CLINICAL ORAL IMPLANTS RESEARCH

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Radiological sinus lift: a new minimally invasive CT-guided procedure for maxillary sinus floor elevation in implant dentistry

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Abstract

Purpose: Implant therapy has become an excellent treatment modality as its inception into the modern era of dentistry. However, when patients present with advanced atrophy of the maxillary alveolar ridge, the procedure of choice to restore the anatomic bone deficiency is surgical maxillary sinus floor elevation or sinus lift. The purpose of this study was to describe the CT guided sinus lift technique and to illustrate the minimally invasive aspect of this new radiological procedure called radiological sinus lift.

Material and methods: For this prospective study, 17 cadaver heads which met our inclusion criteria (edentulous posterior maxillary sector and bone height less than 5 mm) were analyzed using cone beam computed tomography (CBCT) and orthopantomography (OPT). CT and sinus endoscopy was used to guide each step in the procedure. The radiological sinus lift technique consists of the following four stages: *Approach.* A 14.5 G OstyCut needle was inserted mesial to the canine eminence, and manual drilling was performed parallel to the sinus floor. *Osteotomy.* An inner obturator with a blunt tip was introduced to compress bone, to push it in close proximity to the sinus membrane and finally to create an osseous window opening into the submucosal space. *Lifting.* The sinus lift was performed using hydrodissection with dilute iodinated contrast medium. *Filling.* The submucosal space was then filled with an injection of dilute collagen. Success of the radiological sinus lift procedure was defined by the presence of a dome shape visible within the maxillary alveolar recess. All cases were imaged postoperatively using OPT and maxillary CBCT.

Results: Twelve maxillary sinuses underwent the radiological sinus floor elevation procedure. A dome shape of the Schneiderian membrane was achieved in eight maxillary sinuses (66.7%). All failures (n = 4) were caused by mucosal perforation at the time of maxillary sinus osteotomy. Mean height of membrane elevation was 12.0 mm, with a mean intervention time of 45 min.

Conclusion: This experimental study evaluates a new minimally radiological procedure for maxillary sinus floor elevation, which provides an interventional radiological alternative to the classical surgical lateral approach and achieves an equivalent success rate to that cited in the literature for the surgical approach, a low morbidity and a shorter operating time.

Purpose

Implant dentistry has become an excellent treatment modality as its inception into the modern era of dentistry. However, when patients present with advanced atrophy of the maxillary alveolar ridge, surgical maxillary sinus floor elevation or "sinus lift" is a necessary pre-prosthetic procedure to restore the anatomic bone deficiency, to enable implant osseointegration (Figs 1 and 2). This surgical procedure has many drawbacks including expense, operating time, significant tissue trauma with consequent patient discomfort, and risk of sinus mucosal perforation, which may be overlooked due to sinusitis.

The objectives of this study were to describe the CT-guided sinus lift technique and to illustrate the minimally invasive aspect of this new interventional radiological technique.

