Risk Factors in Lateral Window Sinus Elevation Surgery

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Abstract: Maxillary sinus augmentation is the most predictable of the pre-prosthetic surgical procedures. There are however, known and well documented complications that can and do occur. The most common are the intraoperative complications of sinus membrane perforation and bleeding, and the postoperative complications of sinus graft infections, sinus infections, and sinusitis. The majority of these complications can be prevented, or their incidence greatly reduced, through a thorough understanding of maxillary sinus anatomy, the multifaceted etiologies of these conditions, and the steps that can be taken to avoid them. This chapter will discuss both the preoperative and intraoperative procedures that will prevent these untoward outcomes and the necessary treatment modalities that will limit their adverse effects.

Introduction

The maxillary sinus is the largest of the paranasal cavities that include the ethmoidal, frontal and sphenoidal sinuses. It is a cavity with a pyramidal shape comprising a medial wall facing the nasal cavity, a posterior wall facing the maxillary tuberosity, a mesio-vestibular wall containing the canine fossae, an upper wall, which is the orbit floor, and finally, a lower wall that is next to the alveolar process and forming the floor of the maxillary sinus itself (Figure 1) (59).

Figure 1

The maxillary sinus can be involved during implant rehabilitation if clinicians need to regenerate bone in the maxillary posterior areas where the loss of posterior teeth and the subsequent progressive maxillary sinus pneumatization has resulted in alveolar bone atrophy. The reduction of vascularity and the absence of occlusal loads result in a buccopalatal reduction in bone volume (15, 16, 31, 103). Maxillary sinus augmentation was first described by Tatum in 1976 (94) and subsequently published by Boyne & James in 1980 (13). The surgical procedure has been modified over the years and today is considered a predictable treatment for the rehabilitation of atrophic maxillae (121). The selective use of bone replacement grafts, textured implants, and barrier membranes affect the implant survival positively. Piezoelectric surgery, rather than rotary instruments, for lateral window

preparation and membrane separation, has been shown in some studies to reduce intra-operative complications (121). The reliability of the procedure depends on a detailed knowledge of the anatomy and an awareness of possible risk factors, which may affect this surgical procedure. Therefore, the objectives of this paper are:

1) to describe maxillary sinus anatomy and its surgical implications;

2) to assess pathological conditions that could be contraindications to maxillary sinus elevation

3) to describe behavioural conditions impairing maxillary sinus health

4) to diagnose and manage intra-operative and post-operative complications;

5) to draw meaningful, clinical conclusions and give recommendations to increase procedure predictability.

1) Maxillary sinus anatomy and its surgical implications

The two walls mostly involved in the sinus lift procedure (lateral approach) are the antero-lateral and the medial walls. The antero-lateral wall may consist of a thin (less than 1 mm) cortical layer containing vessels, nerves and antral septa or ridges. In some cases, the wall may be thicker, especially in brachy-type patients where cross-facial diameter has increased. In some instances, bone dehiscences may be observed and the surgeon should be very careful in this situation to avoid perforation of the Schneiderian membrane during flap elevation. Regarding the residual crestal bone, it could be assumed that the presence of a thin residual crestal bone (less than 1.5mm, meaning only cortical bone) does not allow effective graft regeneration (92). This is confirmed by a retrospective evaluation of sinus lift procedures showing that less than 4 mm of residual crestal bone is a risk factor for implant survival. The natural ostium is usually located in the medial wall antero-superiorly and in 25% of the cases an accessory ostium is present in the mucosal area called the anterior and posterior fontanelles (89). It is important not to elevate the sinus mucosa up to this point during sinus elevation procedures to prevent the obliteration of the ostium and the creation of a subsequent complication) (Figures 2, 3).

Figure 2a, b,

Figure 3

The maxillary sinus floor may have bone dehiscences around the roots of teeth adjacent to the area of the sinus elevation. In this situation, the apices could protrude into the sinus cavity covered only by the Schneiderian membrane and the surgeon should be aware of this anatomical variability. Furthermore, it should be taken into consideration that after tooth extraction the indentations of the tooth roots in the maxillary sinus floor take time to remodel and the floor to become naturally flat.

1a) The Schneiderian membrane

The inner walls of the sinus are covered by the Schneiderian membrane, a pseudo-stratified, columnar, ciliated epithelium formed by basal, columnar and calyx cells fixed to the basal membrane (Figure 4).

Figure 4 a,b,c

Pommer et al. (74) recently described the mechanical properties of the Schneiderian membrane in humans in a cadaver study. The mean thickness of the membrane was determined to be 90 ± 45 microns (range: 24-350 microns). The mean burst elongation measured 32.6 ± 12.3% (range: 16.7-74.7%) in one-dimensional testing and 24.7 ± 4.7% (range: 15.2–35.5%) in two-dimensional testing. This means that the membrane could be stretched to 132.6% of its original size in one-dimensional elongation, and to 124.7% in two-dimensional elongation. Thicker membranes demonstrated significantly higher stretching ability. A comparison between histological findings and cone-beam computed tomography (CBCT) evaluation was recently made by Insua et al. (42). 597 histological membrane measurements reported a mean Schneiderian membrane thickness of 0.30 ± 0.17 mm, while the mean CBCT membrane thickness was 0.79 ± 0.52 mm. The difference was statistically significant, the CBCT assessment was 2.6 times higher than the histological examination.

Nevertheless, various pathologies could thicken the membrane due to inflammation. When thickening of more than 4 mm is noticed in a CBCT, an ear, nose and throat consultation is recommended. A diseased, thickened membrane may have a gelatinous texture, especially in cases of hyperplastic-hypertrophic sinusitis, making the membrane weaker once the clinician has torn the periosteal layer during surgery. On the contrary, if the thickening is at the level of the periosteal layer, this will make the membrane stronger and less prone to perforation. The difference between a physiologically thickened membrane and a pathological one could be explained from a histological point of view: in the first case the periosteum is thickened while

in the second there is a sub epithelial inflammation in the middle layer (see Figure 4 for reference).

1b) Maxillary sinus septa

The presence of antral septa is recognized as a risk factor for Schneiderian membrane perforation during sinus elevation procedures (113). The septa are bony crests inside the sinus, first described by Underwood in 1910 (111). They usually originate from the sinus floor and may stretch for a variable height on the lateral wall. Septa consist of a bone cortex usually in a vestibular-palatal direction that divide the distal part of the sinus into multiple compartments known as posterior recesses. Krenmair et al. (50) classified septa into primary (which arise from the development of the maxilla) and secondary (which arise from irregular pneumatization of the maxillary sinus floor after tooth loss) and hypothesized that, as teeth are gradually lost, atrophy begins at different times in different regions.

The presence of septa and their dimension might influence the placement of dental implants during sinus augmentation procedures and could interfere with the shape of the anstrostomy. Various surgical approaches have been described to contend with this potential difficulty. The incidence of septa varies from 16 - 58% with an average of about 30% (111, 114, 49, 80). This large discrepancy in incidence is likely due to varying inclusion criteria (height) in reporting septal presence. Analysis of the literature showed, that septa may be located in the anterior, middle and posterior portions of the maxillary sinus showing great variability. When septa are present, a surgical entry utilizing two small sinus antrostomies, placed anteriorly and posteriorly with respect to the septum location, could be considered. A second possibility would be to make a large window that extends over the septum to allow direct access to it from both the anterior and posterior aspects for greater access and visibility. A symmetry of septa between contralateral sinuses was observed (80); furthermore, a complete separation of the sinuses was never observed. It is possible however, that two separate compartments may exist at the working level of a sinus augmentation procedure. In these situations, variations in surgical approach are essential to avoid laceration of the Schneiderian membrane during its elevation. A pre-surgical knowledge of the anatomy, extension, and origin of existing septa should be known to allow for proper navigation during membrane elevation. CT scan imaging is today the preferred method for pre-op detection of septa and other anatomic variations in patients undergoing sinus surgery (80).

1c) Maxillary sinus arterial supply

The vascular network of the maxillary sinus should be properly addressed in order to avoid potential complications during sinus lift surgery (Figures 5A, 5B).

Figures 5A, 5B

The blood supply to the maxillary sinus is formed by three main arteries, which are ramifications of the maxillary artery: the infraorbital artery, the posterior lateral nasal artery and the posterior superior alveolar artery. The vascularization of the antero-lateral wall of the sinus is characterized by the presence of the alveolar antral artery, an intra-osseous anastomosis between the dental branch of the posterior superior alveolar artery and the the infraorbital artery (32, 79). This intra-osseous anastomosis courses halfway up the lateral sinus wall and is present in the cortical bone of the lateral wall of the maxillary sinus in 100% of cases (87, 108, 79). However, from a radiographic point of view, it is evident only in approximately 50% of cases (24, 58).

The alveolar antral artery, whose reported diameter is up to 2.5–3mm by Elian et al. (24), Mardinger et al. (58), and Testori et al. (99), has the potential to cause bleeding complications during lateral window osteotomies. The transection of such an artery is not life threatening because its hemorrhage mostly resolves itself owing to a reactive contraction of the vessel (79). Nevertheless, the impairment in visualization of the surgical field, especially when the diameter is wide (99), could interfere with both membrane elevation and placement of the graft material. If this complication occurs, it is important to avoid electrocautery that may perforate the Schneiderian membrane, and compromise the healing and remodeling of the sinus graft. Hemostasis can be obtained spontaneously or by pressure with a moistened gauze pad. More aggressive bleeding may be treated with bone wax or, the application of hemostatic compression.

An intra-osseous anastomosis between the alveolar antral artery and the infraorbital artery was found by dissection in 100% of the anatomical cases (30/30 sinuses), while a well-defined bony canal, located in the context of the sinus anterolateral wall, was detected radiographically in 94 out of 200 sinuses examined (47% of cases) (79). The diameter of the bony canals was < 1mm in 52 sinuses (55.3% of 94 cases), 1 to 2mm in 38 sinuses (40.4%) and ≥ 2mm in four sinuses (4.3%) (79). The alveolar antral artery displayed three different courses: (1) within the buccal antral wall cortex; (2) between the Schneiderian membrane and the lateral bony wall of the sinus, in which a small concavity was often visible; and (3) under the periosteum outside the lateral wall of the sinus. Variations of this course find the

alveolar antral artery (1) completely intra-osseous at its extremities in 100% of cases; (2) partially intra-osseous in the area usually involved with sinus antrostomy (from second premolar to second molar) in 100% of cases, and (3) variable (either intra-osseous or intra-sinusal or sub-periosteal) in the maxillary tuberosity area. In the sinus antrostomy area, the alveolar antral artery was mostly located close to the Schneiderian membrane and partially encased in the lateral sinus wall in all specimens. No bony layer interposed between the alveolar antral artery and the sinus membrane could be identified by dissection (79). The literature reports that this vessel is located at an average distance of 19.0 mm (87) and 16.4 mm (24) from the alveolar crest of the posterior maxilla. The height of the residual bony ridge, the maxillary atrophy class, and the presence of teeth play a relevant role in determining the location of the vessel, but in the abovementioned papers these parameters were not considered.

