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# Blood clot stability and bone formation following maxillary sinus membrane elevation and space maintenance by means of immediate implant placement in humans. A computed tomography study

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ABSTRACT

*Objective:* The present controlled clinical pilot study proposed to assess blood clot contraction and bone neo-formation following maxillary sinus lift (MSL) with immediate implant placement without using grafts using cone beam tomography exams.

*Materials and methods:* Ten implants were placed in ten patients with a residual bone crest height ≥4 and ≤ 7 mm, in maxillary premolars or 1st or 2nd molars regions, using MSL and immediate implant placement without grafts, by means of the lateral window approach. A resorbable membrane (Bio-Gide®, Geistlich, USA) was used to close the window. Computed tomography images were taken after 15 (T1) and 180 (T2) days to assess the rate of blood clot contraction and bone neo-formation. The images were analysed by OsirixMD software. The Shapiro Wilk test was used to verify the normality hypothesis and the data were submitted to Student's paired t-test.

*Results:* The mean of bone clot height in mesial, apical and distal area referred to implant, presented 4.77 mm, 0.77 mm and 5.30 mm respectively. The mean measurements of new bone formation presented 2.95 mm, 0.44 mm and 3.45 mm. The height contraction (coagulum/new bone formation), between T1 and T2, presented 38%, 43% and 35% respectively, with a significant statistical value $p < 0.05$.

The volume measurements at T1 presented a mean volume of 0.90 $cm^3$ sd ± 0.60 $cm^3$ and at T2 a mean volume of 0.75 $cm^3$ sd ± 0.62 $cm^3$, with a significant volume contraction between T1 and T2, $p < 0.005$. The mean blood clot contraction was 16.52% ± 8.60%.

*Conclusion:* The present study demonstrates consistent bone formation around all assessed implants, although with significant contraction of the blood clot. The need for longitudinal studies to establish a long-term prognosis in different modalities of prosthetic rehabilitation of those implants is strongly suggested.



## 1. Introduction

Maxillary sinus bone augmentation with the use of grafts has been considered a predictable technique for increasing vertical bone of the posterior region of the maxilla (Chiapasco et al., 2009). In this context, similar results are obtained with different graft materials, such as autogenous bone, xenografts, allografts, alloplastic materials and their combinations (Troeltzsch et al., 2016).

Although bone formation is achieved in sinus lift procedures using graft materials, studies have shown that elevation of the sinus membrane, with the immediate installation of implants without graft materials, has resulted in bone neo-formation (Borges et al., 2011; Nasr et al., 2016; Sohn et al., 2010) based on the principles of guided bone regeneration (Dahlin et al., 1989; Nyman, 1991; Retzepi and Donos, 2010). This technique was first described by Lundgren et al. (2004); with an unexpected bone repair in the maxillary sinus, after the removal of an intra-sinusal mucous cyst,

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when new bone formation was observed. The protocol consists of the lateral approach to the maxillary sinus, creating a secluded space by lifting the membrane and maintaining the space through immediate implant placement, clot formation and subsequent repositioning of the bone window (Lundgren et al., 2003). Radiographic evidence showed bone neo-formation in all 10 patients in the study (Lundgren et al., 2004).

Further studies in animals (Sul et al., 2008a,b) and in humans (Cricchio et al., 2011) have demonstrated the predictability of this technique. Palma et al. (2006) were the first to compare the histological findings of maxillary sinus lift, with and without the use of bone grafts, after a period of six months healing. They also investigated the role of implant surfaces on osseointegration under these circumstances. Histologically, bone neo-formation was often deposited in contact with the Schneider membrane in the control group using bone graft. This suggests the osteoinductive potential of the membrane. In addition, clinical and histological findings revealed strong bone response to implants with treated surface, with high-level bone implant contact.

Other authors have evaluated 44 implants in the remaining alveolar bone ridges, 2 mm–9 mm in height. After a period of six months, periapical radiographs and CT scans were performed to measure bone formation. The results showed consistent bone formation with average bone gain of 6.51 mm and survival rate of 97.7% during a period of 27.5 months (Thor et al., 2007).