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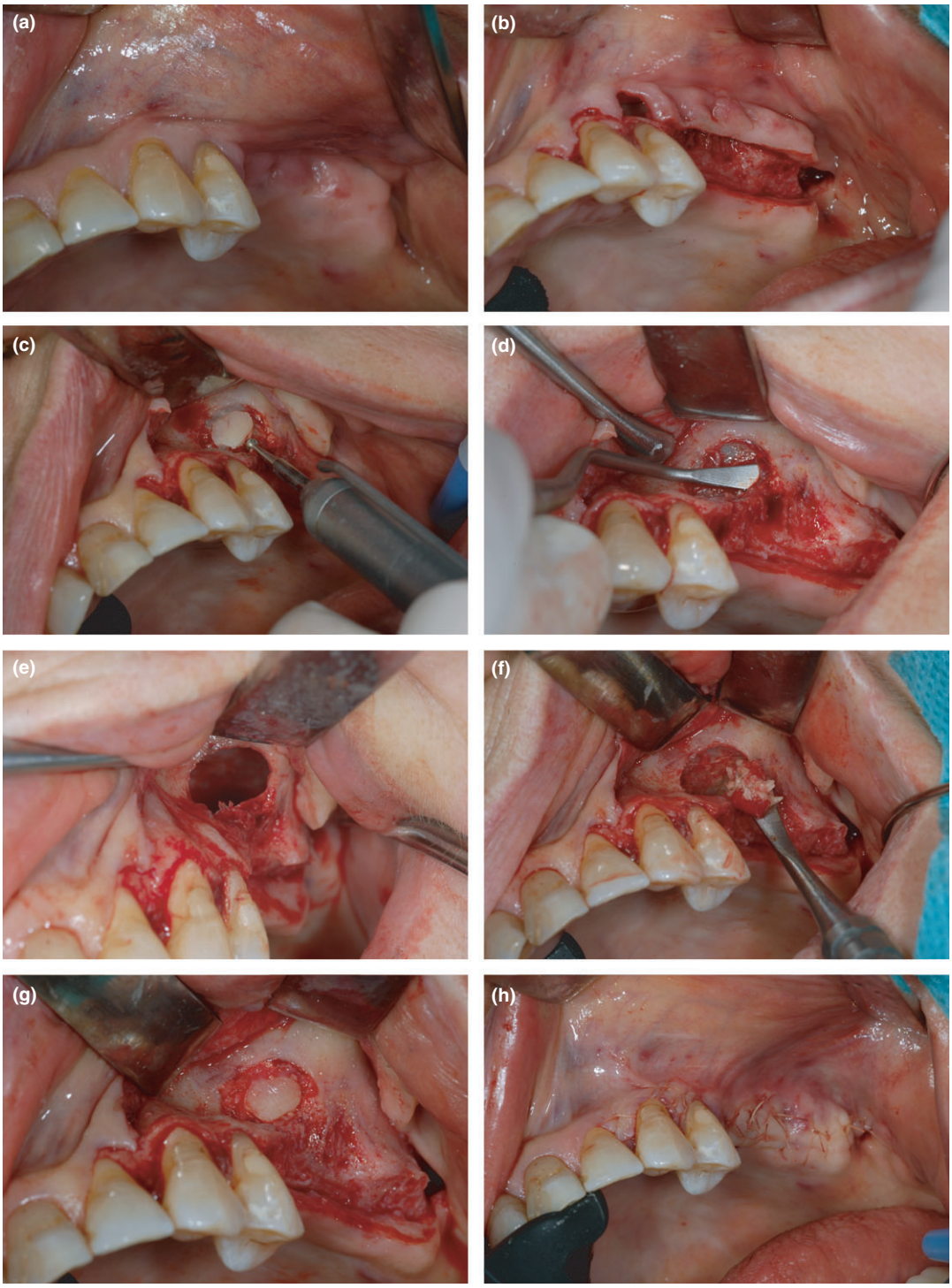

Fig. 1. Stages in surgical maxillary sinus floor elevation. A lateral antrostomy is started with a crestal incision made on the alveolar ridge. A full-thickness flap is then raised to allow access to the lateral antral wall (a–b). Antrostomy is performed with a round burr to create a bone window into the sinus (c). The sinus membrane is then gently lifted from the bony floor by means of an antral curette to free up the sinus membrane (d–e). A space is created after the sinus membrane has been elevated; this space is then grafted with different materials to provide the platform for implant placement (f–h). Implants are placed either simultaneously with the graft or after a delayed period of up to 12 months to allow for graft maturation.

Material and methods

For this prospective study, to met our inclusion criteria (edentulous posterior maxillary sector and bone height less than 5 mm), 17 cadaver heads were analyzed by orthopantomography (OPT) (Orthoralix SD, Philips, Eindhoven, The Netherlands) and by Cone Beam CT (CBCT) (NewTom 5G, QR, Verona, Italia).

The whole procedure was guided using CT (SOMATOM Sensation; Siemens Medical System, Erlangen, Germany). Acquisition parameters used for osseous biopsies were adopted: 100 kV, 45 mA.s, 0.6 mm section collimation. The following reconstruction parameters were used: 0.6 mm slice thickness, 0.6 mm slice intervals. Reconstructions