Rosano et al. (79) showed that the vertical distance from the alveolar crest to the lowest point of the vessel in atrophic maxillae of Cawood & Howell class V and VI was in the first molar area, averaging 11.25 (± 2.99) mm (range between 7.2 and 17.7mm) (79). In the most atrophic cases, where the ridge height is less than 3.0 mm, the distance was significantly lower with respect to lesser atrophic cases. This would confirm that the more resorbed the bone crest, the higher the risk of violation of such a vessel during sinus augmentation procedure. These results are substantially in agreement with a study by Mardinger et al. (58), who found that this vessel was located at a mean distance of 10.9 mm from the crest in classes D, E and at a distance greater than 15 mm in classes A, B and C. Moreover, a well-distinguished bony wall between the intra-osseous maxillary anastomosis and the internal aspect of the maxillary sinus was never found by anatomic dissection in the cadaver study by Rosano et al. (79), and therefore it could be assumed that the lowest border of such a vessel could often be completely adherent to the sinus membrane (that means not radiographically visible) instead of being located inside the buccal wall cortex. This would justify the contradiction between a 100% prevalence of this artery found by dissection and an only 47% prevalence detected by CT scan in the study by Rosano et al. (79). In the present author's opinion, such a contradiction may not be due to the small diameter of alveolar antral artery but is due in fact to the entirely intra-sinusal location of the vessel that could not be seen in a CBCT because it is located outside the boney cavity of the sinus wall. The diameter of the anastomosis was ≥ 2 mm in only 3.3% of the cases by dissection and 2% of the cases by CT scan. This possibility, even if infrequent, is worth taking into serious consideration. The transection of an alveolar antral artery with a diameter over 2 mm is likely to produce

bleeding and impairment of vision. The preservation of such anastomosis may be important not only to avoid bleeding complications but also to support bone graft neo-angiogenesis (79). In this perspective, its concomitant reflection with the Schneiderian membrane during sinus augmentation procedures should be considered if clinically feasible, especially when its diameter is large.

1d) Other anatomical features

When elevating the membrane at the level of the nasal (medial) wall, care should be taken to respect the naso-lacrimal duct: sometimes only a thin layer of bone (a few tens of millimeters) may separate the naso-lacrimal duct from the sinus. (Figure 6a-c)

Figure 6a, b, c

Vertical releasing incisions should be full thickness in keratinized gingiva and split thickness in the alveolar mucosa to avoid neurological injury of the infraorbital nerve. An accessory ostium can allow an endoscope to be inserted into the sinus during maxillary sinus elevation for pre-op an ear, nose and throat evaluation since the natural ostium is not suitable for intrasinus endoscopic examination.

Table 1: Maxillary sinus anatomy and its clinical implications

SINUS ANATOMY	CLINICAL IMPLICATIONS
Membrane thickness	Correlation with perforation rate: a thin membrane results in a higher perforation rate
Angle made by the buccal and palatal alveolus at crest	angle a < 30° (perforation rate 62.5%) angle a < 30° > 60° (perforation rate 28.6%)
Vascularity	The preservation of vascularity may be important not only to avoid bleeding complications but also to support bone graft neo-angiogenesis
Septa	a. Make 2 small antrostomies, one anterior and one posterior to septum or b. Make one large antrostomy gaining

	access to both sides of septum creating good access and visibility
Naso-lacrimal duct	Do not be aggressive when elevating the membrane at the level of the nasal wall: a thin layer of bone (possibly only a few tens of millimeters) may separate the naso-lacrimal duct from the sinus (Figure 6 a-c)
Infraorbital nerve	Full thickness vertical releasing incisions in the premolar area can cause neurological disturbances to the branches of infraorbital nerve
Ostium	If present, an accessory ostium can allow an endoscope to be inserted into the sinus during sinus elevation for ENT evaluation as the natural ostium is not suitable for intrasinus endoscopic examination

2) Pre-surgical sinus assessment: diagnosing pathological conditions of the maxillary sinus

It can be stated that the clinician can lower the risk of pre-operative and post-operative complications if maxillary sinus elevation is performed starting from a healthy sinus with high compliance (104, 106). It is therefore advisable to perform an extensive anamnestic, clinical and radiographic assessment prior to sinus augmentation surgery in order to investigate the sinus health and subsequent sinus compliance and in order to avoid post-surgical complications. It is extremely important during the first consultation to collect a complete history of potential diseases affecting the maxillary sinus, such as nasal obstructions, facial trauma, sinus infections, allergic symptoms, smell and taste dysfunction, pressure related discomfort, chronic respiratory diseases, previous naso-sinusal surgery, facial deformities, scars and mouth breathing. If the anamnesis is positive or there are symptoms of sinusitis, it is advisable to ask for an ENT assessment. The same assessment should be made in case of radiologic signs of radio opacity, previous sinus treatments, impaired nasal breathing, and chronic respiratory diseases. Table 2 proposes a list of questions for a specific maxillary sinus anamnesis.

Table 2: Maxillary sinus medical history

Medical History			Notes
	NO	YES	
Do you suffer from any kind of allergy?			
Do you suffer from any chronic respiratory diseases?			
Do you breathe from both nostrils?			
Have you ever had any an ear, nose and throat disease?			
Do you use any nasal spray drugs?			
Do you, or have you ever, suffered from sinusitis?			
Have you ever had an ENT or a maxillo-facial surgery?			
Do you have problems clearing your ears? (scubadiving or descending from high altitude)			
Do you feel a bitter taste or secretion in the posterior part of the mouth?			
Clinical inspection			**Notes**
	YES	**NO**	
Right Normal Glatzel			

Left Normal Glatzel			
Radiologic evaluation			**Notes**
	YES	**NO**	
Does the CT allow a correct visualization of the osteo-meatal complex?			
Is the osteo-meatal complex patent?			
Are there any signs of radio opacity in the maxillary sinus?			

Final evaluation	
Ask for an ear, nose and throat assessment	
Patient eligible for maxillary sinus elevation	

A CBCT is considered the fundamental tool for evaluation of the anatomy and health of the maxillary sinus. The CBCT should be extended superiorly to include the osteo-meatal complex in order to assess the patency of the ostium. This is a broader field of view than is traditionally obtained for routine maxillary implant placement. Thickening of the mucosa is usually a sign of altered sinus physiology. Carmeli et al. (14) evaluated 560 maxillary sinuses through CT scans and classified different grades of mucosal thickening. A rounded mucosa is usually associated with a low risk for a future maxillary sinus elevation, while an irregular, circumferential and/or complete thickening is associated with an increased risk for sinus obstruction. Another common finding is the presence of mucous retention cysts. Although its pathogenesis is not completely clear, there is some agreement about the theory that it is developed following the obstruction of the ducts of the mucous–producing glands (28). The cyst wall is the ductal epithelium and capsule of the gland (39). Another possibility occurs when serous fluid accumulates in the submucosal layer of the sinus and a serous retention cyst is developed. The mucosa of the sinus then becomes the wall of the cyst (28).

When the lamina propria of the sinus membrane is affected by inflammation and edema, sinus polyps may occur (28). They have a solid consistency and even though it is very difficult to differentiate them from a mucous retention cyst, their treatment is the same (28). A high air-fluid level usually results in bacterial sinusitis and from a radiological point of view, is a straight line or meniscus (28). When the sinus is completely opacified and the sinus cavity is enlarged, this is diagnosed as a mucocele (28). Fortunately, this occurs very rare.ly in the maxillary sinus (88). Pignataro et al. (70) presented a series of clinical recommendations concerning ear, nose and throat contraindications to maxillary sinus elevation (Table 3).

Table 3

EAR, NOSE AND THROAT ASSESSMENTENT OF CANDIDATES FOR MAXILLARY SINUS LIFT PROCEDURE
1) Preventive-diagnostic step aimed at excluding any naso-sinusal diseases that may lead to failure of surgery
2) Preventive-therapeutic step aimed at correcting any pathological findings that represent reversible contraindications to a sinus lift
3) Diagnostic-therapeutic step (if necessary) aimed at ensuring the prompt diagnosis and appropriate treatment of any possible sinus lift-related naso-sinusal complications

Mantovani (57) divided contraindications for maxillary sinus augmentation into potentially reversible and presumably irreversible categories (Table 4).

Table 4. Contraindications for maxillary sinus augmentation

(Modified *from Mantovani M (ed.), Otorhinolaryngological implications in augmentation of the maxillary sinus. In: Testori T, Del Fabbro M, Weinstein R, Wallace S. Maxillary Sinus Surgery, Quintessence 2009) (57).*

PRESUMABLY IRREVERSIBLE ENT CONTRA-INDICATIONS	**POTENTIALLY REVERSIBLE ENT CONTRA-INDICATIONS**
ANATOMIC-STRUCTURAL ALTERATIONS: – Serious deformities and post-traumatic, post-surgical and post radiotherapy scarring on the nasal-sinus walls and/or mucosa lining.	ANATOMIC-STRUCTURAL ALTERATIONS: Stenosis of the drainage-ventilation pathways in the maxillary sinus (sustained by one or more of the following anatomic alterations): septal deviation, paradox curve

	of the middle turbinate bone, conchae bulla, hypertrophy of the agger nasi cell, presence of Haller cell), postsurgical scars or synechiae on the osteo-meatal complex, oro-antral fistula. All these alterations can be resolved by surgery: the maxillary sinus appears to be well-ventilated thanks to a partial uncinectomy
INFLAMMATORY-INFECTIVE PROCESSES – Reoccurring or chronic sinusitis, with or without polyps, which cannot undergo resolution as it is associated with congenital mucociliary clearance alterations (e.g. cystic fibrosis, Kartagener's syndrome, Young's syndrome), to intolerance of acetylsalicylic acid (triad: nasal polyps, asthma, intolerance to acetylsalicylic acid), to immunologic deficiency (e.g. AIDS, pharmacologic immuno-suppression).	INFLAMMATORY-INFECTIVE PROCESSES Acute viral or bacterial rhino-sinusitis, allergy-related rhino-sinusitis, mycotic sinusitis (non-invasive forms), acute repeating and chronic sinusitis sustained by one of the anatomic alterations listed above which obstruct the sinus drainage-ventilation ways, by endo-antral foreign bodies, or by nasal polyps. Functional endoscopic surgery is clearly indicated.
NASAL-SINUS MANIFESTATIONS OF ASPECIFIC SYSTEMIC GRANULOMATOUS DISEASES – Wegener's granulomatosis, "idiopathic midline granuloma" and sarcoidosis	TUMOUR-RELATED – Non-obstructive nasal-sinus benign tumors, both before and after the lifting operation could affect the sinus drainage-ventilation ways or when removal does not affect the mucociliary transportation system (e.g. mucosa cysts, cholesterinic granuloma, antrochoanal polyp) all are easily subject to correction by functional endoscopic surgery).
TUMOR-RELATED – Locally aggressive benign tumors (e.g. inverted papilloma, myxoma, ethmoidal-maxillary fibromatosis) in antrum;	

– Nasal-sinus malignant tumors (epithelium, neuroectodermal, bone, soft tissue, odontogenous, lymphomatosis, metastatic-originated) of the maxillary sinus and/or adjacent structures.	