For a greater scientific basis of less invasive protocols and lower financial costs to treat the posterior region of the maxilla, this study aimed to evaluate the contraction of blood clot and correlation to new bone formation. Cone beam tomography was used in patients who underwent the maxillary sinus lifting procedure, with immediate implant placement without the use of grafts.

## 2. Material and methods

This study was approved by the Ethics Committee: CAAE – 0344.0.213.000-11.

### 2.1. Patient selection

Patients, referred by the university dental clinic for rehabilitation with implants in the posterior region of maxilla, were evaluated. All patients underwent panoramic radiography and computed tomography for preoperative evaluation of the maxillary sinus and surgical planning.

As inclusion criteria, patients should have partial edentulism, ≥4 mm < 7 mm bone height of alveolar ridge remaining in premolars or 1st or 2nd molar maxillary region and approximately 6.5 mm width (Hagi et al., 2004; Jensen and Terheyden, 2009) for 4.1 mm diameter implant placement. In addition, the patients should not show pathological conditions of the maxillary sinus and adjacent teeth, not be smokers, and not present any systemic diseases or conditions that contraindicate surgical procedures.

Patients with history of previous Caldwell Luc sinus surgeries, presence of septa that hamper the detachment procedure of the sinus membrane and implant placement, extremely narrow sinuses and unfavourable inter-maxillary relationship were excluded.

Twelve patients of both genders, 08 females and 04 males, aged 21–65 years, were selected, and each received only one implant in the 1st or 2nd premolar, or 1st or 2nd molar maxillary area.

### 2.2. Surgical procedure

After administering local anaesthesia with lidocaine 1: 100.000 (Alphacaína® - DFL) a horizontal incision was made on the crest of the alveolar ridge and two vertical incisions beyond the gingival mucus line. A full thickness flap exposed the lateral wall of the maxillary sinus. A bone window with a final regular size of 08 mm–10 mm height and 10 mm–18 mm width, with an oval shape (Fig. 1), was obtained by osteotomy of the maxillary sinus lateral wall, using a number 8 spherical diamond drill under sterile saline constant irrigation. The bone window remained adhered to the maxillary sinus membrane and it was folded into the sinus following detachment of the membrane. The remaining bone of the lateral window served as an upper limit to the apical part of the installed implant, improving the space and coagulum at this point.

The height of the membrane elevation was enough to allow the installation of 11 mm–13 mm implants. A surgical guide, produced from the prosthetic planning, determined the ideal position of the drilling site for implant placement (Fig. 1).

The sites were prepared in order to obtain implant primary stability using a sub instrumentation technique. All the implants included in the study showed primary stability.

After placement of the implant and confirmation of complete blood filling the obtained sinus compartment, the window was covered with a collagen membrane (Bio-Gide®, Geistlich, USA) and the flap was repositioned without tension and sutured appropriately by first intention using 0.5 Nylon (Ethicon, Johnson USA) suture.

Medications were prescribed, including: 0.12% chlorhexidine gel twice daily for 15 days in the operated area, 500 mg of Amoxicillin every 8 h for 10 days, Paracetamol 750 mg every 6 h for three days and Benzalkonium Chloride (0.1 mg + 9.0 mg Sodium Chloride – Sorine®) nasal solution four drops in each nostril six times per day for 15 days. The sutures were removed 15 days after the surgery and the patients were monitored throughout the entire period.

### 2.3. CT evaluation

#### 2.3.1. Acquisition Protocol

After 15 and 180 days (T1–T2, respectively) of surgery, Cone Beam Computed Tomography (CBCT) scans were performed using cone beam tomography (KODAK 9500 Cone Beam 3D System Carestream