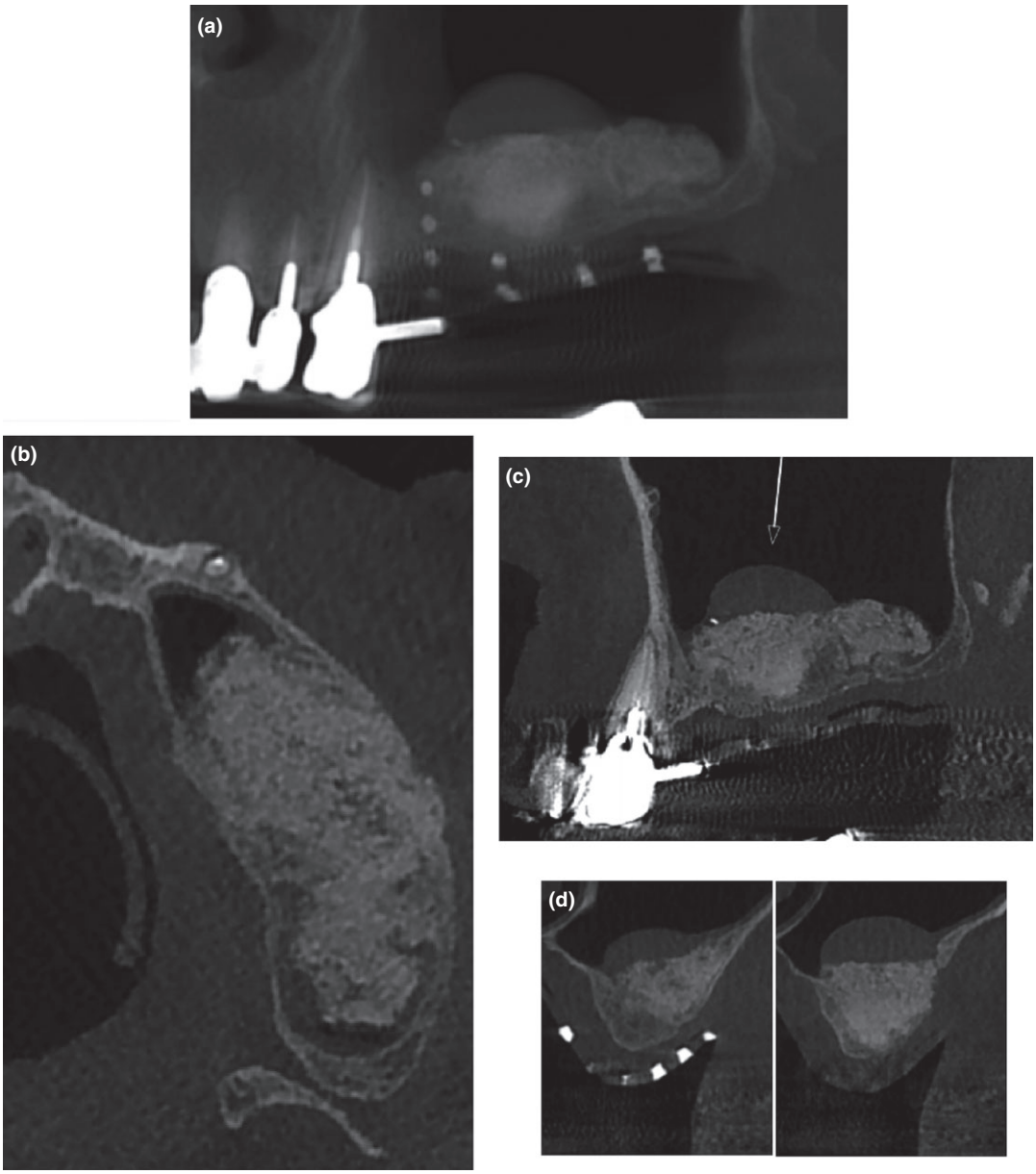

Fig. 2. Cone beam CT pre-implant assessment. Six months after the bone graft, cone beam CT provides information on bone graft osseointegration (a-c), maxillary sinus complications (c), and provides radiological guidance for pre-implant assessment (d).

were processed with a hard filter (H70 h). To highlight and confirm any mucosal perforation, the mucosal elevation was monitored in real time with a 30-degree rigid endoscope (Hopkins II; Karl Storz endoscopy, Tüttlingen, Germany) inserted into the sinus via a hole made below the inferior orbital rim. The combination of isotropic volume CT and endoscopic control provides high definition views during the elevation procedure and increase the accuracy for detection of any perforation.

Thermoluminescent dosimeters (TLD) were placed over each eye and under the angle of the mandible in order to assess the effective dose delivered to the lens of the eyes and the submandibular glands, respectively.

