditions can be accurately evaluated endoscopically without causing any pressure necrosis of the bone. In complementary procedures, the endoscope can assist in sinus lifting intervention, and during the operation, endoscopic observation can further assess bone density and implant stability. In this chapter, we will describe

- General endoscopy-assisted implant surgery
- Endoscopy-assisted implantation procedure with the maxillary sinus lift surgery
- The use of the smart implant for the minimally invasive sinus lift procedure

10.2 The Tools: The Dental Endoscope and the DIVA Smart Implant

10.2.1 The Dental Endoscope

The Modular Dental Endoscope (POLYDIAGNOST GmbH, Hallbergmoos, Germany) is a medical device intended to allow visualization of the root canal or the implantation site and provide access for accessories used in dental implantology [1–3]. The device is a semi-rigid endoscope with a diameter smaller than 1 mm. It has high resolution optics with a 0.55 or 0.9 mm diameter, allowing easy introduction into the endoscopic cannula without being damaged. The optic element is covered with a Nitinol tube protecting it from the instruments which run through the same endoscopic cannula besides the optic element. For easy use, the optic element has an optic shifter adjustable to the cannulas of different length and keeping the optic element at the distal end of the endoscopic cannula all the time (Fig. 10.1).

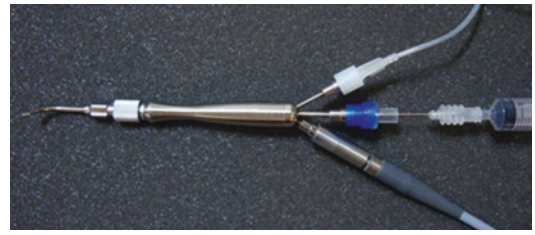

Fig. 10.1 The irrigation and injection cannula enables direct injection of saline and low viscosity material via the instrument channel under direct vision. The cannula can be advanced

Diagnostic and treatment procedures can be performed with the same endoscope by changing the disposable cannula only. Such endoscopes are usually available with an optic system of 6000 pixel or 10,000 pixel and wide field lens (120°). The dental endoscope is used with a Xenon light source, camera, and monitor. The additional instruments for such endoscopes include an irrigation device, injection cannula, mini forceps, microdrills, needles, and brushes.

The semi-rigid endoscope combines the advantages of flexible and rigid mini endoscopes: it has a clear view, a small diameter, stiffness, and good "pushability"; hence, it may be the best instrument available. Miniature endoscope for implantation procedures basically consists of three segments:

- A semi-flexible examination probe, to be inserted into the implantation site or the inner hole of the implant (see below), including an ergonomic handle
- Flexible optical fiber connections for light transmission (toward distal) and image transmission (toward proximal)
- Rigid eyepiece with a cold light source connection and coupler for a high-quality CCD camera.

The flexible optical fiber connection enables the decoupling of the examination probe from the rigid eyepiece, which gains in weight due to the CCD camera and the connected cold light cable. The work can be carried out using minimal effort while maintaining excellent pre-

cision, just as with a purely hand-held instrument. For dental clinics and medical centers, the integrated all-in-one laptop-like system, having a light source, camera, and monitor (Model SIA-COM-01, PolyDiagnost or similar) is recommended.

10.2.2 The DIVA Smart Implant (Upheal Dental Ltd., Netanya, Israel)

The Titanium-Aluminum-Vanadium implant (Ti-6Al-4V ELI) was designed with an internal central port with and dedicated sealing screw [4–7] (Fig. 10.2). This internal channel is essential for endoscopic observation during the implantation procedure and visual assessment of the bone quality, the sinus floor elevation (SFE) during the procedure, and might serve for endoscopic direct observation after the placement of an implant in cases complicated with infection, as well as for grafting material delivery or delivery of medications above the implant (Fig. 10.3). It means that the construction of the implant solves at least three problems, i.e., (1) reduces the risk of complications; (2) improves the maxillary sinus lifting procedure; and (3) secures proper management of inflammatory diseases, bone loss, and low-density bone. Naturally, there is no need to use endoscopy in each and every case and many implantations could be performed routinely. Yet, in complicated cases the DIVA implant provides additional means for observation and/or medical intervention above the implant.

The implants have external standard platform diameters of 3.75 mm and 4.2 mm and were tested in the ISRAC—Israel Laboratory Accreditation Authority for dynamic fatigue test as requested for endosseous dental implants (ISO 14801:2007). They were successfully tested on the animal model [5]. The additional fatigue test (EndoLab Mechanical Engineering) revealed that the run-out bending moment for the newly proposed implant was above the range reached by dental implants of the predicate devices (metal dental implants with a diameter of 3.75 mm were chosen for comparison). The implants were successfully tested for a possible inner screw leakage during screw-unscrew procedures (leakage sealing test, ISO 11737-2:2009; ISO 11737-1:2006; Milouda SOPs – 200.04.0116). In this test, no bacteria growth was detected and the test group and control group met the test's acceptance criteria [4, 5]. The implant was designed that way to make it possible to serve as an implant and at the same time as a drug delivery system. This newly designed implant is actually a two-component system (implant body + inner screw). The inner sealing screw was designed to serve in augmentation procedures, periapical lesion treatment, and for intra-osseous feedback via implant.

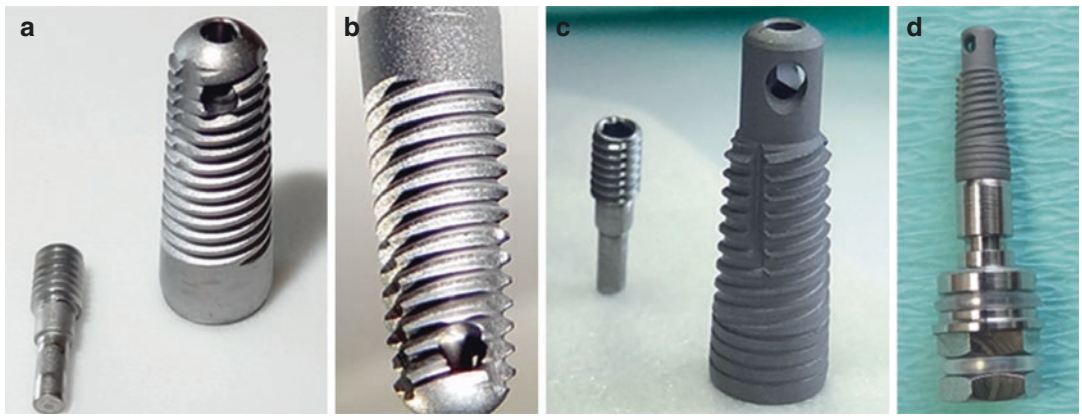

Fig. 10.2 The DIVA implants with the internal sealing screw

Fig. 10.3 An injection of a bony substitute via the inner channel of the implant

10.3 Endoscopy in the Implant Surgery Without Sinus Floor Elevation

Even if no intervention to the maxillary sinus is planned, the dental endoscopy assists implantation to increase the longevity of oral implants by securing proper implant placement into bone of sufficient density. To meet this objective, the dental implant endoscope can perform various tasks. For the planning of surgery, bone conditions can be accurately evaluated without causing any pressure necrosis of the bone. In complementary procedures, the endoscope can assist in sinus lifting intervention, and during the operation, endoscopic observation can further assess bone density and implant stability.