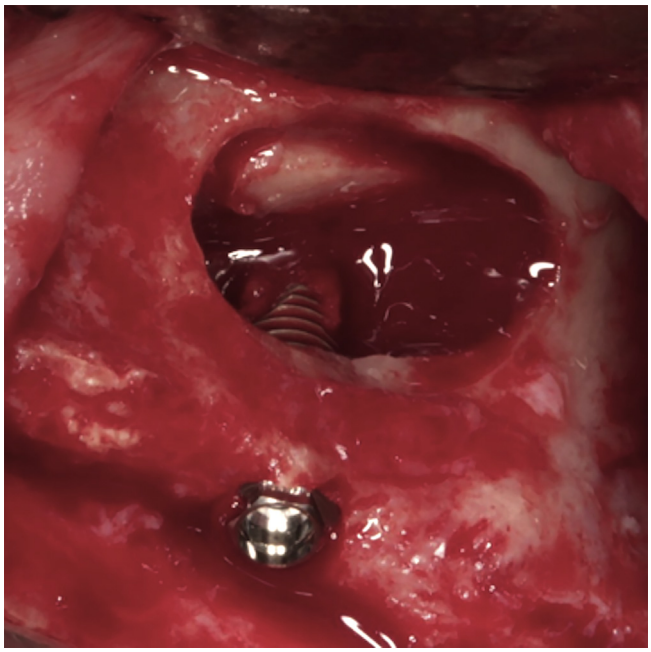

**Fig. 1.** Position of implant insertion, supporting the bone lateral window that remained attached to the membrane.

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Health, Inc. (Rochester, NY) with 0.5 mm thickness and bone filter collimation. The maxillary sinus lifted area with immediate placement of implants was evaluated in order to measure the clot contraction and the new bone formation between the two repair periods.

### 2.3.2. Images for interpretation

The height of blood clot as the new bone formed was measured using the mesial, distal linear points referred to the implant from the sinus internal cortical area pristine alveolar bone to the elevated sinus membrane and in the apical region of the implant to sinus membrane (Fig. 2).

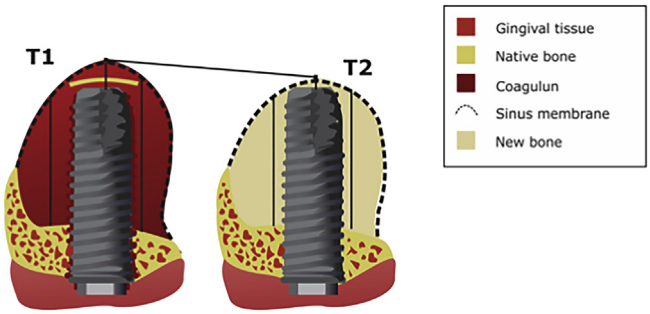


**Fig. 2. Schematic of measurements performed**. Evaluation of blood clot extent at **T1**– 15 days and new bone formation at **T2** – 180 days.

One blinded observer independently reviewed the images processed using the Osirix MD Imaging 6.5 software (PIXMEO, Genebra, Switzerland). The data in DICOM format were transferred to the navigation software that allowed the multiplanar reconstruction (MPR) of the calliper with three-dimensional isotropic voxel (volume element), which provides the same spatial resolution evaluated in any plane. In addition, the software allows the measurement of the bone crest height over the cross section, axial, coronal, and sagittal views. The Cobb angle tool was used to verify the proper layout of the plan. Thereafter, measurements were performed along the longitudinal axis of the implant. Multiplanar data processing was done with 0.6 mm thickness and 0.6 mm spacing.

The linear measurements were based on Borges et al., 2011; they were performed by oblique coronal section, corresponding to the panoramic slice, which allowed evaluation of the mesial and distal implant area. Readings were taken in three sections: the center of the implant, buccal 1.2 mm and 1.2 mm lingual, providing an average for both areas: mesial and distal. The ROI (region of interest) was fixed in the center of the implant (the axial section) and a parallel line was drawn to the vestibular cortical bone to obtain the oblique coronal section (Figs. 3 and 4).

The volume measurement of the blood clot extent as well the new bone formed were done based on Nunes et al., 2018; the authors compared a graft sinus area with only the blood clot area obtained in sinus lift surgery. A trained radiologist manually