The radiological sinus lift technique consists of the following four stages (Fig. 3):

1. *Approach:* By retracting the superior lip and flapless, a 14.5 Gauge OstyCut needle (Bard Biopsy Systems, Tempe, AZ, USA) was inserted mesial to the canine eminence and manually drilled parallel to the sinus floor. Limited CT acquisitions followed the needle tip progression into the anterior alveolar maxillary trabeculation.
2. *Osteotomy*: Eight millimeters anterior to the maxillary sinus, the inner trocar-type stylet was removed. To avoid any perforation risk, the needle was manually drilled for an additional 3 mm in order to embed the empty needle within trabecular bone and ensure a secure support prior to osteotomy. The blunt-tipped inner obturator was introduced in order to compress the bone, to push it in close proximity to the sinus membrane, and finally create an osseous window and an opening into the submucosal space, by detaching a mucosally anchored osseous trapdoor (similar to a greenstick-type fracture).
3. *Lifting*: The sinus lift was performed by hydrodissection with dilute iodinated contrast medium pushed with inflator

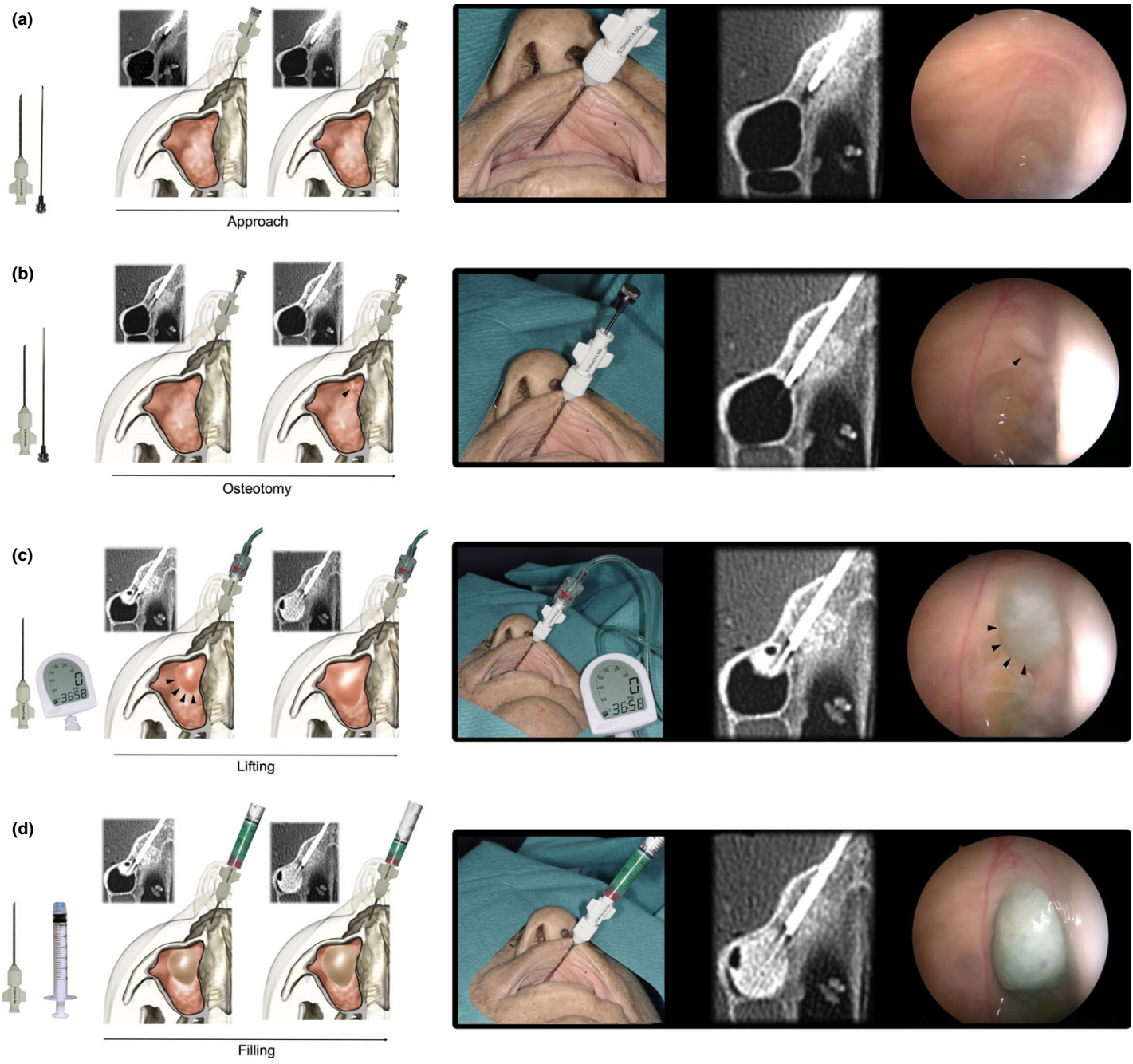

Fig. 3. CT-guided radiological maxillary sinus floor elevation stages. The radiological sinus lift technique consists of the following four stages: *approach* through the trabecular bone of the anterior dental sector (a), *osteotomy* to create an osseous window