A prospective clinical study evaluated this approach and confirmed its reliability (49). Thirty-four patients were evaluated. None presented presumably irreversible but 38.2% presented potentially reversible conditions and were consequently treated and no complications after sinus lift surgery were noticed (refer to Table 4).

2a) Odontogenic sinusitis maxillaris

A sinus lift procedure can be impaired by a pre-existing odontogenic sinusitis. Odontogenic sinusitis represents 10% of all cases of maxillary sinusitis (54, 60) but it is estimated that the real incidence could be between 25 and 40% (61, 2). A survey (53) by ninety-three board certified otolaryngologists and rhinologists reports that an odontogenic source is a common cause of maxillary sinusitis and reported treating an average of 2.9 patients per year with odontogenic maxillary sinusitis, who were initially misdiagnosed. Otolaryngologists also perceived that radiologists rarely consider dental pathology when scanning the maxillary sinus using computed tomography. The exact pathogenesis of odontogenic sinusitis is still not fully understood although impaired Schneiderian membrane integrity due to maxillary dental infections or trauma, odontogenic disease of maxillary bone, tooth extractions, implantology, or endodontic treatment are always present. Microbiological sampling of sinusitis of odontogenic origin reveals a different bacterial flora than that found in rhinogenic sinusitis (81). Usually odontogenic sinusitis is a polymicrobial infection and anaerobic species, from the oral cavity and upper respiratory tract are predominant. The development of sinusitis in patients with predisposing odontogenic disease is variable but a recent review suggested the possible role of the bacterial biofilm related to severity and progression of the odontogenic sinusitis (93). Bacterial biofilm, defined as dynamic polymicrobial communities of slowly-replicating and metabolically-quiescent strains embedded in a matrix rich in exopolysaccharides, proteins and nucleic acid (4), is associated with many endodontic lesions linked to odontogenic sinusitis (Table 5) (91).

Table 5 (43): Bacterial species linked to odontogenic sinusitis

Bacterial species	
Actinomyces spp.	*Clostridium sordellii*
Actinomyces israelii	*Clostridium bifermentans*
Actinomyces viscosus	*Staphylococcus chromogenes*
Actinomyces meyeri	*Staphylococcus epidermidis*
Actinomyces naeslundii	*Streptococcus* spp.
Propionibacterium acnes	
Propionibacterium propionicum	
Peptostreptococcus prevotii	
Gemella morbillorum	

Although no specific studies of odontogenic sinusitis have yet been carried out, the findings of animal studies and clinical trials involving patients with chronic rhino-sinusitis suggest a link between a polymicrobial bacterial biofilm (mainly composed by *Staphylococcus aureus*, *Pseudomonas aeruginosa*, coagulase-negative staphylococci, *Streptococcus pneumoniae*, *Moraxella catarrhalis*, *Haemophilus influenzae* and fungal species) and recurrent or recalcitrant paranasal sinus infections (68, 69, 77, 82, 40). Pathogens mainly involved in Bacterial Biofilm-related chronic rhino-sinusitis are *S. aureus, H. influenzae, P. aeruginosa* and *S. pneumonia* (27, 37) as well as anaerobic species. Particular interest has recently been aroused by the discovery of specific *S. aureus*-producing toxins, which are known to lead to chronic inflammation in patients with chronic rhino-sinusitis and nasal polyps. In the presence of persistent staphylococcal infection sustained by biofilm, toxin production might also occur in the absence of planktonic species, thus leading to chronic immune system activation and persistent inflammation (19). These findings are extremely important especially when choosing the correct antibiotic therapy for treating the sinusitis.

A retrospective evaluation (110) reviewed patients treated surgically for unilateral symptomatic maxillary sinusitis over 7 years. They included 174 patients: the 75% of them

were triggered by odontogenic pathology. Dento-alveolar surgical interventions (64%) were the most common cause. These results suggest that when there is a unilateral maxillary sinusitis an odontogenic cause is very likely. Although understanding the microbiology of the lesion will give a great opportunity to treat the sinusitis in the best possible way, it is always advisable to refer the patients in these cases to ear, nose and throat specialists should resolution not be quickly achieved.

3) Behavioural conditions impairing maxillary sinus health status

Sinus lift procedures could be affected by a number of behavioural and environmental conditions affecting the normal physiology of the maxillary sinus. The use of cocaine, a drug usually inhaled through the nose, has a dramatic effect on the oral mucosa (Figure 7) (11).

Figure 7

In a systematic review addressing hard palate perforation in cocaine abusers, sinusitis is confirmed as one of the most common side effects (85). From a clinical point of view, in the authors' experience, the Schneiderian membrane in these patients appears extremely thin and fragile, requiring a great attention when detaching. Smoking is a well-known risk factor for implant survival (38). A retrospective evaluation on the survival rate of implants placed in grafted sinuses found that smoking more than 15 cigarettes per day was significantly correlated to implant failure (101).

Prevention and Treatment of Surgical Complications

Intraoperative complications

Any list of potential intraoperative complications will be quite extensive given the broad scope of this surgical procedure. It is therefore important to understand that the relative frequency of the majority of these complications is quite low. Most intraoperative complications are primarily the result of surgical difficulties encountered during the course of the augmentation procedure. These may be the result of the presence of complex anatomic situations (thin membranes, incomplete, thick, or convex lateral walls, septa, presence of cysts), the choice of less predictable treatment options, inadequate preoperative systemic and/or local anatomic diagnosis, or operator error.

The most common intraoperative complication is Schneiderian membrane perforation. Other less common complications include intraoperative bleeding, perforation of the buccal flap and much less frequently, injury to the infraorbital nerve, damage to the adjacent dentition, perforation of medial or the orbital wall, implant displacement into the maxillary or paranasal sinuses, and obstruction of the ostium.

Intraoperative bleeding

Etiology and incidence

Intraoperative bleeding results from severing or damaging branches of the vascular supply to the lateral wall of the sinus and the surrounding soft tissues. This bleeding is usually minor and of relatively short duration, but in some instances, it can be profuse and difficult to control. Solar et al. (87) described the blood supply to the lateral wall of the maxillary sinus in cadaver specimens. It consists of the intraosseous and extraosseous branches of the posterior superior alveolar artery, which form a double arterial arcade by anastomosing with the infraorbital artery. Bleeding may occur either from the soft tissue (extraosseous branch) during flap elevation or directly from the lateral bony wall (intraosseous branch) during preparation of the lateral window via rotary instrumentation. There is also the possibility of bleeding from the medial wall of the sinus if the posterior lateral nasal artery is damaged (26). The posterior superior alveolar, infraorbital, and posterior lateral nasal artery are all branches of the maxillary artery that provide a source for vascularization for the sinus graft.

Prevention

Although bleeding does not occur on every occasion that this artery is damaged, it seems prudent to use three-dimensional (3D) planning as a means of avoiding, if possible, an encounter with the artery (Fig. 8). In some cases, the artery can be visualized within the lateral wall after elevation of the flap (Fig. 9). In many instances a window can be made coronal to the location of the artery and the superior portion of the membrane elevation can be performed internally to the required height. Again, it should be realized that the artery is not always located within the lateral wall. The artery can be located just internal to the lateral wall and may pass in and out of the bony wall throughout its antero-posterior course in the lateral sinus wall. When located outside the lateral wall, it is susceptible to damage from both rotary and hand instruments. The external branch of the PSA artery may also be damaged when making vertical releasing incisions for flap elevation.

Figure 8

Figure 9

Once it is anticipated that the possibility of a bleeding complication exists, it is prudent to locate the position of the artery on the cross-sectional CT images and then use antrostomy instruments that can respect the integrity of vascular and other soft tissues while still creating the window in the ideal location for access to and elevation of the sinus membrane. If rotary instruments are used, diamond burs are preferable to carbide burs as they are less likely to catch and tear the membrane. Piezosurgery®, a concept of ultrasonic bone surgery developed by Vercellotti and specifically adapted for sinus elevation surgery (115), provides a means of avoiding this complication almost entirely. Piezoelectric surgery uses low-frequency ultrasonic vibrations (range of 24–32 kHz for the various commercial systems) to perform cutting (osteotomy) and grinding (osteoplasty) procedures on bone. This low-frequency selective cutting action provides safety for soft tissues, as it is incapable, if used correctly, of cutting blood vessels or the Schneiderian membrane. Piezoelectric surgery has been used successfully to avoid soft-tissue complications (both vascular and neural) in numerous oral surgical procedures, such as Le Fort osteotomies (10) and mandibular sagittal split osteotomies (33). The Piezosurgery® technique has seen widespread use in Europe for over 17 years and today at least six piezoelectric surgery devices are available in the US market. Since introduction of this technique to the USA in 2005, numerous clinicians have realized its advantages in sinus elevation surgery. Piezoelectric surgery has minimized bleeding episodes

during preparation of the lateral window. The selective cutting action (bone cutting only) allows the operator to dissect the posterior superior alveolar artery from the bony window area, leaving it completely intact. Piezoelectric surgery has minimized bleeding episodes during preparation of the lateral window for most operators, including the authors. A recent systematic review showing comparable results regarding membrane perforations for both rotary and piezoelectric techniques is based on only 4 studies (1 favouring each technique and 2 with comparable results) with operator experience being a greater factor in the results than the actual surgical technique (5).