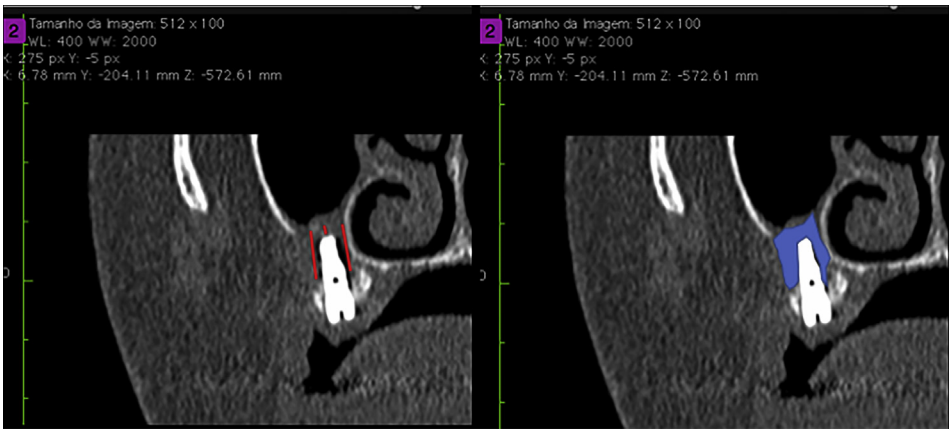


**Fig. 3. Measurement methodology**. Oblique coronal section, corresponding to the panoramic slice, which allowed evaluation of the apical, mesial and distal implant height measures and blood clot volume in T1.

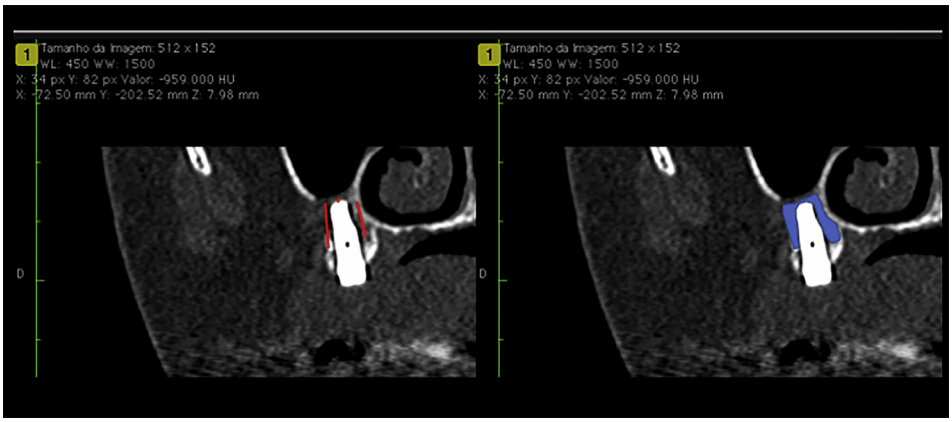


**Fig. 4. Measurement methodology**. Oblique coronal section, corresponding to the panoramic slice, which allowed evaluation of the apical, mesial and distal implant height measures and new bone formation volume in T2.

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delineated the blood clot area as well as the new bone formation area image using the manual tool at the sagittal, axial, and coronal sections of the image. The program automatically defined the areas and the final volume obtained (Figs. 3 and 4). All measurements were performed on all postoperative CBCT images. The amount of blood clot formation was measured 15 days after surgery (T1) and the new bone formation 180 days after surgery (T2).

### 2.4. Statistical analysis

The G*Power version software (G*Power®, version 3.1.9.2; Institute for Experimental Psychology, Dusseldorf, Germany) was used to evaluate the test power. As the calculated power met the desired 0.80 power limit, it was concluded that the sample size was appropriate for the paired T-test.

The Shapiro Wilk test was used to verify the normality hypothesis. After verifying that the p-values are greater than 0.05, the paired T-test was selected.

The Student's paired t-test was used to evaluate differences in the amount of bone formation between T1 and T2. The level of significance was set at 5% and the statistical tests were performed using Graph Pad Prism 5:00 software (Graph Pad Software, San Diego, USA).

## 3. Results

The procedure was well tolerated by all patients and no pathological condition was observed in the postoperative maxillary sinus. A total of 12 treated surface implants (Neodent®; Brazil) with lengths ranging from 11 mm to 13 mm were installed. During the procedure, there were two perforations of the Schneider membrane. As the perforation diameters were small, the use of collagen membrane resolved the situation and it was not necessary to abort the surgery. However, these implants were excluded from the study regarding the analysis of clot contraction.