opening into the submucosal space (arrow) (b), *lifting* performed by hydrodissection with a dilute iodinated contrast medium (arrows) (c), *filling* the submucosal space with injection of dilute collagen, visible as a dome shape (d). Note on the endoscopic views the posterior and superior alveolar artery course in the maxillary sinus lateral wall.

(Blue Diamond; Merit Medical Systems, South Jordan, UT, USA). If CT acquisitions demonstrated a dome shaped appearance of the Schneiderian membrane (similar to a submucosal cyst), it was assumed that no mucosal perforation had occured. To gradually achieve mucosal detachment, this inflation–deflation procedure was performed three to four times in order to create a submucosal space.

4. *Filling*: The submucosal space was then filled with injection of dilute collagenous sponge (GelitaSpon; Gelita Medical B.V., Amsterdam, Netherlands) directly into the OstyCut needle. The radiological sinus lift procedure was deemed successful by the presence of a visible dome shape within the maxillary alveolar recess. Mucosal perforation (signified by dome shape deflation, or the absence of maxillary mucosal lifting) was considered a failure.

All cases were scanned postoperatively with OPT and maxillary CBCT (Figs 4 and 5).

Results

The radiological sinus floor elevation procedure was performed on 13 maxillary sinuses within 17 cadaver heads. One sinus was excluded because a Schneiderian membrane