Endoscopy during routine implantology and during implant site preparation depends on the timing of the procedure. In immediate implant placement, endoscopic evaluation of socket condition can be performed in real time. The irrigation procedure allows observing the cavity walls of the immersed bleeding alveolar socket under variable magnification. Irrigation is crucial in every endoscopic procedure since the implant's locus must be filled with fluid to allow free and full visualization of the 120°-wide field. To maintain good visibility, the area must be lavaged, preferably with isotonic saline. Thus, intravenous tubing containing isotonic saline is connected to the irrigation port, and the endoscope's move forward is accompanied by a gentle flow of saline. Cortical and cancellous bone structures can be differentiated in situ, and pathologies are detectable even with capillary bleeding.

In late implantations, a pilot hole is drilled into the recipient site and expanded by using progressively wider drills. Before each drill is used, endoscopic observation assures that anatomical structures, like the inferior alveolar nerve, maxillary sinus are avoided [4–7].

Irrigation and suction are possible through small diameter cannula that irrigate and connect the suction to the side port of the endoscope. After assuming the form of the implant site, the tip of the irrigation cannula should be fixed one or two millimeters in front of the tip of the suction cannula, using the endoscope's control module, to prevent premature removal of the rinsing saline.

During surgery itself, endoscopic inspection of perforations and of other drilling and implant preparation errors can be performed, and endoscopic assistance in flapless implant procedures is possible.

10.3.1 Combined Endoscopic and Computerized Guided Implant Surgery

On our experience and in addition to the aforementioned benefits, when endoscopic assistance was added to the computerized guided implant surgery (surgical stent usage), we found further advantages, such as safe and flapless implantation surgery by identifying and avoiding anatomical structures and verifying the surgical stents position, preoperative planning of implant and prosthetic location, predictable procedure with

possible immediate loading, shorter surgical and prosthetic procedure and improved postoperative morbidity.

10.3.2 Future Perspective

We hypothesize that future studies will find that endoscopic implant techniques can also significantly reduce the associated complication rate. Nevertheless, the need for intensive training might be considered a disadvantage. We envision that additional applications of modular dental implant endoscope will be developed in the future. These include assistance in implant planning and design, development of a membrane suitable for endoscopic application for the closure of perforations, and endoscopic nerve repositioning.

10.4 When and Why the Maxillary Sinus Floor Elevation/ Augmentation Is Needed?

Endoscopically guided implant placements of the implants with internal port can be performed at any dental location both in the maxillae bones and the mandible. Yet, certain locations in the maxilla might require additional procedure known in various publications as maxillary sinus lift surgery, subantral augmentation, maxillary sinus floor elevation, maxillary sinus augmentation, or maxillary ridge augmentation. Regardless of dental implants installation, Philip Boyne was the first to report the elevation of the maxillary sinus floor for preprosthetic reasons in 1960. The maxillary sinus was augmented prior to a tuberosity reduction to increase the interarch distance and create a more symmetric maxillary arch for denture prosthesis [8]. Before we go further, let us recall general anatomy of the area.

10.4.1 Anatomy and Physiology of the Maxillary Sinuses

Humans have four-paired air-filled spaces that surround the nasal cavity called paranasal sinuses, these include: frontal and ethmoid sinuses between the eyes, sphenoid sinuses behind the ethmoid bone, and maxillary sinuses surrounding the nasal cavity. The maxillary sinuses are the largest of the paranasal sinuses. According to the existing theory, the biological roles of sinuses include decreasing the relative weight of skull, increasing voice resonance, providing a buffer against blows to face, insulating structures, and humidifying/heating inhaled air [9].

The maxillary sinus is a pyramid-shaped cavity, with an anterio-lateral wall corresponding to the facial surface of the maxilla (Fig. 10.4). Its size remains minimal until the eruption of permanent teeth. The average dimensions of the adult maxillary sinus are a width of 25–35 mm, a height of 36–45 mm, and a length of 38–45 mm. Its convex floor is approximately 1 cm below the nasal floor, with its deepest point usually being in the first molar region. Roots of the maxillary teeth frequently cause convolutions in the floor of the sinus [10]. Anteriorly, the sinus extends to the canine or premolar region. The maxillary sinus will maintain its overall size while the posterior teeth remain in function, but tends to expand with

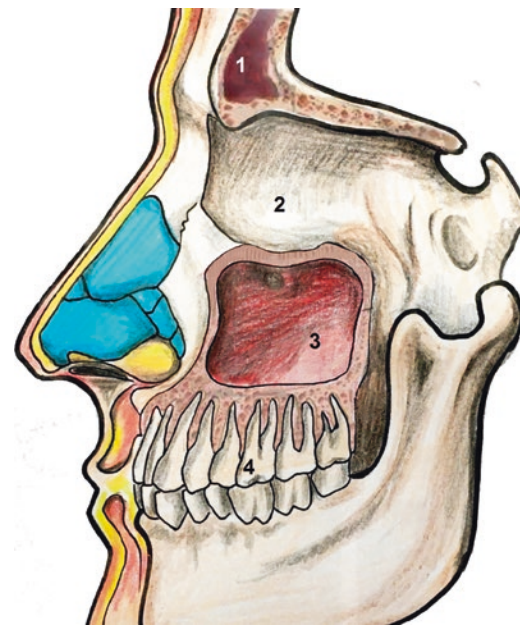

Fig. 10.4 The maxillary sinus and the teeth. *1*—the frontal sinus, *2*—the medial wall of the orbit, *3*—the maxillary sinus, *4*—the maxillary teeth

age and especially when posterior teeth are lost. The extent of this pneumatization varies from person to person and from side to side, with direction being both inferiorly and laterally. At the edentate stage, expansion often continues until only a paper-thin bony wall on the lateral and occlusal sides are left. One theory for this expansion is that the alveolar bone exhibits atrophy as the strain from occlusal function is reduced [9].

The inner walls of the maxillary sinus are lined with the sinus membrane, also known as the *Schneiderian membrane*. This membrane consists of ciliated epithelium cells resting of the basement membrane. It is continuous with, and connects to, the nasal epithelium through the ostium in the middle meatus. The blood circulation to the maxillary sinus is primarily obtained from the posterior superior alveolar artery and the infraorbital artery, both being branches of the maxillary artery. Many anastomoses are occurred between these two arteries in the lateral antral wall. The nerve supply to the sinus is derived from the superior alveolar branch of the maxillary division of the trigeminal nerve (CN-V).

10.4.2 The Bone Quantity/Bone Quality Issues

Compared with laboratory animals, the lowest bone density and fracture stress values were found in the human samples. The fundamental cause for differences in the survival of dental implants is bone quality. Currently, the assessment of bone quality is based on radiographic evaluation and on the subjective sensation of resistance experienced by the surgeon when preparing the implant site. The bone quality of the patients should be initially assessed by the cone-beam CT (CBCT) and CT images. The bone density can be measured at the CT images. At the same time, additional qualitative objective methods for evaluating bone quality are needed, and indeed, endoscopic observation of the site can determine the quality of bone density. Both anterior and posterior parts of the maxilla initially have poor bone quality, but the poorer one can be found in the posterior maxilla.