A total of 7 implants with 11 mm and 3 implants with 13 mm, all with 4.1 mm diameter were evaluated during the follow-up period. All implants showed a new bone formation in the previous blood clot region, and a new maxillary sinus floor height was obtained after this technique was performed.

The height at T1 and T2 measures at mesial, apical and distal area referred to implant were presented in Tables 1 and 2. The mean of bone clot height and new bone formation, as the height (coagulum/new bone formation) contraction were presented in Table 3.

The 3D volume measurements were performed, and at T1 the mean coagulum volume formation mean volume was 0.9011 $cm^3$ sd ± 0.6038 $cm^3$ and at T2 the mean volume was 0.7522 $cm^3$ sd ± 0.6229 $cm^3$, with a significant volume contraction between T1 and T2, $p < 0.005$. The mean blood clot contraction was 16.52% sd ± 8.60%.

**Table 1**
T1 Coagulum height: mesial, apical and distal measurements (mm) referred to implant.

| Patients | Mesial | Apical | Distal |
|---|---|---|---|
| 1 | 7.13 | 0.55 | 5.71 |
| 2 | 6.52 | 0.39 | 5.92 |
| 3 | 1.44 | 0.29 | 3.98 |
| 4 | 3.14 | 0.52 | 3.94 |
| 5 | 2.56 | 0.53 | 3.37 |
| 6 | 5.82 | 1.21 | 4.37 |
| 7 | 3.13 | 0.76 | 4.52 |
| 8 | 8.34 | 1.51 | 9.41 |
| 9 | 4.24 | 0.69 | 5.81 |
| 10 | 4.45 | 1.32 | 6.01 |
| *Mean–Sd* | 4.77 ± 2.21 | 0.77 ± 0.42 | 5.303 ± 1.72 |

**Table 2**
T2 New bone formation height: mesial, apical and distal measurements (mm) referred to implant.

| Patients | Mesial | Apical | Distal |
|---|---|---|---|
| 1 | 4.43 | 0.25 | 1.89 |
| 2 | 4.92 | 0.25 | 4.81 |
| 3 | 0.98 | 0.25 | 0.89 |
| 4 | 1.97 | 0.35 | 1.81 |
| 5 | 1.95 | 0.25 | 2.19 |
| 6 | 3.28 | 0.56 | 8.98 |
| 7 | 1.29 | 0.42 | 1.19 |
| 8 | 5.75 | 0.92 | 5.81 |
| 9 | 2.19 | 0.33 | 2.98 |
| 10 | 2.79 | 0.85 | 3.96 |
| *Mean–Sd* | 2.95 ± 1.16 | 0.44 ± 0.42 | 3.45 ± 1.46 |

**Table 3**
Percentage and significance of contraction (Coagulum/New bone formation, height) at mesial, apical and distal measurements referred to implant.

| | Mesial | Apical | Distal |
|---|---|---|---|
| T1 | 4.77 mm | 0.77 mm | 5.30 mm |
| T2 | 2.95 mm | 0.44 mm | 3.45 mm |
| Contraction | 38% | 43% | 35% |
| *p*= | 0.00001 | 0.00041 | 0.00011 |

Test T student – 0.05 level significance.

## 4. Discussion

To the best of our knowledge, this study was the first to evaluate the blood clot contraction and the correlation to bone neoformation following the MSL with immediate implant placement without using grafts by cone beam tomography exams.

The preference for regular implants (≥10 mm), based on the clinical situation and anatomic characteristics of the sinus, is a consolidated option and is scientifically validated for single implant posterior maxilla rehabilitation (Hagi et al., 2004; Jensen and Terheyden, 2009). Currently, with the positive results achieved using the crestal approach and the use of short implants, these options could also be considered (Gastaldi et al., 2017). However, as a criterion for the selection of patients for the present study, the need for ≥4 mm of residual bone had to be considered in order to achieve primary stability for performing sinus lift with simultaneous installation of regular implants.

All patients showed that sinus floor elevation and immediate implant placement without the use of grafts resulted in new bone formation, evaluated by the tomographic analysis. The results are consistent with previous studies in animal models (Bassi et al., 2015; Palma et al., 2006; Sohn et al., 2010) and humans (Borges et al., 2011; Lundgren et al., 2004) that showed new bone formation after this procedure.