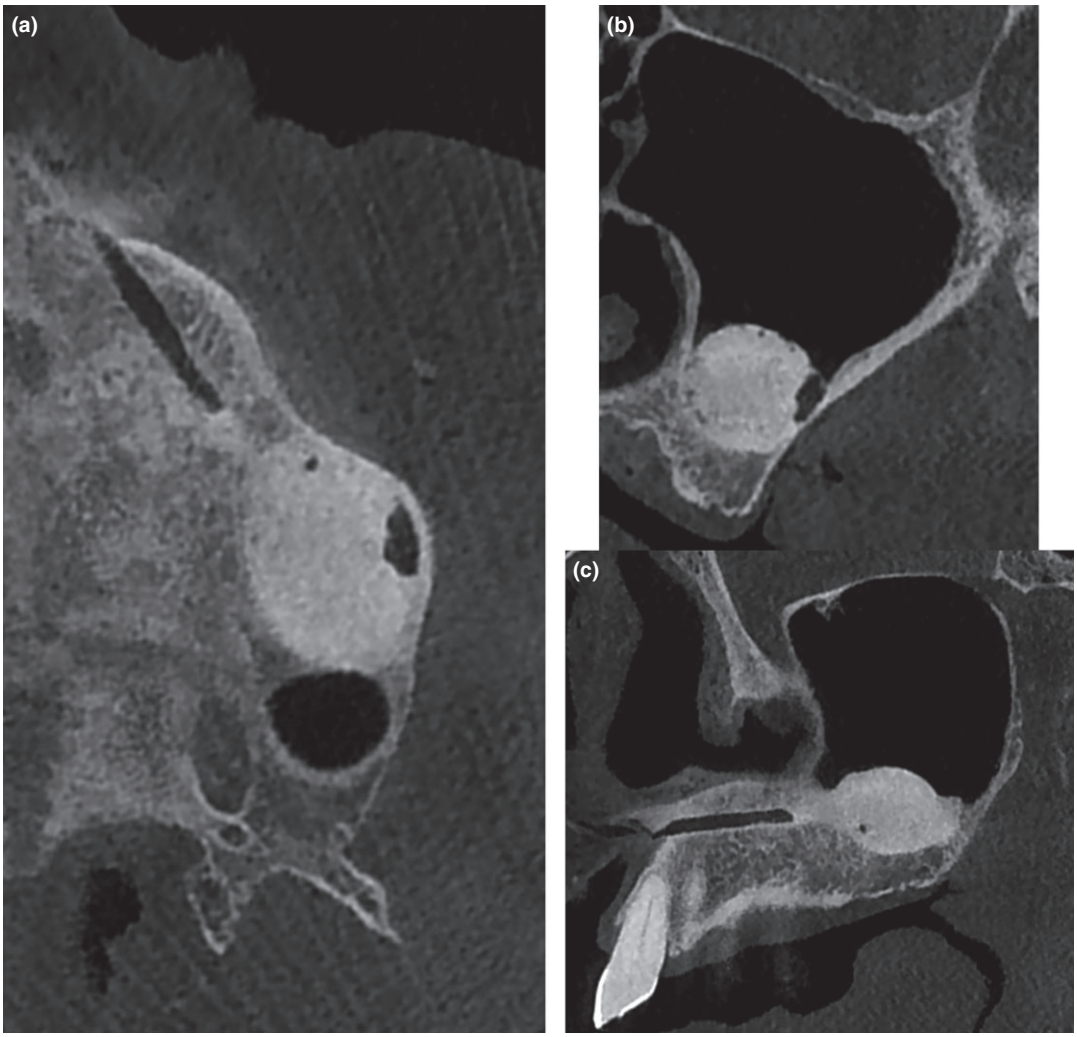

Fig. 4. Post-operative Cone beam CT (axial, coronal, and sagittal views). A dome-shaped appearance confirms procedure success without perforation (b). The needle approach is visible in axial section as a boneless line (a). The membrane elevation and the submucosal filling material occupy the edentulous maxillary sinus floor (c). No sinus complication occured in this case of radiological sinus lift.

perforation occurred during the suborbital osteotomy in preparation for the endoscopic approach. A dome shape within the Schneiderian membrane was achieved in eight maxillary sinuses (66.7%). All failures ($n = 4$) were caused by mucosal perforation at the time of inner maxillary sinus osteotomy, and all failures were visible endoscopically and on CT images. If hydrodissection was performed successfully (signified by a dome shape of the membrane), then the submucosal space was filled using dilute collagen (1.3 cc mean). Mean residual ridge height was 3.3 mm in successful cases. Mean elevated membrane height and width to the sinus floor were 12.0 and 12.2 mm, respectively. Mean intervention time was 45 min (30 to 65 min). Mean radiological exposures were 79.2 mGy.cm for DLP and 23.1 mGy for CTDIv. Mean effective doses to the lens of the eyes and to the submandibular glands were 2.0 and 1.7 mGy, respectively.

Discussion

Reconstruction of edentulous areas of the maxilla with dental implants has become common practice. In some situations, there is a lack of supporting bone as a result of atrophy. As dental implants can only be placed if there is sufficient bone to adequately stabilize them, bone augmentation procedures represent an effective treatment option for these patients. Currently, two main surgical approaches to the maxillary sinus floor elevation procedure can be found in the literature.

The direct approach, external lateral antrostomy, is the classic, and the more commonly performed technique originally described by Tatum (Tatum 1986). If residual alveolar bone height was less 5 mm, this procedure is the only available and consists of the preparation of a top-hinged door in the lateral maxillary sinus wall. This door is displaced inward and upward together with the Schneiderian membrane to a horizontal position forming the new sinus bottom. Separating this membrane is a delicate and difficult procedure, which often requires special elevators to minimize the perforation risk. The new raised floor creates a subantral space, which is then filled with graft material. One of the drawbacks of the lateral approach is that it requires the raising of a large gingivo-periosteal flap for surgical access.

Summers advocated the indirect approach in cases where initial residual bone height was greater than 5 mm: the crestal or internal transalveolar approach (Summers 1994). The procedure consists of creating a green-stick-type fracture of the cortical bone of the sinus floor by preparing the implant bed using osteotomes of increasing diameters. The indirect sinus floor elevation causes less tissue trauma and allows the patient to