Treatment

Many techniques exist to control vascular bleeding in sinus elevation surgery. These include:

- Direct pressure on the bleeding point
- Use of a localized vasoconstrictor
- Bone wax
- Crushing the bone channel around the vessel (hemostat)
- Use of electrocautery (with care near membranes)
- Suturing of the vessel proximal to the bleeding point.

The use of a vasoconstrictor (1:50,000 epinephrine) is more effective in controlling soft tissue bleeding that may occur when making releasing incisions before elevation of the mucoperiosteal flap, while electrocautery is more effective in controlling a bone bleed from the cut lateral wall. It should be kept in mind that electrocautery, when used to control vascular bleeding from bone in the vicinity of the Schneiderian membrane may result in membrane damage and therefore should be used with caution. Crushing the bleeding end of an intrabony vascular channel to compress the bone and vessel may be effective but care again must be taken to avoid membrane perforation by direct pressure.

This can be accomplished by careful release of the Schneiderian membrane immediately internal to the vessel (making the window slightly larger, while diverting the blood flow with a suction tip to provide better vision) and then clamping the vessel with a hemostat.

Bleeding encountered during sinus elevation will usually be gently flowing in nature. In some instances, however, this bleeding may be pulsating. In general, the appearance is worse than the severity of the condition. Bleeding, even of the pulsating variety, may stop spontaneously or after several minutes of direct pressure as a result of clot formation within the bone

channel surrounding the artery. One technique that may be used is to have the surgical assistant place a high-volume, narrow-tipped evacuator close to the bleeding point to eliminate blood flow into the surgical field. Window preparation, membrane elevation, and grafting can be completed while diverting bleeding in this manner. The bleeding usually stops by the time the grafting is completed and, after closure postoperative bleeding is usually not encountered. Note that suction is utilized only to create adequate vision. It is detrimental to halting the bleeding.

Best clinical practice includes:

- Obtain preoperative CT images to locate the vessel.
- Visualize the vessel clinically.
- Avoid the vessel, if appropriate, when designing the window.
- Use piezoelectric surgery to avoid trauma to the vessel.
- Have materials on hand to control bleeding (electrocautery, local with 1:50,000 epinephrine, bone wax, resorbable suture material).

Schneiderian membrane perforation

Etiology and incidence

Perforation of the Schneiderian membrane is the most common intraoperative complication in sinus elevation surgery (5, 124). The reported incidence in the literature varies from lows of 11% (83) to a high of 56% (45) when rotary window preparation is used. Most experienced clinicians estimate their perforation rate to be approximately 25% when using conventional rotary instruments. In retrospective CT-scan studies performed at the New York University Department of Periodontology and Implant Dentistry (Poster Presentation, AO Annual Meeting, 2002) the perforation rate was shown, a close relationship to membrane thickness and to a lesser degree to the presence of septa. The perforation rate was 41% when the membrane thickness was less than 1.5 mm and 16.6% when thickness was greater than or equal to 1.5 mm. The perforation rate in a separate study of 136 sinus elevations was 44.2% when a septum was present and 35.7% when septa were absent. In a retrospective CT study by Cho et al. (18), the perforation rate was shown to be related to sinus width or, to be more specific, the angle made by the medial and lateral walls at the floor of the sinus. The perforation rates were 62.5% for the narrow anterior part of the sinus (angle < 30°), 28.6% for the wider middle part of the sinus (angle 30–60°), and 0% for the widest posterior portion (angle > 60°) (Figure 10). A recent CT study by Chan et al. (17) identified another “angle”, which defines the various configurations of the palatonasal recess and must be taken into

consideration when elevating the Schneiderian membrane from the medial wall (Figure 11). It is the angle made where the alveolus meets the medial wall of the sinus. If this angle is acute, and is located within approximately 10 mm from the sinus floor (an area where graft material is likely to be placed), care must be taken in keeping the elevator on the bone surface while not trapping and thus tearing the membrane.

Figure 10

Figure 11

There are numerous manoeuvres that must be performed during sinus elevation surgery that may place the Schneiderian membrane at risk. These include:

- Flap elevation (placing an elevator through a thin crest or lateral wall or through a previous oroantral fistula that has healed with soft tissue only)
- Preparation of the lateral window (specifically with rotary instruments)
- Elevation of the Schneiderian membrane with hand instruments (narrow sinus, acute angles, thin membrane, and in close proximity to septa)
- Placement of graft material (excessive pressure against membrane)

Prevention

A thorough knowledge of the 3D anatomy of the sinus is essential if the perforation rate is to be kept to a minimum. A CT analysis will give information relating to the thickness of the crest and lateral walls, presence of discontinuities in the bony walls, width of the sinus, slope of the anterior sinus wall, membrane thickness and the presence, size and location of septa. Clinicians will also gain information relative to sinus health and patency of the osteo-meatal complex. This evaluation may indicate the need for pre-surgical treatment that can avoid complications, such as postoperative sinusitis and infection. Figure 12(a, b) shows a defect in the lateral sinus wall created during a failed sinus elevation. Likewise, lateral wall defects may be created during extraction of teeth. It is possible that an aggressive flap elevation may cause a tear in the membrane at this location. If a discontinuity is known to exist, a split-thickness flap dissection over the site will avoid a laceration of the sinus membrane. Having 3D knowledge of the existence, location and anatomy of a septum will help determine the best location for the antrostomy in order to facilitate an uneventful membrane elevation.

Figure 12 a. b.

A septum may initially be seen as a ridge crossing the sinus floor but it will generally continue as a spine, reaching its highest extent on the medial wall (Figs. 13 a-c) (114).
Septa can be quite large (Fig. 14) but, with proper access, they can be circumvented. In rare cases the septum can be high enough to divide the sinus, at least at the working level, into two separate compartments (Figure 15).

Figure 13 a. b. c.

Figure 14

Figure 15

Once inside the sinus, good access and good vision will greatly facilitate membrane elevation. The location of the lateral window and its size will affect the clinician's ability to elevate the membrane safely. Having the window in a location that gives the best access to areas where instrument angulation, and hence membrane elevation, is difficult will have a profound effect on the operator's ability to keep his or her hand instruments directly on the bone surface. Changes in instrument angulation are required to go across the floor and up the anterior and medial sinus walls. The anterior portion of the sinus can be very narrow, requiring coordination and visibility to prevent inadvertent membrane perforation. Many experienced clinicians feel that the ideal location for the window is 3 mm superior to the sinus floor and 3 mm distal to the sloping anterior wall, which allows a controlled membrane elevation to be accomplished while keeping the elevating instruments on the bone surface at all times. Of the 11 perforations encountered by Zijderveld et al. (124), five were in relation to septa and four were made when releasing the membrane anteriorly with poor visibility. The superior extent of a sloping anterior wall may require the window to be far from a traditional oval or rectangular window. The shape of the window in this type of case should be trapezoidal with the superior osteotomy cut being longer and more anterior than the inferior osteotomy, always keeping the window within 3 mm of the anterior wall. The anterior sinus wall should be considered an extension of the sinus floor and the most predictable way to reach it during membrane reflection is by following the floor in an anterior and superior direction.

When septa are known to be present, it is advisable to lengthen the window in the antero-posterior direction so that the window is located both anterior and posterior to the septum. This allows for a lateral to medial elevation of the membrane from both sides of the septum. It must be realized that it is extremely difficult to elevate a membrane from a sharp septum in a mesial to distal direction while keeping the elevator on the bony surface at all times. While

making two separate windows has been proposed for this task, some explanation is required. It is likely that the two separate windows will be so decreased in size that access and vision will be made even more difficult. In practice, creating one large window with improved access to both sides of the septum may be a more practical solution. A useful technique is to perform a complete osteotomy, which entails removal of the lateral window by osteoplasty or careful lifting and removal of the bony window. This will readily reveal the location of a septum and allow for its removal and subsequent membrane elevation from both sides. While enlarging, the window will improve both access and visualization it must be mentioned that a recent study by Avila-Ortiz (6) has shown a significant inverse correlation between window size and vital bone formation. While this may be true, there is no evidence that the reported difference has clinical significance in regard to the outcome of implant survival.

An evolution in surgical protocols has resulted in two techniques for window preparation that most authors and clinicians have found to result in substantially decreased membrane perforation rates. These techniques involve the utilization of piezoelectric surgical inserts or DASK® drills.

Piezoelectric inserts have proven to be safe near soft tissue due to their engineered low frequency ultrasonic vibration. In a series of 100 consecutive sinus elevations using piezoelectric surgery, Wallace et al. (120) reported a membrane perforation rate of 7%. In these series, all perforations occurred when completing the elevation via hand instruments, with no perforations occurring when using the piezoelectric inserts. Blus et al. (12) reported two perforations in 53 sinus elevations for a 3.8% perforation rate using two different piezoelectric devices. In a report of 56 consecutive sinus elevations, Toscano et al. (107) reported a 3.6% perforation rate using piezoelective surgery. Conflicting data were reported by Barone et al. (7), who reported on 13 bilateral cases using Piezosurgery® on one side and a rotary diamond window preparation on the other as a within-patient control. The perforation rate was 30% with Piezosurgery® compared to 23% with the diamond bur control. Barone's results are contrary to the other publications and the positive clinical experience with piezoelectric sinus elevation surgery at both the New York University Department of Periodontology and Implant Dentistry and the Columbia University Division of Periodontics for the past 10 years.

Piezoelectric surgical techniques may differ depending upon the thickness and shape of the lateral sinus wall. If the window is thin, a diamond insert can be used to make a superior

hinge or a free-floating bone island attached to the membrane (Fig. 16a, b). This is then elevated horizontally. If the lateral wall is thick or it becomes convex in the malar eminence area, the entire lateral wall in the window area can be eliminated via osteoplasty (Fig. 17a-c). You will be looking directly at the Schneiderian membrane, which can now be elevated with a combination of piezoelectric and manual elevators. Working directly against the membrane may seem to place the membrane at risk for perforation, but the membrane may be even more susceptible to damage from the sharp edges of an elevated bony window. While a histological comparison of vital bone formation with these two techniques is lacking at this time, clinical evidence from the author's 14-year experience with this technique does not show a difference in outcome as measured by implant survival rate.