As for bone quantity, in 1981 Kayser attracted attention to the *atrophic posterior maxilla* by reporting that with maxillary premolar occlusion (shortened upper dental arch) 50–80% of chewing capacity is maintained [11]. Implant placement to reconstruct missing dentition in the posterior maxillary alveolar ridges is well accepted in the modern prosthetic dentistry, but it is often challengeable because of anatomical limitations and peculiarities as well as technical ones, of these:

- The absence of adequate *bone quantity* especially when inadequate vertical height of the residual/native alveolar bone is observed in the presurgical imaging. This bone loss is due to one or more of the following factors:
  - Rapid sinus pneumatization: caused by an increase in osteoclastic activity of the periosteum [12] results in loss of vertical bone height.
  - Ridge resorption (post extraction)
  - Periodontal disease
  - Trauma
  - Pathology and resection/surgery
- Poor *bone quality*, usually a Class III (porous cortical and fine trabecular "balsa wood" type) or Class IV (fine trabecular "Styrofoam" type) according to Lekholm and Zarb [13–16] (Fig. 10.5).
- Difficult hygiene accessibility
- Difficult surgical accessibility
- Higher occlusal loading in the molar regions in comparison with other areas, resulting in a lower success rate than elsewhere in the maxillary or the mandible [17]

To overcome these limitations, a variety of procedures have been reported in the literature: ridge bone grafts; sinus lifts (also designated as sinus floor elevation—SFE); and tilted, short, zygomatic, and pterygoid implants. Each method has its advantages and disadvantages, when the former two ones—separately or in combined—enables placing implants of adequate height as well as axial orientation. SFE is discussed in detail below. It can be performed with or without sequential subantral augmentation, while ridge

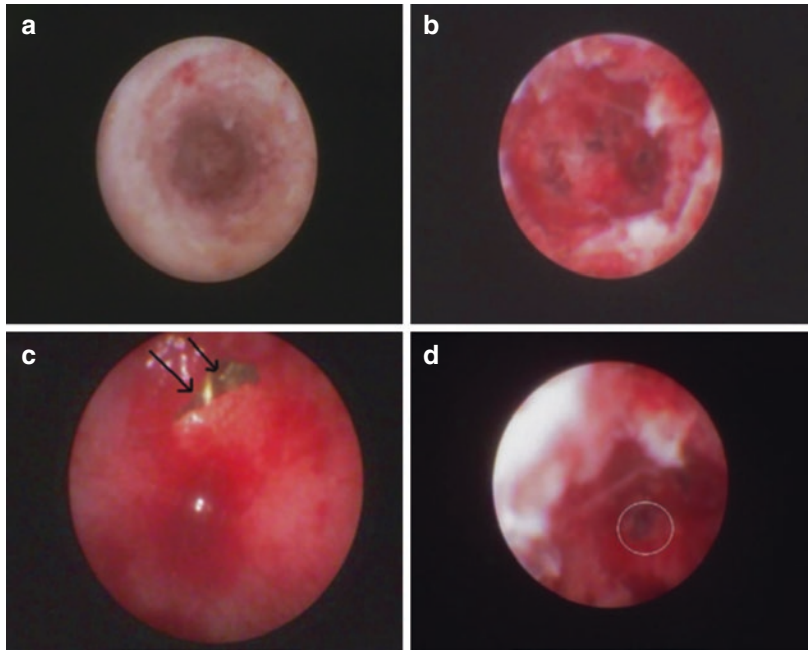

Fig. 10.5 Endoscopic observation of the drilling site can determine the quality of bone density. (**a**) Endoscopic demonstration of high-density bone quality. (**b**) Endoscopic demonstration of low-density bone quality. (**c**) Endoscopic view of socket immediately after extraction. Note (*arrows*) fenestration in the cortical wall. (**d**) Intraoperative view during drilling for implant in the location of the first lower molar. Due to the poor bone quality, the inferior alveolar nerve can be observed (*yellow circle*) (Nahlieli et al. 2011)

bone grafting in this area can be done in either one of these fashions:

- Onlay grafting [18, 19], depends on the inter-arch distance in the area of lost teeth
- Guided bone regeneration [20, 21]
- Appositional bone graft or saddle-graft [22]
- A combination of two or more of the above-mentioned procedures [23]

10.5 Indications and Contraindications for the Sinus Floor Elevation

As with any therapeutic procedure, treatment success depends on appropriate patient selection, careful evaluation of the anatomy, surgery planning, identification and management of any pathology, sound surgical procedures, and appropriate postsurgical management both by the healthcare team and patient himself.

Since the main goal of the sinus floor elevation (SFE) is to restore the posterior maxillary dentition by placement of endosseous dental implants, deficient of alveolar bone height in this area is the primary indication for the procedure, especially when less than 7 mm of vertical bone height exists. Other factors that must be considered include: the patient health, the dental and periodontal statuses, and the likelihood of a beneficial outcome. A thorough evaluation of the patient and the judgment of the clinician ultimately determine whether the procedure is indicated for any particular individual.

Contraindications to maxillary sinus floor elevation surgery are similar to that of other surgical procedures in the maxillofacial field in terms of the systemic health status, with the addition of some local consideration of the maxillary sinus itself, so that patients must be in good general health and free of diseases that affect the maxilla or maxillary sinus.

In short summary, the contraindications are:

Local factors	Systemic contraindications
Presence of tumors	Radiation therapy
Maxillary sinus infection	Uncontrolled metabolic disease (e.g., diabetes)
Severe chronic sinusitis	Excessive tobacco use
Scar or deformity of the sinus cavity (usually from previous surgery)	Drug or alcohol abuse
Dental infection	Psychologic or mental impairment
Severe allergic rhinitis	CF (yet questionable)
Chronic use of topical steroids	History of fungal infection (yet questionable)

10.6 Endoscopy and the DIVA Implant in the Implant Surgery with the Maxillary Sinus Floor Elevation

With a well-established long-term success [24–26], SFE is a currently well-accepted procedure to treat bone atrophy in posterior maxilla in purpose to compensate the bone loss by creating increased bone volume and thus permitting the installation of implants with adequate length as well as ideal axial orientation. Yet, high incidence of intraoperative complications also has been reported [27]. Thus, attempts were continually made to find a less-invasive approach, and SFE continues to be an important part of the implant surgeon's repertoire.

For the purpose of dental implantation, the procedure was first introduced orally by Hilt Tatum at the Alabama Implant Congress in 1976 [28, 29], but first published in the literature by Boyne and James in 1980 in a report on maxillary sinus floor augmentation [30], where they described a two-stage implant surgery of a lateral window osteotomy with sinus floor preservation and elevation superiorly, and simultaneous subantral bone augmentation (particulate autogenous bone graft harvested from the iliac crest was used); 3 months later, *blade implants* were placed to support removable or fixed reconstructions. In 1986, Tatum suggested and reported a less-invasive one-stage sinus floor elevation with subsequent augmentation and implant placement, a method that involved raising the membrane using an inferior crestal approach through the implant preparation site [31]. A "socket former" was used to prepare the implant site and create green-stick fracture of the sinus floor. A *root-formed implant* was placed and allowed to heal in a submerged way.

The crestal approach was refined later by Robert Summers, the change/transition which can be attributed to the so-called minimal invasive sinus lift surgery [32]. Summers actually described another crestal approach designated *the osteotome sinus floor elevation* (OSFE) using tapered osteotomes with increasing diameters, each with concave tip (Fig. 10.6) in attempt to gain vertical bone height by retaining and relocating all the existing bone. Thus, when the osteotome is pushed toward the sinus floor, bone shavings from the lateral walls of the osteotomy are collected in its concave part before being pushed upward into the subantral plane elevating the sinus floor and membrane with minimal risk. Using this approach, Summers reported a 96% success rate at 18 months after loading 143 press-fit submerged implants in type IV bone [33]. Advantages of this approach are well reported in the literature, citing reduced morbidity and postoperative discomfort as well as shortened surgical time [34–36]. Our opinion is that the minimal drilling for osteotomy preparation may be required before introducing the osteotome in some cases (such as in type III bone quality). Summers further modified the OSFE technique by adding bone graft into the osteotomy prior to sinus elevation [36]. This was referred to as the *bone-added osteotome sinus floor elevation* (BAOSFE) technique. Autogenous, allogenic, and/or xenogenic bone grafts were added to increase the volume below the elevated sinus membrane. Using the BAOSFE technique, consistent sinus membrane elevation of 4–5 mm was described by Summers. Other reports have demonstrated a wide variation in the amount of sinus elevation that could be predictably achieved [37–39].