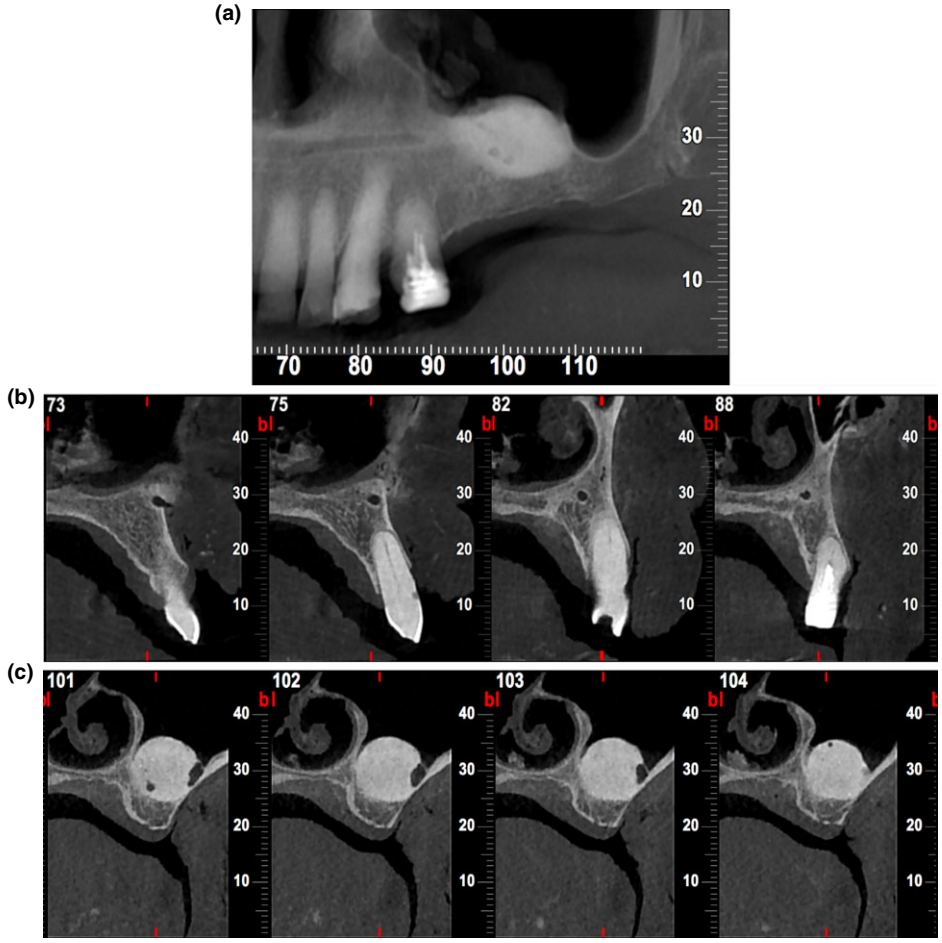

Fig. 5. Post-operative Cone beam CT (panoramic (a) and radial views). In the toothed maxillary anterior sector (b), the approach under the nasal floor to access to maxillary sinus floor can be followed on radial views. In the edentulous maxillary posterior sector (c), the dome shape provides a greater amount of submucosal space augmentation to the atrophic maxillary ridge. This facilitates implant planning to allow use of the largest possible implant.

recuperate faster than with the external lateral window approach. However, poor visibility and decreased space for handling surgical instruments were found to increase the risk of mucosal perforation (Stelzle & Benner 2011).

The interventional radiological sinus lift technique described in the present experimental study uses a flapless approach to the maxillary sinus. The CT-guided procedure allows a real-time accurate view of each of the four steps illustrated above and also permits a minimally invasive technique. The anterior approach with a 2 mm needle gives access to the anterior sinus border, easily allowing homogenous hydrodissection to lift the Schneiderian membrane overlying the medial and lateral maxillary sinus walls, from front to rear of the maxillary sinus. Drilling though the trabecular anterior segment in the direction of the sinus, to the inner sinus cortex is necessary to avoid reflux during lifting and to secure the needle in place. A lateral approach to the sinus would possibly have failed for these reasons. A submucosal filling material is needed to stabilize the detached sinus membrane in the highest possible position to achieve sufficient augmentation height and width for implant insertion. Some studies proved a form of stable collagenous sponge in combination with the resulting stable blood clot to be sufficient in stabilizing the sinus membrane above the achieved subantral augmentation volume (Troedhan et al. 2012).