The mechanism of bone formation in this protocol is based on guided bone regeneration principles (GBR) (Nyman, 1991; Retzepi and Donos, 2010). Bone formation in MSL, without the use of grafts and with immediate implant placement, could be performed by the migration of undifferentiated mesenchymal cells of bone marrow to the adjacent alveolar bone, and possible displacement of tissue fragments during the surgical procedure into the cavity filled by the clot (Lundgren et al., 2004).

Another hypothesis for the mechanism of bone formation is the presence of the high number of maxillary sinus membrane periosteal cells, which play an important role in the process of neogenesis in presenting the osteogenic and osteoinductive

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properties demonstrated in previous studies (Palma et al., 2006; Srouji et al., 2009, 2010). However, there is no consensus regarding the participation of the Schneider membrane in the bone formation process, using this protocol. Histological studies in animal models have not shown the role of the Schneider membrane in bone formation in the early healing period (Scala et al., 2010, 2012).

Precise methods were needed to acquire images for more reliable results, in order to evaluate the proportion of blood clot contraction and the amount of bone formation. In this context, a CBCT measurement tool was use, as it is considered a highly accurate and reproducible technology, providing highly accurate and detailed images (Loubele et al., 2007).

One of the main advantages of CBCT is the accurate visualization of soft tissue and hard tissue in a single scan, which provided reliable measurements of the clot, in the T1 and T2 (Cremonini et al., 2011). The artefact caused by metal structures could be an impediment to the evaluation of CT images. Cremonini et al. (2011) evaluated the influence of artefacts on the accuracy of linear measurements between CBCT and TCMS. Images were acquired by these tomography scans: with and without metal frame. The results showed that the presence of metal artefacts did not alter the linear measurements acquired. However, their presence raised the degree of difficulty of evaluation. It is noteworthy that the present study used the implant platform as an absolute reference in the measurement methodology, which facilitated the acquisition of linear measurements, providing greater accuracy.

On 15th post-operative day, the CBCT image revealed that the cavity, formed by lifting the maxillary sinus, was filled by the blood clot in all patients. The six-month postoperative CBCT image showed bone formation in all cases. The blood clot and the implant maintain the space to allow new bone formation. The present study aligns with the literature (Kim et al., 2010; Scala et al., 2010, 2012) in demonstrating blood clot contraction after the repair period with an average contraction of 22.40% sd ± 8.60%. These data must be considered as showing a good result since the autogenous bone grafts, considered the gold standard in bone reconstruction techniques, present a mean contraction ratio of 40% after the healing period (Browaeys et al., 2007; Fellah et al., 2008). Also, these results demonstrate that the blood clot by itself is not capable of maintaining the space created after the MSL procedure, suggesting a limitation of its bone forming ability.

Studies have also shown the collapse of the membrane on the implants, suggesting that the space created after the elevation of the membrane is not maintained only by installing a single implant (Sul et al., 2008a,b) and that the air pressure inside the cavity of the maxillary sinus can cause the collapse of the sinus membrane on the implant thus interfering with new bone formation (Kim et al., 2010).

This study showed new bone formation on all sites of implant placement, with a ratio of 34.38% with a maximum value of 107%. In addition, Pearson's test showed a positive correlation between the amount of bone formation and amount of the clot formed. These data confirm the importance of the blood clot in filling the entire length of the cavity created after the MSL and immediate implant installation to attain greater bone formation.

The present study used a resorbable collagen membrane to close the lateral window, acting as a mechanical barrier to prevent the invasion of tissue and the formation of a fibrous connective tissue, following the MSL (Kim et al., 2010).

The success rate for six months of follow-up after the surgery was 100%. Studies have shown high survival rate, similar to the survival rates for conventional implant treatment (Cricchio et al., 2011; Nasr et al., 2016; Thor et al., 2007). A study evaluated 44 patients who received 80 implants during a follow-up period of five years. The implants were installed in ridges with 5 mm average height for lateral approach to the maxillary sinus window. The results showed a 100% survival rate during the follow-up period, mean bone gain of 7.44 sd ± 1.94 mm (Wallace et al., 2005).