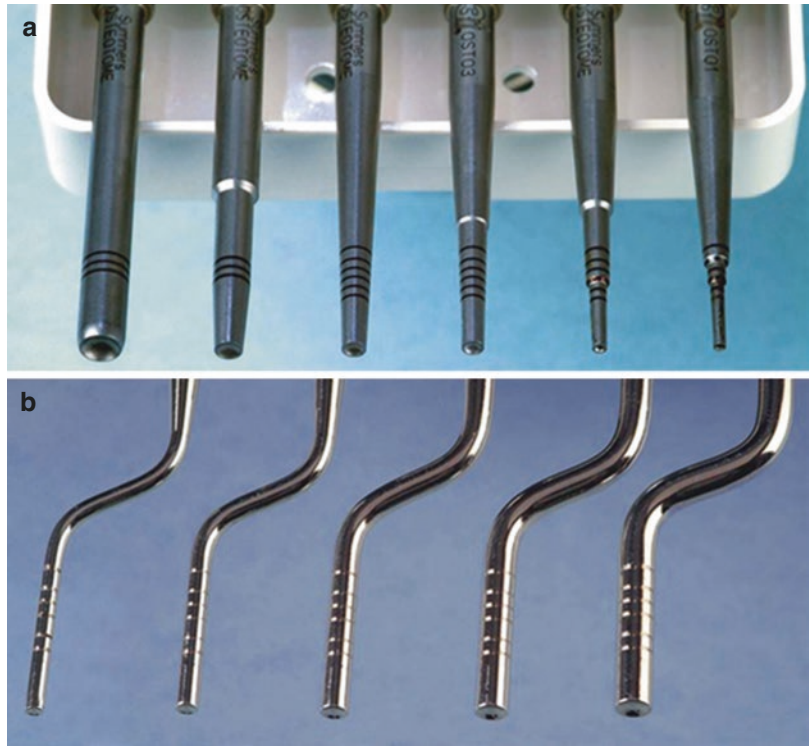

Fig. 10.6 The osteotome instruments used for the implantation procedures. (**a**) Straight osteotomes, (**b**) offset osteotomes

While the osteotome sinus floor elevation or the OSFE technique is considered to be a "conservative" approach to sinus lifting, it is, unfortunately, a "blind" technique because it does not allow a surgeon to visualize the Schneiderian membrane during the osteotomy. Limitation of the augmentation amount as well as the difficulty to control the osteotome tapping force—to avoid perforation—were reported [40, 41]. In addition, verification of success according to this technique can only be observed with postoperative radiographs. For these reasons, it considered a technique-sensitive procedure. Using an endoscope during the BAOSFE procedure has been recommended to overcome these limitations will be discussed later.

10.6.1 Techniques and Modifications of Sinus Lift Surgery

The concept of sinus lift surgery was established and confirmed in many retrospective and prospective controlled studies in the literature [42]. In general, there are two major well-accepted approaches to elevate the sinus floor: lateral window approach and transalveolar (transcrestal) approach, each with lots of modifications being evolved around. The lateral window approach can be one- or two-stage techniques for the implant placement; while the latter is a one-stage technique, mainly based on available residual bone and the possibility of achieving the primary stability of the implant.

As would be expected for such a popular procedure, various technical modifications reported to the both original "lateral window" and "transcrestal" sinus floor elevation approaches, such as:

- Membrane elevation by inflation of a balloon catheter such as MIAMBE technique [43, 44]
- The use of hydraulic pressure [45]
- The use of negative pressure [46]
- Gel-pressure technique [47]
- Reamer-mediated transalveolar SFE [48]
- Implants with internal port (iRaise [49, 50], DIVA [5–7])

Although the effect of these alterations on the outcome is still questionable, some of these surgical techniques can ease and fasten the surgical procedure as well as minimize the postsurgical morbidity.

10.7 Endoscopic-Assisted SFE

Baumann and Ewers in their cadaver study reported an impressive bone gain of 13 mm when osteotome sinus floor elevation was performed under endoscopic control [51]. Intraoperative visualization of membrane integrity using an endoscope during the BAOSFE procedure has been recommended especially when anticipated sinus elevation is greater than 3 mm [52]. The SFE can be controlled by the use of endoscope, whether by direct subantral endoscopy or indirectly using intra-antral endoscopy (sinuscopy) [2–7, 53].

10.7.1 The Dynamic Implant Valve Approach

High demand for minimally invasive procedures led us to invent the implant for a one-stage transcrestal-approached surgery, so that the implant placement is enabled along with sinus floor elevation with or without subantral augmentation as preferred, all these benefits at the same minimal invasive procedure. We have developed the "DIVA—dynamic implant valve approach," an upheal dental system based on the idea of an implant with internal central port and inner sealing screw. This innovation facilitates and expedites the minimally invasive time-saving sinus lift procedure, increases success rates, and reduces complications (particularly the risk for inadvertently tearing the Schneiderian membrane and a nerve damage).

This system was tested in vitro, and later its feasibility was tested in a large animal model (swine), and the first successive results were published in 2014 [4–6]. The testing revealed that the DIVA can be successfully used for augmentation procedures, especially of the maxillary sinus, in a standard fashion, as well as for intra- or postoperative delivery of therapeutic agents, and in combination with a dental endoscope for direct vision during the procedure. To date, more than 250 patients were treated with DIVA so that each patient underwent SFE with subsequent implant insertion, and more than 600 implants were inserted. The implants were inserted in the maxilla both with bone level < 5 mm and with bone level > 5 mm (in lesser number of cases). The number of implants per patients varied from one to eight. The failure happened in 4% without further complications. No correlation was found between failure cases and the bone density or quality. Follow-up (4–24 months) showed that in majority of cases (96%), the implantation was totally successful from objective clinical view, radiographic findings, and subjective patients' viewpoints [6].

The DIVA implants were successful in patients with atrophic posterior maxilla and native vertical bone range 3–9 mm. All patients were augmented subantrally using jelly alloplastic material injected via the implant port. There was no significant difference ($p = 0.32$) in the complication rate between implants inserted in bone level < 5 mm and those in bone level > 5 mm [7]. It was concluded that DIVA is a predictable one-stage implant surgery technique for implantation in posterior atrophic maxilla. By which, SFE becomes less invasive and with lower morbidity, the surgical field view is optimized during the procedure, adequate bone height can be achieved with long-term stability, and high acceptance by patients.

Depending on the preference of the surgeon, this approach can be used with gingival flap elevation or flapless, and endoscopically controlled if warranted. In our opinion, it is highly recommended to expose the alveolar ridge bone by performing a mid-crestal gingival incision with buccopalatal gentle elevation of the gingiva, even with the use of release incisions if needed as well, in order to assess both adequate mesiodistal location and axial orientation of the

implants, and for direct visualization of bony bounders of the implantation site to avoid and manage cortical perforation or cracks while inserting the implant, the thing that cannot be done without exposure and direct visualization of the surgical field. The following describes our modification for SFE and outlines the basic surgical technique using the DIVA system, which is a minimally invasive approach procedure that requires one surgeon.