Figure 16a-b

Figure 17a-c

The DASK® (Dentium Advanced Sinus Kit) technique utilizes a 6 or 8 mm diameter dome-shaped diamond drill to make the lateral window. The drill runs on a conventional implant motor at a speed of 800 – 1,200 rpm with internal irrigation. The window can be made to have a round shape by utilizing an up and down movement, or it can be made to any size or shape desired by moving the drill in a lateral direction. This technique results in a complete osteotomy (total removal of window) in a safe manner as the large drill diameter and slow speed do not seem to cause the "drag" which is detrimental to membrane integrity. The drill appears to selectively cut bone leaving the exposed membrane intact. Membrane elevation then begins with either a motor-operated or hand operated instrument that is similar in shape to the familiar "trumpet-shaped" piezoelectric elevator (Figure 18a-d). This technique, described as a lateral bone-planing antrostomy, has been shown in a preliminary study by Lozada et al. (55) to result in a perforation rate of 5.6%. An additional study by Nishimoto et al. (64) presented 50 consecutive cases with a perforation rate 4%.

Figure 18a-d

Treatment

An intact sinus membrane is essential for graft containment when using a particulate autogenous or particulate bone replacement graft as a sinus grafting material. This is not necessarily the case when using block grafts (109, 46). Elevation of the Schneiderian membrane helps to form a compartment in which the particulate graft material can be placed and confined. The elevated membrane forms the distal and superior walls of this

compartment, while the bony sinus walls form the inferior (crest), anterior, medial and lateral walls. Proussaefs et al. (76) showed that failure to contain the particulate graft due to membrane perforation will result in decreased bone formation (14.2% vs. 33.6%) and a decreased implant survival rate (70% vs. 100%).

Should the sinus membrane be torn or perforated, the fragility of the remaining membrane is increased and care and attention are required to complete the elevation. This is best accomplished by elevating the membrane around the perforation, thereby releasing tension on the perforated area of the membrane, as opposed to working directly in the weakened area of the perforation. It is still necessary to complete the sinus membrane elevation from the floor, medial, and anterior bony walls to allow the blood supply from the bony walls to vascularize the graft. Some clinicians prefer to make a small repair to stabilize the damaged area before completing the elevation. If this is done, the repair should be evaluated for stability before placing the graft material.

The most common means of repairing a perforated Schneiderian membrane is to use a bioabsorbable collagen barrier membrane as a patch. Other techniques involve the use of lamellar bone sheets, sutures to close the perforation, or the use of growth factor-enriched biologic barrier membranes, such as L-PRF (if blood is drawn at the time of surgery).

Many techniques have been reported for repair of perforated or torn Schneiderian membranes (30, 72, 75, 84, 100, 116). These techniques are specifically chosen based on both the size and location of the perforation and the perceived need to stabilize the repair to keep it securely in place. Without stabilization, it is possible for the repair to shift in position or even be drawn up through the perforation into the body of the sinus during or after graft material placement. The choice of a specific repair material will be based on the above factors as well as the physical characteristics of the material. Zijderveld et al. (124) and Shlomi et al. (84) preferred to use lamellar bone sheets for repairs owing to the material's rigidity. The following discussion is based on the paper by Testori et al. (100), which presents four specialized repair techniques for larger perforations using bioabsorbable collagen barrier membranes.

The following generalizations should be helpful when attempting repairs:

- Very small perforations may self-repair by membrane fold-over or clot formation,
- Large perforations will require large repairs for stability,
- Large repairs tend to tent superiorly when grafts are placed,

- Repair membranes placed near the lateral wall tend to shift medially when graft is placed,
- Repair membranes that are soft and shapeless when wet are not ideal for large repairs.

It is not uncommon to perforate the Schneiderian membrane with high-speed rotary instruments (diamond burs) when performing a lateral window osteotomy. With careful membrane elevation, it is possible that these perforations remain small. When the membrane elevation is completed, the small perforation will either, disappear in the folds of the elevated membrane or, more likely, self-repair with a small blood clot. In this type of case a separate repair procedure is not indicated as the goal of graft material containment has been biologically achieved. If a very small perforation is still evident, it can be repaired with a biological L-PRF fibrin repair (Intralock International Inc, Boca Raton, FL, USA), or it can be covered with a soft repair membrane such as CollaTape® (Sulzer Dental, Plainsboro, NJ, USA) or GelFilm® (Upjohn Company, Kalamazoo, MI, USA).

If the perforation is larger (greater than 5 mm), one should use a bioabsorbable membrane that retains its shape (BioGide®; Geistlich Pharma NA, Inc. Princeton, NJ, USA) or remains stiff when wet, such as BioMend® (Zimmer Dental, Carlsbad, CA, USA); OsseoGuard® (BioMet 3i, Palm Beach Gardens, FL, USA), or Dentium® Collagen Membrane (Dentium USA, Cypress, CA) or similar absorbable membranes. The amount of stability that can be achieved with the repair is directly proportional to the amount of coverage over the intact portion of the sinus membrane. There is no reason to avoid making a new roof for the graft material compartment with the repair membrane since it has been shown in animal studies that the elevated Schneiderian membrane plays a minimal role in vascularization and bone formation in the graft (41, 35). Figure 19a-b shows an example utilizing a collagen repair membrane that forms a new roof in the damaged graft material compartment. Note that the Schneiderian membrane has been elevated to the horizontal position, demonstrating Schneiderian membrane release from the medial wall.

Figure 19a-b

As perforations become still larger (rents or tears greater than 10 mm), non-stabilized repairs become unpredictable, as they tend to shift medially while packing the graft material and may even rise upwards, through the tear, with partial or complete loss of the graft material into the sinus cavity. This untoward event may lead to blockage of the ostium, postoperative

sinusitis, or a sinus infection. A major loss of graft material containment may necessitate a re-entry for removal of all particulate graft material.

Repair techniques have been developed to address both larger tears and tears in difficult locations. If, after final membrane elevation, the perforation resides close to the lateral, superior aspect of the window preparation, it is quite common for the repair membrane to shift medially while the particulate graft material is being placed. This is due to the convex shape of the lateral wall in the malar eminence (first molar) area, the upward tenting of the membrane when packing, and the likelihood that the repair membrane is not sufficiently wide to reach the medial wall. To counteract this shifting tendency, use a large membrane (usually an adjusted 20 × 30 mm size) and leave a portion of it outside the window folded in a superior direction and have it rest on the medial wall (Fig. 20a, b). This is a simple repair modification that will prevent any medial and/or superior shifting of the membrane with concomitant loss of graft material into the sinus proper.

Figure 20a-b

In some instances, further stabilization can be achieved by a combination of the above-described folding technique with external tacking and/or internal suturing. Again, the membrane elevation must be completed to expose the bony walls and their vascular supply before completion of the repair. It must also be realized that the torn Schneiderian membrane is very fragile and all suturing must be accomplished with small needles with minimal tension on the remaining membrane. Most often, it is not possible to suture the tear completely closed. When this is the case, it is possible to use the sutures as struts upon which to rest the repair membrane. The sutures can course between two sections of torn membrane or between the membrane and small holes drilled in the lateral wall (Figs. 21a, b). Evidence of radiographic success of the repair procedure after 9 months is shown in Figs. 21c, d.

Figure 21a-d

In extreme situations, there may be insufficient membrane fragments remaining to retain a suture. At this point a decision has to be made as to whether to abort the procedure or perform a more extensive repair. In the following case (Figs 22a-d) the Loma Linda pouch technique (75) was used, along with additional stabilization tacks (100) to create a complete container for placement of the graft material. A large 30 × 40 mm BioGide® membrane (Geistlich, Wolhusen, Switzerland) was pushed through the window to create an internal sinus pouch to hold and confine the graft material. The edges of the membrane were left

outside the window to hold it in position. Two tacks were also required to keep the entire membrane from slipping into the sinus and through the perforation.

Figure 22a-d

The choice of a particular repair membrane will often be made by operator preference. General guidelines as to the type and location of the defect will be helpful in making this choice. In most cases, a membrane that retains its stiffness and shape when wet is advisable. This membrane will stabilize by contact with the remaining, intact Schneiderian membrane. With a Loma Linda type of repair, there is minimal or no remaining Schneiderian membrane. In this case a soft, mouldable membrane is desired to reach an intimate contact with the available bony walls and create the "pouch-like space for the particulate graft material.

There is a relatively large literature base pertaining to implant survival following perforation and repair of the sinus membrane. Papers by Proussaefs et al. (76), Jensen et al. (43) (report of the sinus consensus conference of 1996) and Khoury (48) state that implant survival is negatively affected by membrane perforations. Hernández-Alfaro et al. (39) report that the implant survival rate is inversely proportional to the size of the membrane perforation. Other authors present data showing that survival rates are not affected by perforations (3, 44, 83, 84, 100). The latter has been the experience at the New York University Department of Periodontology and Implant Dentistry when proper repairs are made and they remain intact throughout the postsurgical healing period and do not affect the implant survival rate. A study by Froum et al. (29) reported the average percentage of vital bone was 26.3% ± 6.3% in the perforated (repaired) sinuses versus 19.1% ± 6.3% in the non-perforated sinuses. While this difference was significant, there was not a significant difference in implant survival rates.

The presence of a bioabsorbable repair membrane against the elevated Schneiderian membrane does not impede the blood supply to the graft as the reflected Schneiderian membrane does little to provide a blood supply. The Loma Linda pouch technique, however, presents a theoretical problem in that the repair membrane completely surrounds the graft and is likely at least to delay the vascularization of the graft from the lateral sinus walls. The vital bone formation in the two large repairs presented above was 30% and 32% by volume, respectively, which is considered a favourable result when using 100% xenograft. Testori et al. (100) presented results from 20 cases with large perforation repairs. All patients had minimal postoperative symptoms and all cases showed clinical, histological, and radiographic evidence of successful sinus elevation with 100% implant survival.

If repair procedures do not appear to give a stable result, it may be necessary to abort the grafting procedure and allow the sinus membrane to heal. A reasonable waiting time, confirmed by ear, nose and throat physicians, should be in the vicinity of 4 months; 2 months for smaller perforations. Should this be the treatment of choice, the placement of a bio absorbable barrier membrane over the window may prevent soft-tissue encleftation into the sinus cavity. It will most likely be necessary to perform a split thickness re-entry flap over the window owing to the likelihood that the periosteum may be joined to the newly formed Schneiderian membrane in the window area. The residual small amount of soft tissue is then elevated along with the Schneiderian membrane to create the roof of the graft material compartment. This can be covered with a bioabsorbable collagen barrier membrane to isolate this small amount of connective tissue from the graft (Figure 23).

Figure 23

Another repair technique involves the utilization of autogenous leukocyte-platelet rich fibrin membranes fabricated with the IntraSpin® System and protocol (L-PRF/IntraSpin, Intra-Lock, Boca Raton, FL). The patient's blood is drawn, spun in a calibrated centrifuge, and a fibrin clot is then obtained by compression. The compressed fibrin clot is resilient and pliable and can be cut or pieced together to make a biologically active repair membrane that is rich in platelets, leukocytes, growth factors, and cytokines. (22, 23, 86) The prepared membranes have a strong adhesiveness allowing them to join together to facilitate the repair of large perforations. The fibrin membranes have sufficient strength that makes it convenient to join them together via suturing (Figures 24 a-d).