The surgical protocol has shown great predictability when performed appropriately. It was based on achieving primary stability of the implant, on the permanence of the security of the sinus space through the appropriate higher displacement of the Schneider membrane and the stability of the clot blood formed after the displacement of the membrane (Lin et al., 2011).

This procedure has the advantages of reducing the treatment time to the same time of bone formation, lower costs, lower morbidity when compared to autogenous bone grafts, and no possible cross-contamination risks related to heterogeneous graft, and it is a very acceptable procedure for both the sinus mucosa and the maxillary sinus ostium (Kim et al., 2010; Lin et al., 2011; Sohn et al., 2008; Wallace et al., 2005).

## 5. Conclusion

The present study demonstrated consistent bone formation, despite blood clot shrinkage after sinus floor elevation and immediate implant placement without the use of grafts. In addition, it corroborates that the protocol of immediate implant installation in its strict indications emphasizes the need for longitudinal studies to establish a long-term prognosis for these implants in different types of prosthetic rehabilitation.

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## References

Bassi AP, Pioto R, Faverani LP, Canestraro D, Fontão FG: Maxillary sinus lift without grafting, and simultaneous implant placement: a prospective clinical study with a 51-month follow-up. Int J Oral Maxillofac Surg 44: 902–907, 2015

Borges FL, Dias RO, Piattelli A, Onuma T, Gouveia Cardoso LA, Salomão M, et al: Simultaneous sinus membrane elevation and dental implant placement without bone graft: a 6-month follow-up study. J Periodontol 82: 403–412, 2011

Browaeys H, Bouvry P, De Bruyn H: A literature review on biomaterials in sinus augmentation procedures. Clin Implant Dent Relat Res 9: 166–177, 2007

Chiapasco M, Casentini P, Zaniboni M: Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants 24: 237–259, 2009

Cremonini CC, Dumas M, Pannuti CM, Neto JB, Cavalcanti MG, Lima LA: Assessment of linear measurements of bone for implant sites in the presence of metallic artefacts using cone beam computed tomography and cone beam tomography. Int J Oral Maxillofac Surg 40: 845–850, 2011

Cricchio G, Sennerby L, Lundgren S: Sinus bone formation and implant survival after sinus membrane elevation and implant placement: a 1- to 6-year follow-upstudy. Clin Oral Implants Res 22: 1200–1212, 2011

Dahlin C, Sennerby L, Lekholm U, Linde A, Nyman S: Generation of new bone around titanium implants using a membrane technique: an experimental study in rabbits. Int J Oral Maxillofac Implants 4: 19–25, 1989

Fellah BH, Gauthier O, Weiss P, Chappard D, Layrolle P: Osteogenicity of biphasic calcium phosphate ceramics and bone autograft in a goat model. Biomaterials 29: 1177–1188, 2008

Gastaldi G, Felice P, Pistilli R, Barausse C, Trullenque-Eriksson A, Esposito M: Short implants as an alternative to crestal sinus lift: a 3-year multicentre randomised controlled trial. Eur J Oral Implantol 10: 391–400, 2017

Hagi D, Deporter DA, Pilliar RM, Arenovich T: A targeted review of study outcomes with short (< or = 7 mm) endosseous dental implants placed in partially edentulous patients. J Periodontol 75: 798–804, 2004

Jenssen SS, Terheyden H: Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone garfts and bone substitute materials. Int J Oral Maxillofac Implants 24: 218–236, 2009

Kim HR, Choi BH, Xuan F, Jeong SM: The use of autologous venous blood for maxillary sinus floor augmentation in conjunction with sinus membrane elevation: an experimental study. Clin Oral Implants Res 21: 346–349, 2010