10.8 Preoperative Planning

Presurgical evaluation of the maxillary sinus should be primarily accomplished using radiographic examination. Cone-beam CT (CBCT) scan is the authors' modality of choice for this purpose although several observations about the anatomy can be made with a periapical or panoramic projection. The maxillary sinus should be evaluated for any pathology, masses, or the presence of septa (Figs. 10.7 and 10.8). Immediately prior to surgery, a practitioner should ask a patient to rinse the oral cavity with a chlorhexidine digluconate solution 0.2% for 1 min.

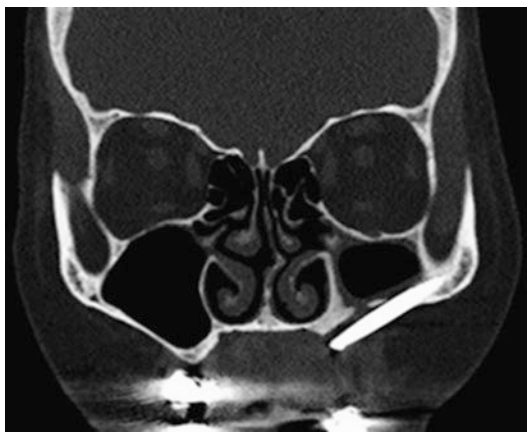

Fig. 10.7 Cone beam CT (CBCT) scan is the modality of choice for observations about the anatomy of the sinuses, a periapical or panoramic projection also can be of help. Note the difference between the left and the right maxillary sinuses

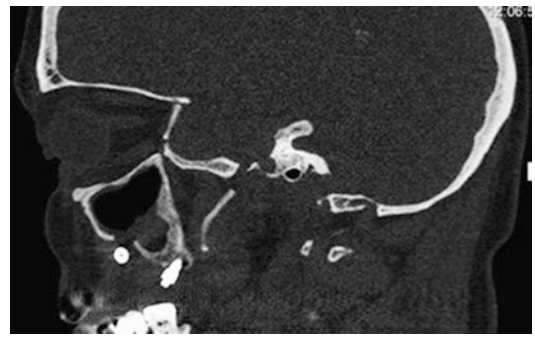

Fig. 10.8 The maxillary sinus should be evaluated for any pathology, masses, or the presence of septa

10.9 The Crestal Incision

As the first step, make an antero-posterior crestal incision placed slightly toward the palatal aspect of the edentulous area and supplemented by buccal releasing incisions at the anterior and posterior ends of the horizontal incisions when necessary. Elevate a full-thickness flap to expose and access the alveolar crest in the planned implant sites.

10.10 Osteotome Technique (OSFE)/Transalveolar Approach/Crestal

The crestal approach for the osteotomy is initiated by marking the site with a small round bur, followed by a 2-mm twist drill for the osteotomy preparation ending within 1 mm short of the sinus floor as suggested by Reiser et al. for predictable SFE [39].

Following the drilling, we apply the osteotome technique (OSFE technique) differently from that described originally by Summers [36], using a 2.7 mm curved osteotome into the drilling site to reach the left subantral 1 mm cortical bone, and to rupture it along with its adherent sinus membrane, so that the cortical bone is still connected to the sinus membrane above (Fig. 10.9a–c). This technique compresses the crestal bone and creates a bone disk that further

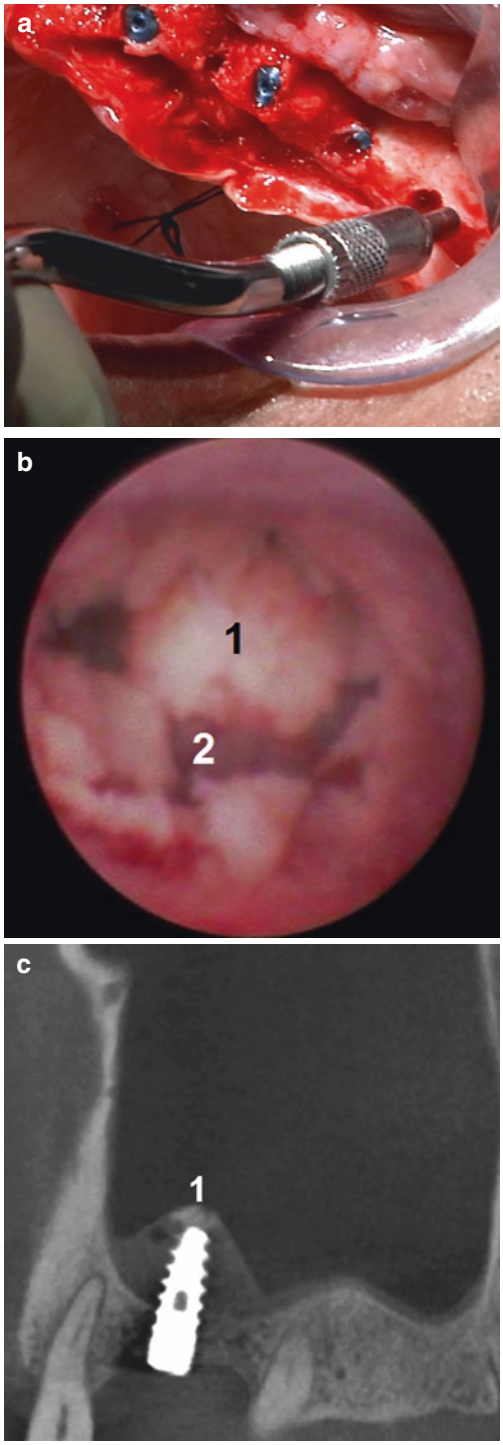

Fig. 10.9 (**a**) The osteotome technique—preparation of the implant site with 2.7 mm curved osteotome; (**b**) the endoscopic view following the osteotome procedure indicates the bony disk (*1*) and the Schneiderian membrane (*2*); (**c**) CBCT image demonstrates the creation of the stable tent with the bony disk (*1*) supported by the implant

being transferred subantrally to the sinus by the implant slow ratcheting will be performed later. The patient should be instructed to perform the Valsalva maneuver multiple times during the procedure to ensure membrane integrity.

In cases of the bone level being smaller than 5 mm, the osteotome technique enables primary stability for the implant, stable subantral tent and bone connected to the sinus membrane (bone disk).

10.11 Direct Endoscopic Evaluation (Optional)

In complicated cases, after the bone plate is split (transalveolar osteotomy) and before primary stability insertion of the dental DIVA implant, the surgeon can insert the tip of the endoscope beyond the existing sinus floor to verify the bony disk separation/fracture and its cephalic connection the sinus membrane (Fig. 10.10a, b).

10.12 Implant Insertion and Sinus Membrane Elevation

After the bone plate is split, the implant (diameter: 3.75 mm; length: 13 mm) can be inserted till, primary stability is reached (Fig. 10.11a). Then, the internal screw should be removed (Fig. 10.11b), bleeding from the caudal implant opening is usually seen in this stage due to the bone fracture and membrane separation around its apex (Fig. 10.11c). Now, begin saline irrigation via the internal port, introduce 1 cm^3 of saline followed by 1 mm of slow ratcheting (Fig. 10.11d), and keep on performed this until reaching the implant length level needed. We prefer performing this irrigation by using a non-hermetically sealed flexible plastic tube connected to syringe. The integrity of the Schneiderian membrane can be evaluated by the respiratory movement of the saline level via the implant caudal opening (Fig. 10.11e).