Figure 24 a, b, c, d

Mucous retention cysts

Mucous retention cysts are a fairly common occurrence in the maxillary sinus. In a tomographic study by Maestre-Ferrin et al. (56), radiographic abnormalities were observed in 38% of observed cases with 10% being mucous retention cysts. These cysts are not, by their presence alone, a complication or contraindication for maxillary sinus elevation. They may become problematic when they are elevated during sinus grafting and, as a result, block sinus drainage through the ostium. The likelihood of this outcome can be detected by performing a preoperative CT analysis. The presence of cysts is readily detected and they can be diagnosed as not being a potential problem (small volume), a complication that can be handled at the time of surgery by drainage with a large gauge needle, or a problem that must be treated via

functional endoscopic sinus surgery prior to sinus elevation surgery. These lesions are unlikely to respond to antibiotic or anti-inflammatory medications and it is therefore prudent to refer the patient to an ENT specialist to diagnose and/or treat these conditions prior to sinus augmentation surgery. A healthy sinus with a thin membrane and patent ostium is shown in Fig. 25. Figures 26a,b radiographically demonstrate a mucous retention cyst and polyps. Mucous retention cysts and polyps can be differentiated from each other by form and location. Cysts are typically dome-shaped and arise from the sinus floor. Polyps typically have a pedunculated base and arise from the sinus walls. A yellow fluid aspirant is pathognomonic for a sinus cyst.

Figure 25

Figure 26a, b

A generalization can be made that a cyst, which occupies 2/3 of the total sinus volume is likely to block drainage through the ostium if elevated. If it is determined that elevation of the cyst will lead to a complication (postoperative sinusitis due to blockage of sinus drainage), there are two distinct treatment options. The first is functional endoscopic sinus surgery prior to sinus elevation to remove/marsupialize the cyst. A second option is to aspirate the contents of the cyst at the time of sinus elevation surgery. A lateral window is created by a complete osteotomy technique involving total removal of the window. Access is now present for the insertion of a 22-gauge needle through the sinus membrane and into the cyst to remove the contents via aspiration (Figure 27 a-d).

Figure 27a, b, c, d

A question remains as to whether intra-operative aspiration, which leaves the cyst lining in place, can be as effective as endoscopic marsupialization, which removes a majority or all of the cyst lining. A study by Hadar et al. (36) that followed up on endoscopic cyst removal showed reformation of the cyst in 3% of the cases. A study by Testori et al. (98) followed cases treated by intra-operative cyst aspiration for 1-3 years during maxillary sinus elevation. Only cysts bigger than 1 cm along the long axis and located in the area to be elevated, where included in the study. Fifteen patients were included and the mean follow-up was 8 years, no intra- or postoperative complications occurred. Postoperative disappearance of antral cysts was radiologically documented in 12 patients whose Schneiderian mucosal thickness ranged between one and two millimeters by CT scan analysis after a six-month healing period (Fig 28a,b). In the remaining three patients, a six-month post-operative CT scan showed the

presence of residual antral cysts with a reduced size that did not affect implant survival rates. There was no occurrence of sinusitis after deflation and no new complications occurred intra- and post-operatively. Thirty-one implants (5 in a one-stage and 26 in a two-stage procedure) were placed six months after the sinus surgery with only one failure occurring due to mobility a month after insertion. In January 2014, the cumulative implant survival rate was 96.8%.

Figure 28a-b

Other intraoperative complications

Complications, such as tears in the buccal flap and injury to the infra-orbital nerve generally result from poor surgical technique. Buccal flap tears may result from attempts to release the flap to achieve primary closure. This is usually an unnecessary procedure in a typical sinus elevation. Since there is no change in external dimensions, the flap will close tension free without release. Loss of primary closure is more often a problem when simultaneous ridge augmentation is performed. Be aware of the possibility that the flap may be thin in the area of release and that the direction of the bone surface changes in the area of the malar eminence. Blunt or pressure injury to the infra-orbital nerve may result during flap retraction. If the flap elevation extends superiorly to this position, the exit of the nerve from the bone should be visualized and retraction placed distal to it. It is also possible to injure this nerve during sharp dissection to release the flap for primary closure. The exit-point of the nerve from the skull is just below the infra-orbital notch. Location of this anatomic structure is crucial before performing these procedures (Figure 29).

Figure 29

In cases of severe maxillary atrophy it is possible to find the nasal floor in a crestal location, where one would expect to find the maxillary sinus. The preoperative CT-scan shows that there is no residual crestal bone and that the proposed restoration in cross section #97 will not be located below the sinus, but beneath the nasal passage (Figure 30a). The postoperative axial view shows that, in addition to a posterior sinus graft, the nasal floor has also been grafted (Figure 30b). In this particular case, no remedial therapy was advised as the ostium remained patent and the nasolacrimal duct was undisturbed. This sinus was grafted with Puros® allograft. The entire graft (nose and sinus) resorbed and only the sinus was re-grafted 14 months later.

Figure 30a-b

Best clinical practice includes:

- Performing pre-surgical diagnosis with CT scans to disclose difficult anatomy, vessel location, and sinus pathology, presence of cysts.
- Making the window in the best location (3 mm from the floor and anterior wall).
- Using piezoelectric surgery or DASK® for lateral osteotomy and initial membrane elevation.
- Elevating the membrane from lateral to medial, keeping the elevators on bone at all times.
- Perforations can be repaired with collagen barrier membranes or biologic L-PRF membranes.
- Using a collagen repair membrane that remains rigid when wet to achieve the most stable repair. L-PRF is both resilient and adhesive.
- All repairs must be stable.
- Aspirating mucous retention cysts if elevation might block sinus drainage

Postoperative complications

Postoperative edema, ecchymosis, mild to moderate discomfort, minor nosebleed, minor bleeding at the incision line, and mild congestion are within the scope of expected patient responses to this procedure. Some are due to manipulation of the facial flap and others to the manipulation of the sinus membrane.

Major postoperative complications after sinus elevation surgery are relatively uncommon. They include graft infections, sinus infections, postoperative sinusitis, profuse postoperative bleeding, flap dehiscence, oro-antral fistula formation, formation of inadequate graft volume for implant placement, loss of graft material containment as a result of either sinus membrane rupture or exfoliation of graft material through the sinus window, maxillary cyst formation (63, 52), migration of dental implants into the sinus graft, the sinus cavity proper, or the paranasal sinuses (25), and failure of dental implants.

A consensus conference by the Academy of Osseointegration (1) concluded that the maxillary sinus elevation was the most predictable of the pre-prosthetic augmentation procedures. They further concluded that complications were relatively few, generally localized and easily remedied. While this is for the most part true, it should be realized that improper handling of complications may lead to more serious adverse outcomes, such as an intraorbital abscess, intracranial abscess, or migration of implants into the maxillary sinus or paranasal sinuses (25)

In a prospective study of 100 consecutive sinus elevations, Zijderveld et al. (124) reported an 11% incidence of membrane perforations and a 2% incidence of bleeding as intraoperative complications when utilizing a rotary window technique. The postoperative complications listed in order of most frequent occurrence were loss of implants (4%), wound dehiscence (3%), graft infections (2%), postoperative maxillary sinusitis (1%), and loss of or inadequate graft volume (1%). While postoperative complications are relatively infrequent, understanding how to cope with them may be vital for the ultimate success of the elevation procedure.

Postoperative infections

Etiology and incidence of sinusitis / sinus infections

Postoperative infections are relatively infrequent, with infection rates reported between 2% and 5.6% (62, 84, 124), with often no distinction being made between a true sinus infection or a sinus graft infection. The incidence of postoperative infections can be reduced by utilizing protocols involving proper case selection (preoperative diagnosis), pre- and postoperative infection control with appropriate antibiotics and sound surgical techniques. When infections are suspected, therapy should be rendered quickly and effectively in order to avoid great adverse outcomes.

Infections after sinus elevation surgery can occur in two locations. Most commonly the infection is not a true sinus infection but an infected sinus graft. It should be remembered that the sinus graft is not actually in the sinus, but is located below the elevated sinus membrane, hence the term subantral augmentation. True sinus infections are less common but may have more widespread consequences if not appropriately managed due to the interconnectivity of the paranasal sinus network.

Postoperative sinus infections may commonly arise from two general sources. The first is through exacerbation of a previously existing, asymptomatic, chronic sinus condition (infection or inflammation) by the anticipated postoperative inflammatory changes. The second source is from contamination through a membrane perforation or tear with bacteria from the oral cavity or infected sinus grafting material.

Pre-existing inflammatory sinus disease (seasonal, tooth-related) may, under less than ideal conditions, be a factor in the etiology of postoperative sinus infection. A healthy sinus is considered to have a high “compliance”, which may be defined as the ability of the sinus to

respond and recover from a bacterial or inflammatory threat. An unhealthy sinus does not have the same level of innate ability to respond.

Common conditions that lead to acute sinusitis, are blockage of the osteo-meatal complex by inflammatory changes resulting from tooth related problems (endodontic or periodontal) and seasonal allergic reactions. The most common causes of sinusitis following sinus elevation procedures are likely to be infection / inflammation relating to inadequately contained sinus grafts that have contaminated the sinus proper through recognized or unrecognized perforations or blockage of drainage by the elevation of mucous retention cysts or severely thickened sinus membranes.

In cases where inflammation and/or infection from a recognized etiology is present (periodontal, periapical, allergic), pre-surgical antibiotic/anti-inflammatory therapy, along with removal of the etiology, will in many cases resolve the problem before augmentation surgery. Figures 31 a-c show that the etiology of the sinus pathology was the infected molar teeth. These were removed and the patient was placed on a course of Augmentin and prednisone therapy leading to almost complete resolution of the sinus pathology.