Iatrogenic sinus membrane perforation is the most commonly encountered surgical complication. It may cause termination of the augmentation surgery if the perforation is large and overcomes the ability of the operator to seal it. This complication has been associated with a higher incidence of sinusitis due to bacterial graft contamination and/or graft migration into the sinus and thus endangers graft as well as implant survival (Pikos 1999; Schwartz-Arad et al. 2004). The risk of sinus membrane perforation has been reported to be as high as 58% for the lateral surgical approach (Pjetursson et al. 2008; Hassani et al. 2012). Using transcrestal sinus elevation techniques perforation rates are less common – between 2% and 25% (Berengo et al. 2004). The indirect approach has increased patient acceptance and has the advantages of reduced patient discomfort and morbidity (Emmerich et al. 2005). But in a recent study (Chan et al. 2012), direct endoscopic views of the membrane elevation achieved during the indirect approach showed that the true incidence of perforation may be currently underestimated due to difficulties in identifying a membrane perforation clinically. In the present cadaveric study, only the osteotomy step risks perforation (which was observed in 33.3% of cases) and any perforation viewed endoscopically were invariably depicted on CT images. The real-time endoscopic view is therefore not necessary to depict any perforation, as CT is sufficient for detection (signified by leak of contrast into the sinus cavity).

An attractive prospect for decreasing this mucosal perforation risk would be to design a piezo-electrical instrument to introduce into the needle lumen to safely make the osteotomy.

Dose exposures were very low in comparison with the diagnostic reference level. According to the recommendations, the mean DLP during radiological sinus lift (79.2 mGy.cm) corresponds to the equivalent of half to third of the dose of a maxillary dental CT scan acquisition (SFR/OPRI 2014). However, an interventional procedure guided by CBCT would allow further reduction of the dose exposure and increased accuracy of the technique approach.

Conclusion

The present experimental study evaluates a new minimally invasive radiological technique for maxillary sinus floor elevation in patients with edentulous posterior maxillary segments. This study proposes an interventional radiological CT-guided alternative to the more traumatic classic surgical lateral antrostomy approach, which has an equivalent success rate to those cited in the literature for the surgical approach. This new CT-guided technique opens the way to interventional procedures in the dentomaxillofacial radiology.

References

Berengo, M., Sivolella, S., Majzoub, Z. & Cordioli, G. (2004) Endoscopic evaluation of the bone-added osteotome sinus floor elevation procedure. *The International Journal of Oral and Maxillofacial Surgery* **33**: 189–194.

Chan, H.-L., Oh, T.-J., Fu, J.-H., Benavides, E., Avila-Ortiz, G. & Wang, H.-L. (2012) Sinus augmentation via transcrestal approach: a comparison between the balloon and osteotome technique in a cadaver study. *Clinical Oral Implants Research*: 1–6. doi: 10.1111/j.1600-0501.2012.02506.x.

Emmerich, D., Att, W. & Stappert, C. (2005) Sinus floor elevation using osteotomes: a systematic review and meta-analysis. *Journal of Periodontology* **76**: 1237–1251.

Hassani, A., Motamedi, M.H., Saadat, S., Moshiri, R. & Shahmirzadi, S. (2012) Novel technique to repair maxillary sinus membrane perforations during sinus lifting. *Journal of Oral and Maxillofacial Surgery: Official Journal of the American Association of Oral and Maxillofacial Surgeons* **70**: e592–e597.

Pikos, M.A. (1999) Maxillary sinus membrane repair: report of a technique for large perforations. *Implant Dentistry* **8**: 29–34.

Pjetursson, B.E., Tan, W.C., Zwahlen, M. & Lang, N.P. (2008) A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part I: Lateral approach. *Journal of Clinical Periodontology* **35**(Suppl 8): 216–240.

Schwartz-Arad, D., Herzberg, R. & Dolev, E. (2004) The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. *Journal of Periodontology* **75**: 511–516.

SFR/OPRI. (2014) Guide des Procédures Radiologiques: critére de Qualité et Optimisation des Doses Mis á jour le 26/03/2014 par Société Française de Radiologie.

Stelzle, F. & Benner, K.U. (2011) Evaluation of different methods of indirect sinus floor elevation for elevation heights of 10 mm: an experimental ex vivo study. *Clinical Implant Dentistry & Related Research* **13**: 124–133.

Summers, R.B. (1994) A new concept in maxillary implant surgery: the osteotome technique. *Compendium (Newtown, Pa)* **15**: 152, 4–6, 8 passim; quiz 62.

Tatum, O.H. (1986) Maxillary and sinus implant reconstruction. *Dental Clinics of North America* **30**: 207–229.

Troedhan, A., Kurrek, A. & Wainwright, M. (2012) Biological principles and physiology of bone regeneration under the Schneiderian membrane after sinus lift surgery: a radiological study in 14 patients treated with the transcrestal hydrodynamic ultrasonic cavitational sinus lift (intralift). *International Journal of Dentistry* **2012**: 576238.