Thus, the authors suggest that membrane elevation by water injection as discussed above as hydraulic/diffuse pressure is preferable over using the blunt elevator in the margins to dissect the sinus membrane and to elevate it. The

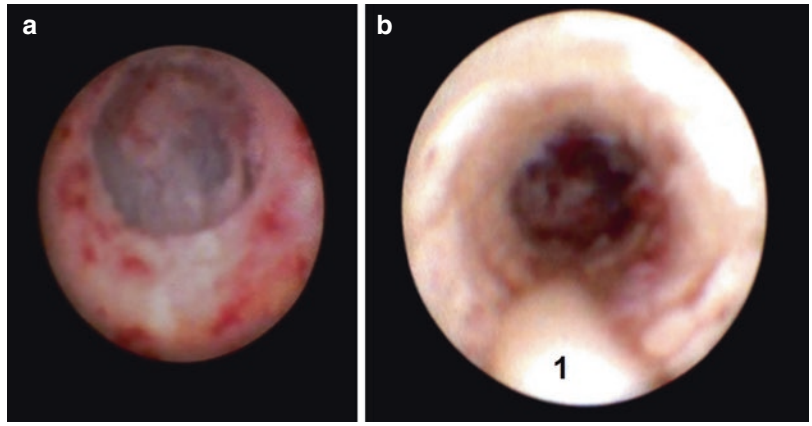

Fig. 10.10 (**a**) Endoscopic closed sinus elevation: intraoperative endoscopic view, note the intact sinus membrane after the endoscopic procedure. (**b**) Intraoperative endoscopic view during closed sinus elevation, note the jet cannula (*1*) during the membrane elevation

latter is more likely to jeopardize the sinus membrane integrity. The results of the procedure should be evaluated after the implantation (Fig. 10.11f).

10.13 Injection of Grafting Material as Needed

After completion of the sinus floor elevation, either liquid or jelly bony substitute can be optionally injected via the inner channel of the implant in order to stabilize the tent formation. Remember that the vital periosteum alone initiates bone regeneration and production in the absence of any calcified structure or augmentation material, as Srouji et al. [54] were able to prove; only a stable subantral blood coagulum is needed. We use 0.5–1 mL of βTCP with Hylanoronic acid (Cerasorb Paste Curasan AG Kleinostheim, Germany) for tent stabilization for each implant. Another good options is to inject the collagen paste (OsteoBiol, Tecnoss, Giaveno, Italy) around the implant or PRF/PRP. The DIVA injection adaptor can also be used. Then, and regardless of your choice, insert the internal sealing screw which comes as additional part within the DIVA kit and tighten it.

The authors suggest that liquid or jelly materials are preferable to the sharp-edged autogenous bone mass or bone substitute chips, which are more likely to jeopardize sinus membrane integrity when directly placed in contact with the sinus membrane (Fig. 10.12).

Following graft placement and final ratcheting of the implants, the mucoperiosteal flaps can be repositioned and sutured with 4-0 monofilament sutures without tension.

10.14 Postoperative Care and Follow-Up

Patients should be instructed not to wear their dentures for 2 weeks postoperatively until the prosthesis is relined with a soft liner as accepted. Antibiotics should be prescribed for 7–10 days and analgesics as required. Sutures should be removed 2 weeks following surgery and postsurgical visits can be scheduled at monthly intervals to check the course of healing (Fig. 10.13).

10.15 Second-Stage Surgery and Prosthetic Loading

After a healing period of 4–6 months, second-stage surgery can be carried out, stability of the fixtures should be verified, and healing abutments can be connected to the implants on the way for definitive prosthetic rehabilitation by fixed bridges.

10.15.1 Complications

The complications encountered in all minimally invasive sinus lift procedures and their modifications are dramatically less than those encountered in the lateral window approach and its

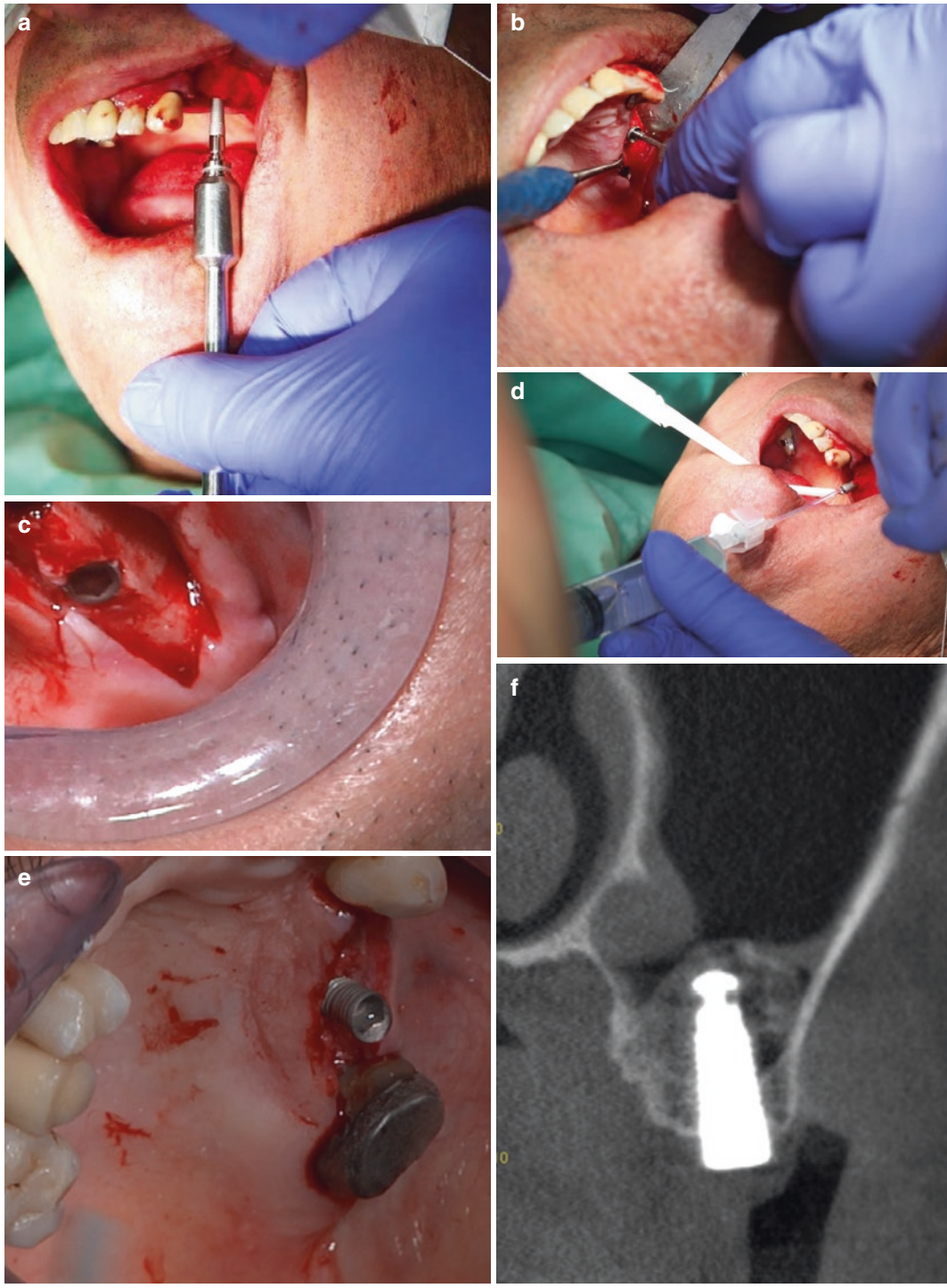

Fig. 10.11 Implant insertion and sinus membrane elevation: (**a**) the implant is inserted till primary the stability is reached; (**b**) the internal screw should be removed; (**c**) bleeding from the caudal implant opening is to be assessed; (**d**) saline irrigation via the internal port includes 1 cm^3 of saline followed by 1 mm of slow ratcheting; (**e**) the integrity of the Schneiderian membrane is evaluated by the respiratory movement of the saline level via the implant caudal opening; (**f**) the results of the procedure should be evaluated after the implantation. CBCT demonstrates a selective sinus floor elevation