Figure 31a-c

Patients with a preoperative diagnosis of, or symptoms of, acute sinusitis or acute chronic sinusitis should receive or be referred for appropriate pre-surgical therapy and, if referred, a medical clearance should be obtained before sinus elevation surgery is performed. This therapy may be in the form of antibiotic therapy (Augmentin or Levaquin are appropriate), combined antibiotic and anti-inflammatory therapy (one such regimen might include Augmentin (amoxicillin–clavulanic acid (875 mg/125 mg twice daily x 10 days) and prednisone (40 mg for 3 days, 20 mg for 3 days, 10 mg for 3 days), or endoscopic sinus surgery to remove pathologic tissues or to perhaps widen the ostium to create more favorable drainage. It would not be considered inappropriate to take another CT to determine if this therapy has been successful prior to performing the sinus elevation. Sinus elevation surgery will, in general, result in a short-term inflammatory reaction in the sinus, possibly compounding any previously existing pathology. This response is highly elevated when bone morphogenetic proteins (BMP-2) are used as part of a sinus graft as cellular responses increase dramatically. The response is short- lived and will resolve without therapy (Figure 32a-c), however, it is advisable to inform the patient of this likely occurrence.

Figure 32a-c

Etiology and incidence of sinus graft infections

This is the most common form of infection encountered after sinus elevation surgery. The incidence of postoperative sinus graft infections has not been separately documented but, by inference, the incidence is approximately 2–5%. The most common symptoms may include local tenderness, nasal obstruction, pain, swelling, fistula formation, flap dehiscence and suppuration from a fistula or the incision line. Increased intra sinus pressure may be a secondary factor, which may result in blocked sinus drainage. Symptoms may appear soon after therapy (within 2 weeks) or may first appear after a few months sometimes, but not always, proceeded by vague symptoms. Figures 33 a-b present a typical CT-scan appearance of a late (2-month) postoperative infection. A somewhat common appearance is that of a "black hole" in the central portion of the graft with a radiopaque dome or "halo" over the graft. Both views show what appears to be an undisturbed layer of graft material (normal dense opacity) surrounding the infected core. Upon open debridement, this dome feels quite solid and may not be easily removed.

Figure 33a,b

Sinus graft infections may be caused by:

- pre-existing sinus infection via perforation (should not treat symptomatic patient)
- contamination of the surgical site:
  - salivary/bacterial contamination of the graft material, instruments, or membrane
  - untreated periodontal disease
  - adjacent periapical pathology
  - lapses in the chain of sterility
  - extended surgical time
- infected simultaneous lateral ridge augmentation procedures.

Prevention of sinus graft infections

As an infected sinus graft can be a catastrophic event for a patient in terms of morbidity, additional therapy, increased treatment time, and possible systemic complications, all efforts should be made to prevent this untoward outcome.

Preoperative diagnosis of potential sources of graft infection is invaluable. Pre-existing periapical pathology, when the apices of infected teeth are in (or close) to the sinus, produces a reaction in the sinus that may be one of inflammation and/or bacterial contamination (Figure 34). When the membrane is elevated these bacteria are immediately enclosed in a bone graft placed in a confined space; an ideal incubator. Localized endodontic and periodontal therapy should be completed before sinus grafting, or the hopeless teeth should be extracted.

Figure 34

Simultaneous extraction of teeth that penetrate the sinus floor may open a pathway to infection as the sinus graft is immediately connected to the oral cavity through the extraction socket, which may or may not be covered by a flap release with primary closure. Sinus grafts with simultaneous ridge augmentation procedures are a further extension of the above extraction socket scenario. Barone et al. (8) reported on 124 sinus elevations, 26 with simultaneous lateral ridge augmentations. The infection rate was 3% for the sinus graft only group (n = 98) and 15.4% for the group that had simultaneous ridge augmentations (n = 26). Five of the seven infections occurred in smokers. The cause of the infection in these cases and in other ridge augmentation studies has been attributed to the breakdown of primary soft-tissue closure over the grafted site with exposure of the barrier membrane and subsequent graft contamination. It should be noted that in a ridge augmentation procedure the incision line is directly over the barrier membrane, while in a properly designed sinus graft the membrane should be distant from all incision lines. Soft-tissue healing appears to be affected in a negative way by smoking, but smoking alone has not been shown to be a negative factor in pure sinus grafting procedures. In a study by Levin et al. (51) onlay bone grafts had a higher complication rate in smokers than non-smokers but there was no such relationship present in pure sinus lift grafts.

Another overlooked source of graft contamination is the utilization of non-sterile instruments either directly in the sinus or to manipulate the particulate graft material. Instruments that have been sterilized prior to the surgical procedure do not remain sterile once they have been introduced into the oral cavity. A common procedural error is to utilize an instrument such as a periosteal elevator that has been utilized in the mouth to hydrate/mix the graft material or carry it to the sinus. This is a breakdown in sterile surgical protocol that must be avoided.

Prophylactic procedures play an important role in prevention of infection. Many antibiotic regimens have been recommended for this purpose. In the author's experience amoxicillin–

clavulanate (Augmentin) is the drug of choice. The spectrum is greater than that of amoxicillin or ampicillin owing to the presence of clavulanic acid, which is active against β-lactamase-producing bacteria. Augmentin 875/125 mg twice daily for 7 - 10 days (starting the night before surgery) is an effective prophylactic dose. Historically, clindamycin (Cleosin) has been recommended for penicillin-allergic patients. However, some clinicians feel that clindamycin is not the ideal prophylactic antibiotic for these patients. In all our authors' experience over more than 28 years of sinus grafting, the majority of observed or reported infections occurred in patients taking prophylactic clindamycin or no antibiotic at all. The authors have used levofloxacin (Levaquin) or moxifloxacin (Avelox), second and third generation bactericidal fluoroquinalones, with much more favorable results. As there have been numerous reports of Achilles tendon rupture, tendonitis, and peripheral neuropathies following use of fluoroquinalones, especially when used in conjunction with steroids (65, 90), the use of Zithromax or Biaxin, both bacteriostatic macrolides, may be an alternative for penicillin-allergic patients. In general, the sinus graft infection rate appears to be higher in penicillin-allergic patients. An unrelated study by Wagenberg & Froum (117) reported an infection rate 3.3 times higher after immediate implant placement when amoxicillin could not be used owing to a history of allergy. The following recommendations are given as measures to reduce the incidence of postoperative infection. (Table 5)

• **Table 5**

Clinical recommendations to limit intra-operative and post-operative complications
1. Careful assessment of the medical history of the patient
2. Pre-operative CT scan to evaluate sinus anatomy and identify pre-existing pathology
3. Proper patient selection stressing a healthy maxillary sinus
4. A smoking cessation protocol is always recommended and, especially in case of heavy smokers (≥15 cigarettes a day), evaluated with caution
5. Resolution of periodontal and endodontic diseases
6. Adequate antibiotic prophylaxis
7. Achieve full mouth plaque score and full mouth bleeding score <15%. In case of provisional crowns, it is advisable to remove the temporary crowns and disinfect the abutments with antiseptic solution
8. Preoperative disinfection of the skin with an antiseptic solution and mouth rinses with

chlorhexidine
9. Use of sterile draping and infection-control protocol
10. Keep the incisions distant from the antrostomy
11. Prevent salivary contamination of bone graft and/or other biomaterials,
12. Intra- and postoperative control of the hemostasis
13. Prevention of bone overheating
14. Use of two different surgical sets of instruments: one for the flap elevation phase and the other for the grafting phase
15. Rinsing the surgical field with sterile saline solution
16. Keeping the surgical time as short as possible
17. Postoperative chlorhexidine rinses
18. Correct postoperative pharmacological therapy
19. Pre-planned check-ups: weekly for the first month and monthly for the following 3 months

Treatment

Treatment of sinus graft infections should begin immediately after symptoms are recognized. The most common symptom is swelling over the lateral window site. Other symptoms include localized pain and/or tenderness, fistula formation, flap dehiscence, and suppuration. Sinus graft infections usually occur within the first 2 weeks after therapy. Late infections (1 - 6 months) occur less frequently. In general, infections are quite evident with reported patient discomfort and observed clinical swelling. Sometimes the symptoms are less evident with drainage occurring through a small fistula in the area of the lateral window. On other occasions the symptoms are so mild (non-specific mild discomfort) that the diagnosis is delayed for up to 1 month or more. Early treatment is essential as the partial or total loss of the graft is a possible negative outcome. Other negative outcomes include the occurrence of an oroantral fistula, which will require surgical correction, and the possible development of a sinusitis due to loss of graft containment.

Treatment can generally be described as involving four stages, each more invasive than the other, which are performed sequentially, as needed, until the infection resolves. The waiting time between stages is in the order of 7 – 10 days at a maximum, as positive effects should be noted by that time. The 4 stages are:

1. Reinstitution and/or change of antibiotic therapy.
2. Insertion of drain with antibiotic therapy.
3. Partial or complete debridement of the graft material or
4. Total debridement of the graft and sinus cavity by oral approach and/or functional endoscopic sinus surgery.

Without a microbiological assay, immediate therapy is directed toward the most common pathogens and the common resistant strains of bacteria. The antibiotics chosen should be able to achieve high tissue concentrations and have the broadest possible spectrum. If signs of infection are noted, it may be appropriate to change from the antibiotic used in prophylaxis to one with a wider spectrum (Augmentin or Levaquin). Metronidazole, a member of the nitroimidazole group, may be included for its bactericidal effect against gram-positive and gram-negative anaerobic bacteria. It must be used with an additional antibiotic (Augmentin or Levaquin) that is effective against facultative bacteria. A culture can be taken to obtain information in case the infection is resistant to the chosen antibiotic. In many instances, however, it is difficult to obtain a culture that is not contaminated by oral bacteria or to obtain results in a reasonable amount of time.

If a Penrose drain is placed, it is best, if possible, to place it in a location that is not directly over the graft. Placing the drain through an incision over the window and graft site may increase the potential for an oro-antral fistula. Figure 39 shows the placement of a Penrose drain in an existing fistula. The drain was left in place for 3 days, and after removal, the infection resolved.

Figure 35

If the infection does not respond to either of the above therapies, debridement of the infected graft material may be the only remaining means of infection control. All graft material can be removed followed by thorough flushing of the subantral space. Re-grafting at the time of debridement is an option when signs of infection are minimal, but the risk of re-infection may be increased. It is usually advisable to wait until symptoms disappear before retreatment. In cases of late infections that present as in Figures 41a-c, an alternative therapy of partial debridement may be considered. Attempting to remove the hard "shell" surrounding the infected central portion of the graft will probably result in destruction of the surrounding Schneiderian membrane. To avoid this negative consequence, it may be advisable to leave the "shell" in place after thorough debridement and irrigation of the central portion of the infected graft. Urban et al. (112) have reported on this technique with successful results in 8

cases. The collagen membrane and discolored / infected graft materials are removed, the cavity is rinsed with saline, treated with doxycycline putty for 2 minutes, rinsed again, and closed without additional grafting. Implant placement and re-grafting of the central part of the graft can generally commence with minor change to the original schedule. The retained portion of the graft matures and allows for implant placement and stability. Histology showing vital bone in this non-grafted repair location has been shown by Khouly et al. (47).