Lin IC, Gonzalez AM, Chang HJ, Kao SY, Chen TW: A 5-year follow-up of 80 implants in 44 patients placed immediately after the lateral trap-door window procedure

to accomplish maxillary sinus elevation without bone grafting. Int J Oral Maxillofac Implants 26: 1079–1086, 2011
Loubele M, Guerrero ME, Jacobs R, Suetens P, van Steenberghe D: A comparison of jaw dimensional and quality assessments of bone characteristics with cone-beam CT, spiral tomography, and multi-slice spiral CT. Int J Oral Maxillofac Implants 22: 446–454, 2007
Lundgren S, Andersson S, Sennerby L: Spontaneous bone formation in the maxillary sinus after removal of a cyst: coincidence or consequence? Clin Implant Dent Relat Res 5: 78–81, 2003
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 6: 165–173, 2004
Nasr S, Slot DE, Bahaa S, Dörfer CE, Fawzy El-Sayed KM: Dental implants combined with sinus augmentation: what is the merit of bone grafting? A systematic review. J Cranio-Maxillo-Fac Surg 44: 1607–1617, 2016
Nunes FAS, Pignaton TB, Novaes Jr AB, Taba Jr M, Messora MR, Palioto DB, et al: Evaluation of a bone substitute covered with a collagen membrane for ridge preservation after tooth extraction. Clinical and tomographic randomized controlled study in humans. Clin Oral Implants Res 29: 424–433, 2018
Nyman S: Bone regeneration using the principle of guided tissue regeneration. J Clin Periodontol 18: 494–498, 1991
Palma VC, Magro-Filho O, de Oliveria 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 8: 11–24, 2006
Retzepi M, Donos N: Guided bone regeneration: biological principle and therapeutic applications. Clin Oral Implants Res 21: 567–576, 2010
Scala A, Botticelli D, Rangel Jr IG, de Oliveira JA, Okamoto R, Lang NP: Early healing after elevation of the maxillary sinus floor applying a lateral access: a histological study in monkeys. Clin Oral Implants Res 21: 1320–1326, 2010
Scala A, Botticelli D, Faeda RS, Garcia Rangel Jr I, Américo de Oliveira J, Lang NP: Lack of influence of the Schneiderian membrane in forming new boneapical to implants simultaneously installed with sinus floor elevation: an experimental study in monkeys. Clin Oral Implants Res 23: 175–181, 2012
Sohn DS, Lee JS, Ahn MR, Shin HI: New bone formation in the maxillary sinus without bone grafts. Implant Dent 17: 321–331, 2008
Sohn DS, Kim WS, An KM, Song KJ, Lee JM, Mun YS: Comparative histomorphometric analysis of maxillary sinus augmentation with and without bone grafting in rabbit. Implant Dent 19: 259–270, 2010
Srouji S, Kizhner T, Ben David D, Riminucci M, Bianco P, Livne E: The Schneiderian membrane contains osteoprogenitor cells: in vivo and *in vitro* study. Calcif Tissue Int 84: 138–145, 2009
Srouji S, Ben-David D, Lotan R, Riminucci M, Livne E, Bianco P: The innate osteogenic potential of the maxillary sinus (Schneiderian) membrane: an ectopic tissue transplant model simulating sinus lifting. Int J Oral Maxillofac Surg 39: 793–801, 2010
Sul SH, Choi BH, Li J, Jeong SM, Xuan F: Effects of sinus membrane elevation on bone formation around implants placed in the maxillary sinus cavity: an experimental study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 105: 684–687, 2008a
Sul SH, Choi BH, Li J, Jeong SM, Xuan F: Histologic changes in the maxillary sinus membrane after sinus membrane elevation and the simultaneous insertion of dental implants without the use of grafting materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 105: e1–e5, 2008b
Thor A, Sennerby L, Hirsch JM, Rasmusson L: Bone formation at the maxillary sinus floor following simultaneous elevation of the mucosal lining and implant installation without graft material: an evaluation of 20 patients treated with 44 Astra Tech implants. J Oral Maxillofac Surg 65: 64–72, 2007
Troeltzsch M, Troeltzsch M, Kauffmann P, Gruber R, Brockmeyer P, Moser N, et al: Clinical efficacy of grafting materials in alveolar ridge augmentation: a systematic review. Journal of Cranio-Maxillo-Facial Surgery 44: 1618–1629, 2016
Wallace SS, Froum SJ, Cho SC, Elian N, Monteiro D, Kim BS, et al: Sinus augmentation utilizing an organic bovine bone (Bio-Oss) with absorbable and no absorbable membranes placed over the lateral window: histomorphometric and clinical analyses. Int J Periodontics Restor Dent 25: 551–559, 2005

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