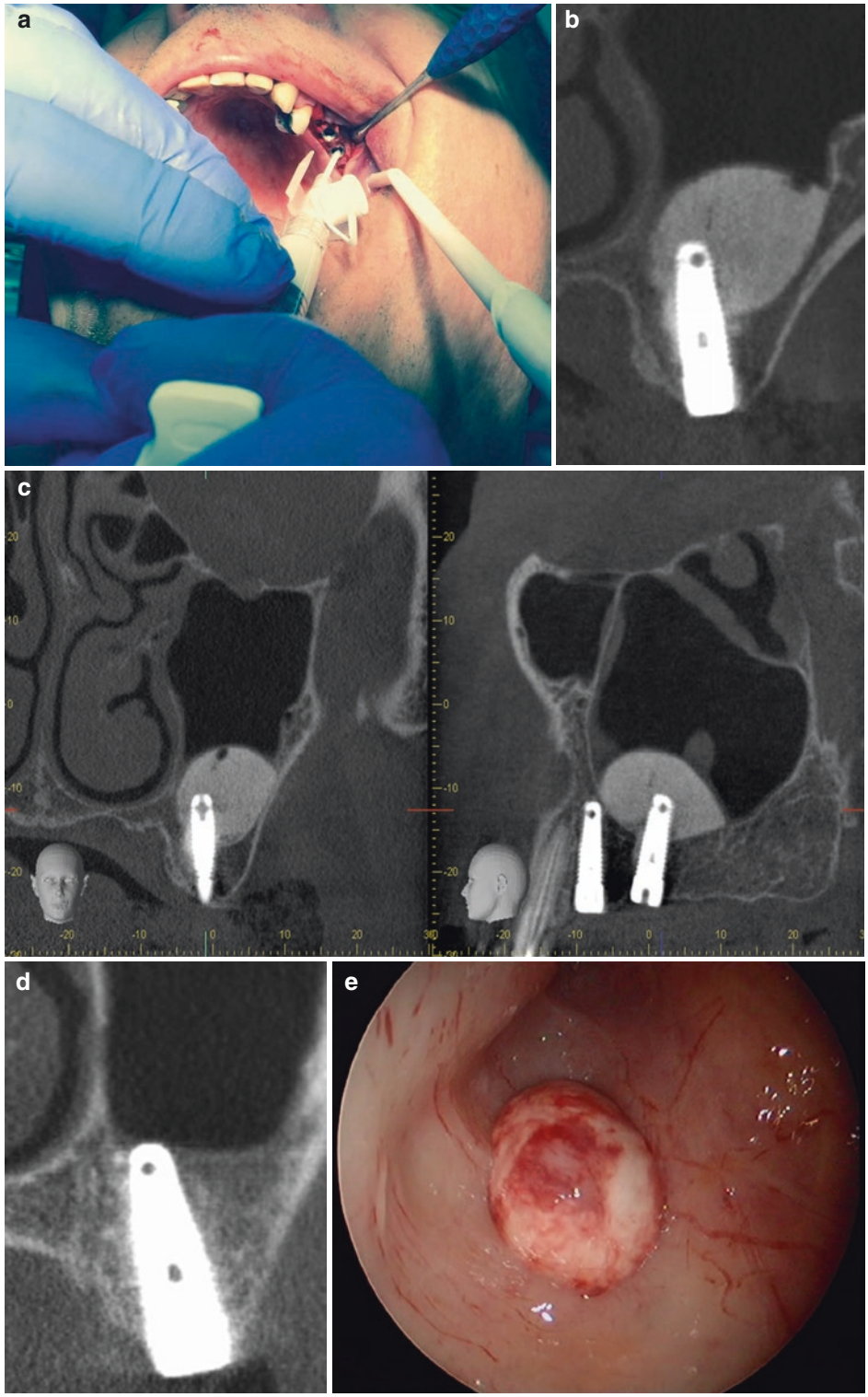

Fig. 10.12 (**a**) βTCP Paste (Cerasorb Curasan AG Kleinostheim Germany) injection via the DIVA channel; (**b**, **c**) immediate CBCT imaging; (**d**) 16 weeks postoperative CBCT demonstrating bone regeneration around the DIVA implant; (**e**) endoscopic view of the sinus site of the selective sinus elevation with the DIVA implant, note the 360° coverage of the implant with the βTCP paste (*white*). The bone disk is in the center of the picture

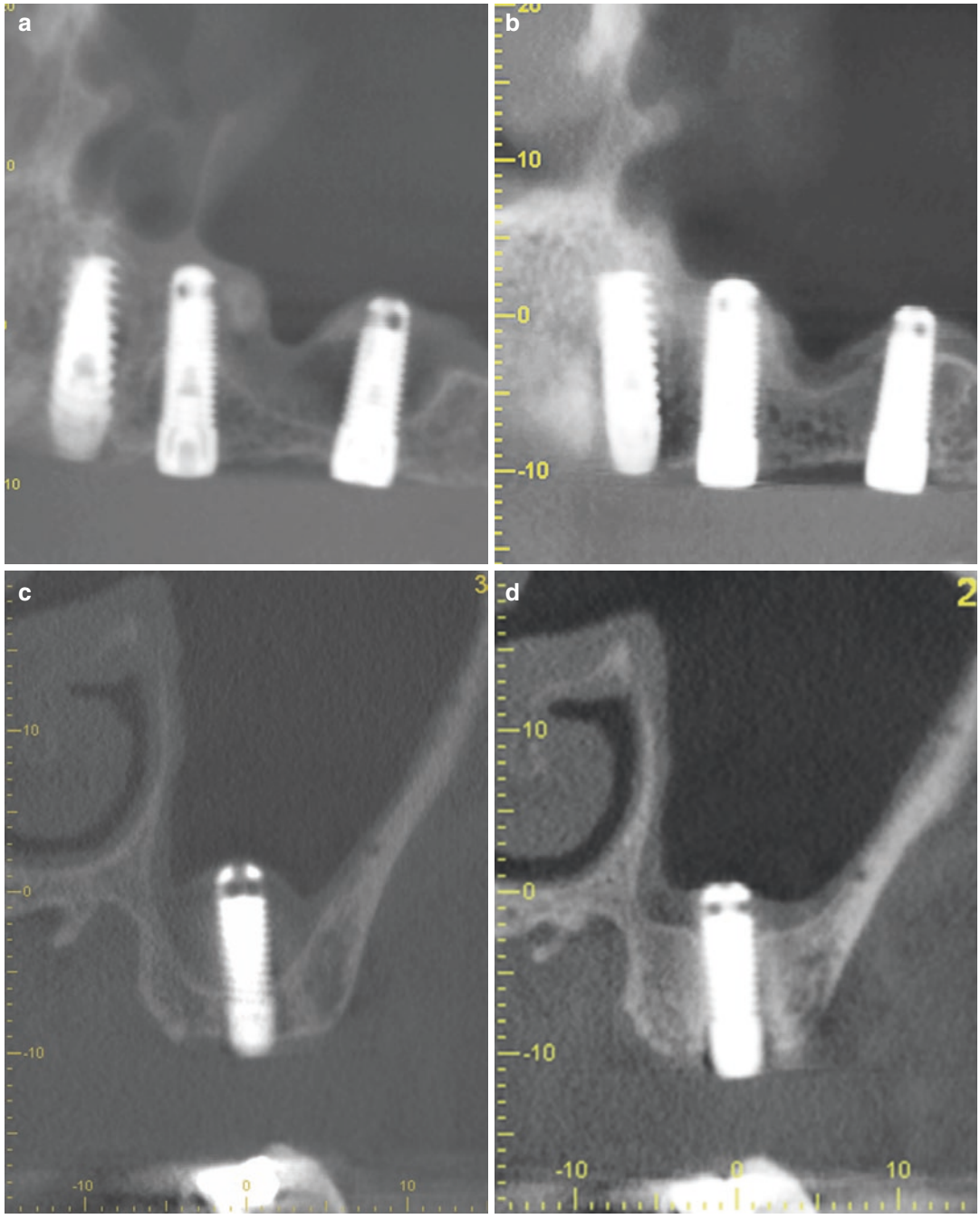

Fig. 10.13 Follow-up assessment. (**a**) CBCT image (sagittal section view) of 56-year-old female taken immediately after the selective sinus elevation, insertion of two DIVA implants, and creation of the stable tent; (**b**) the same patient 16-week follow-up demonstrates the formation of the bone in the tent; (**c**) the immediate coronal section view image of the same patient; (**d**) the 16-week follow-up coronal section view of the same patient; (**e**) CBCT image (coronal section view) of 60-year-old female taken immediately after the similar procedure; (**f**) the same patient 16-week follow-up demonstrates the formation of the bone in the tent

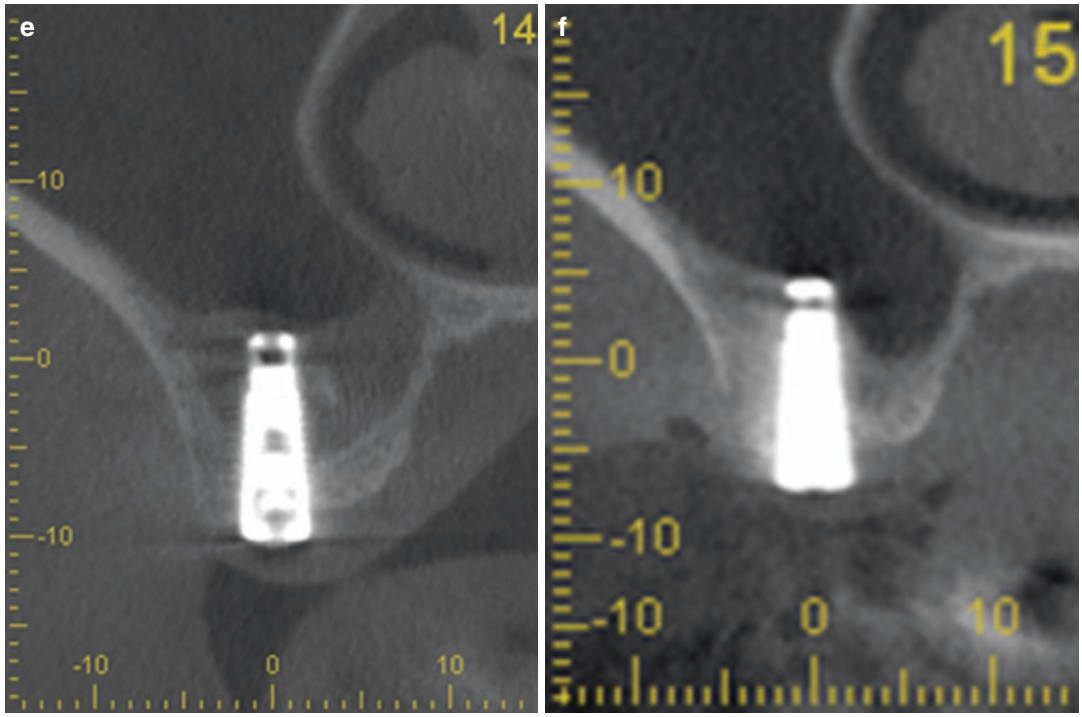

Fig. 10.13 (continued)

modifications. Owing to techniques, similarities in MI-SFE, the complication encountered are almost the same, and include membrane perforation, bleeding, sinusitis, sinus cavity obliteration, implant dislodgement, and sequestration and infection of one graft material [55]. Specifically in OSFE, and because of osteotome tapping, a benign paroxysmal positional vertigo (the so-called OSFE-BPPV) can occur in incidence less than 3% as was reported [56, 57]. Paraesthesia is also a rare complication reported in MI-SFE.

Membrane perforation during the MI-SFE techniques can be minimized using sound clinical planning and accurate determination of available preoperative bone height. Research has found that implants can heal uneventfully if a small perforation without graft dispersion occurs [58]. The incidence and management of these complications is well discussed in the above-mentioned literature.

10.16 Alternatives to Performing a Sinus Lift

When SFE is contraindicated, and for achieving the prosthetic/prosthodontic goal mentioned, there are several alternative techniques available by which the surgeon can avoid manipulation of the sinus floor.

10.16.1 Short Implants

The simplest solution is placing short implants which greatly reduce the chances of entering the sinus cavity upon insertion. Short implants, ≤8 mm in length, when placed without grafting offer the opportunity of a less complex, cheaper, and faster treatment. Reports of the successful use of shorter implants to avoid encroachment of pneumatized sinuses are available [59, 60].

However, an analysis of longitudinal studies, which included 16,344 implants, demonstrated that along with other risk factors, poor bone quality in connection with short implants seemed to be associated with failure [61].

In general, and regardless the implantation site, reports also have shown implants shorter than 10 mm are less successful than longer implants [13, 62–65].

Although there is a paucity of data comparing short implants in the posterior maxilla with long implants in grafted sinuses, it is possible that in the future the improved implant surface topography may further raise the survival rates for these shorter implants.

10.16.2 Tilted Implants

Another option without a compromise in the optimal implant length is placement of the implants in a tilted fashion either mesially or distally in a way that they do not penetrate the maxillary sinus. By this alternative treatment option, longer implants, with lengths of up to 15 mm, can be placed and anchored with larger cortical bone contact [66]. Nevertheless, long-term data regarding tilted implants success are still limited [66–68].

10.16.3 Zygomatic and Pterygoid Implants

Either passes through the sinus cavity or laterally, zygomatic implants can be used. Although these implants yield high survival rates, when infection occurs their removal is difficult [69–71]. As it is with tilted implants, non-axial implants prone to significant crestal bone loss after remodeling are complete, leading to increased probing depths and peri-implant pathologies.

The pterygoid implant passes through the maxillary tuberosity, pyramidal process of palatine bone, and then engages the pterygoid process of the sphenoid bone. However, in some studies they are placed in a more anterior position, in the pterigomaxillary area and parallel to the posterior wall of the sinus [72–75]. Such implants avoid the need for bone grafting in the atrophied or resorbed maxilla, eliminate prosthetic cantilevering, improve axial loading, and achieve stability and high rates of long-term success.

10.16.4 Onlay Bone Graft

Onlay bone grafts may be used for a horizontal or vertical augmentation of the residual ridge; however, vertical ridge augmentation using block grafting does not achieve a predictable bone height gain [75]. Although horizontal ridge augmentation by way of guided bone regeneration is predictable, augmentation in a vertical direction is not.

Conclusion

We see the DIVA contribution to MI-SFE surgery as follows:

- More quantity of elevation and the implant's height
- Less perforations
- Less discomfort and PBBV during the surgical procedure
- Reduced operative time
- Intraoperative option for control and intervention by an endoscope

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