Best clinical practices:

- Ensure proper case selection, proper prophylactic antibiotics, and infection-control surgical protocol.
- Treat early if infection suspected.
- Change the treatment if no response within 7 days.

Postoperative sinusitis

Etiology

By decreasing the size of the sinus by grafting the floor, maxillary sinus floor elevation has the potential to create more favorable sinus drainage. Many clinicians have noticed that patients who presented with a history of low-grade chronic sinusitis before sinus elevation surgery were less susceptible to this condition after that surgery was performed. This is due to both the decreased volume of the sinus and the fact that the sinus floor is now closer to the ostium, or point of drainage. This assumes that a proper membrane elevation that extends up the medial wall has raised the floor without creating a narrow, difficult to drain, crestal extension of the sinus floor against the medial wall. Generally, one should expect to see a short-term increase in membrane thickness due to a post-surgical inflammatory response. This would appear to be temporary as a study by Peleg et al. (67) of follow-up evaluations of 24 sinus grafts revealed that 12 membranes decreased in size, 11 remained the same and one increased in size.

Sinusitis after sinus elevation surgery, which has been reported in 3–20% of cases (7), is generally mild in nature. Symptoms may include mild discomfort, stuffiness, and difficulty in breathing. A moderate to severe postoperative sinusitis is most likely due to blockage of osteo-meatal drainage owing to inflammation and/or sinus infection. The various etiologies of sinusitis include:

- postsurgical inflammatory changes

- bleeding into the sinus after membrane perforation
- bacterial contamination / infection after membrane perforation
- blockage of the osteo-meatal complex due to:
  - intrasinus bleeding
  - graft material lost through perforation
  - elevation of large cysts or thickened membranes to the level of the ostium.

Prevention

Prevention of postoperative sinusitis begins with an evaluation of patient medical history and final case selection. Patients with a previous history of inflammatory sinus disease are more likely to have a postoperative sinusitis than patients with a negative history (103, 104). Preoperative sinus pathology should be evaluated by CT analysis and potential problems possibly addressed before sinus elevation surgery. The proper pre-surgical protocol thus may include:

- 3-dimensional treatment planning to discover pre-existing pathology
- prior treatment of inflammatory disease by antibiotic and anti-inflammatory medications
- resolution of pathology by functional endoscopic sinus surgery.

A protocol suggested by Torretta et al. (106) recommends that all pre-existing reversible sinus conditions be addressed prior to sinus elevation surgery. If the problem is due to potential or actual blocked drainage, positive therapy might involve endoscopic marsupialization of a mucous retention cyst, removal of polyps or thickened membranes, or surgical widening of the ostium via functional endoscopic sinus surgery. If perforation of the sinus membrane occurs during elevation surgery, it must be repaired in a manner that the repair membrane is stable and prevents particulate graft material from escaping into the sinus cavity, as this may be a nidus for inflammatory changes, infection, or blockage of the ostium. As will be seen, treatment for sinus infections may become more complex if the integrity of the Schneiderian membrane is lost.

Treatment

Many clinicians routinely prescribe decongestants such as oxymetazoline (Afrin) for postoperative use. The postoperative incidence of cases requiring this therapy is so

infrequent an occurrence that many clinicians do not include this in their usual postoperative protocol but prescribe it on an as-needed basis. Nasal lavage with sterile saline rinses can be used as adjunctive therapy. Treatment will depend on the severity and presumptive etiology of the sinusitis. A mild sinusitis may respond to decongestants. If the etiology is a combination of inflammation and infection combined antibiotic and anti-inflammatory therapy may be effective. If there is no resolution, and the situation involves infection in both the graft and the sinus, therapy may involve a surgical approach orally and/or via endoscopic surgery. As can be seen from the discussion above and the summary below, treatment may become more complex if graft material containment is lost. Two therapeutic protocols should be considered (96).

Best clinical practice includes:

1. If the graft is well contained under the Schneiderian membrane but signs and symptoms still persist after an additional pharmacological regimen (usually 7 additional days), partial or total removal of the bone graft by oral access combined with additional pharmacological therapy is recommended.
2. If the graft is not contained under the sinus membrane and loss of graft material into the sinus is present (as seen on CT-scan) and symptoms still persist after extended antibiotic therapy (usually 7 additional days), a multidisciplinary approach to manage the complication is mandatory.

The above information can be utilized to create an algorithm for the treatment of sinus graft infections, sinus infections, and postoperative sinusitis (Figure 36).

Figure 36

It is apparent in the algorithm that if symptoms occur early or remain after a time interval of 3 weeks, a CBCT should be taken for diagnostic purposes. The results of the scan determine a pathway for treatment that is directed by containment or lack of containment of the graft material. If the graft material is not contained, graft removal by an intraoral approach, with or without functional endoscopic sinus surgery, is usually required. If the implants do not have sufficient bone support following loss of the graft, they will also be removed. In cases where the graft material is contained (sinus graft infection), the therapeutic course is determined by the patient's response to a series of increasingly invasive attempts to resolve the infection. In order, they consist of a second round of antibiotics, partial graft / implants removal and

complete graft removal if there is no resolution. Infections of the maxillary sinus can have quite severe adverse outcomes well beyond loss of the graft material. Pan sinusitis, intraorbital abscesses with possible loss of sight, and intracranial abscesses have been mentioned in this chapter. The greatest errors that one can make in these cases are waiting too long to begin therapy, waiting too long before changing an ineffective therapy, and not taking advantage of the knowledge and skills of other surgical specialists by referral.

Other postoperative complications

Loss of graft material through the surgical window

An increase in intrasinus pressure, which may be caused by postoperative inflammation or bleeding from within the sinus can result in loss of graft material through the window (Fig. 37a-b). This is likely to occur if a membrane was not placed over the window or if the membrane was not properly stabilized. The displaced graft material is likely to cause an elevation in the buccal mucosa. This can be removed with a small flap entry (not over window or membrane) or left in place and addressed at the time of implant placement. Some clinicians stabilize bioabsorbable barrier membranes with resorbable tacks or a mattress suture. The incidence of this complication is quite low, making routine mechanical membrane stabilization unnecessary. It would be appropriate, however, to choose a membrane that is flexible when wet so that it may conform to the shape of the lateral wall. An alternate method of stabilizing the repair membrane is to place it immediately within the sinus window, over the graft, extending approximately 2 mm in each direction for stabilization (97) (Fig 38a-b).

Figure 37 a-b

Figure 38 a-b

Migration of implants into sinus or sinus graft

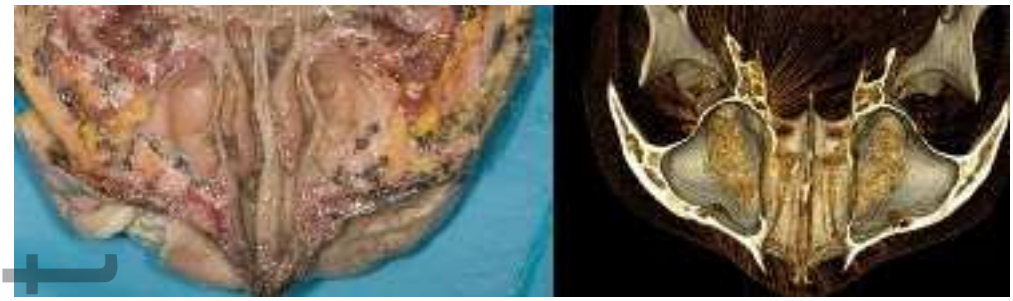
This complication was more common when cylindrical implants were used in the posterior maxilla (78). It is still seen with screw-form implants when biological boundaries are pushed to or beyond the limit (Fig. 39). The problem is usually due to an initially inadequate or early loss of primary stability. It can also be caused by the loss of supporting bone owing to infection. Many clinicians reserve simultaneous implant placement for those cases that have a minimum of 4–5 mm of crestal bone. While simultaneous placement has been reported to be successful in 1–2 mm of crestal bone (67), one must consider the potential risk. If an implant

is placed in 1–3 mm of crestal bone and primary closure is not achieved and maintained, the early formation of the biological width may remove more than half of the supporting bone well before the graft has matured and become supportive.

Figure 39

Conclusions

The maxillary sinus elevation procedure using a lateral window approach has been shown to be the most successful bone augmentation procedure that is performed as a pre-prosthetic procedure before implant placement (1). When success is measured by patient outcome (success of the grafting procedure) the high success rate achieved is due to the fact that complications are minimal and can be reduced through proper case selection, proper preventive antibiotic selection, good surgical technique, and proper and prompt handling of intra-operative and postoperative complications when they occur. Properly performed sinus grafting does not alter proper sinus function (103) and does not alter the characteristics of the voice (95). When measured by implant outcome (implant survival rate) it has been shown that implant survival rates in the high 90th percentile can be achieved through proper decision making with regard to implant surfaces (textured), graft materials (highest survival with xenografts) and the placement of a barrier membrane over the window (1, 122). Each discussion of the prevention of an intra-operative or a postoperative complication in this chapter included the advisability of obtaining a preoperative CT scan analysis. The authors believe that this should be considered as part of the universal standard of care. Most clinician's feel that the information obtained relative to sinus health and sinus anatomy is a key factor in reducing complications to a minimum.



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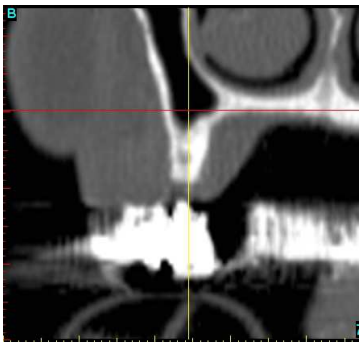

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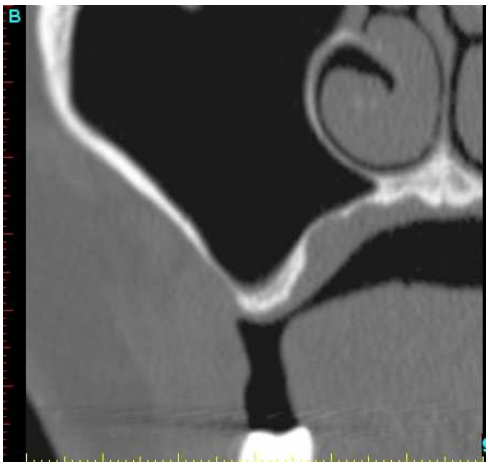

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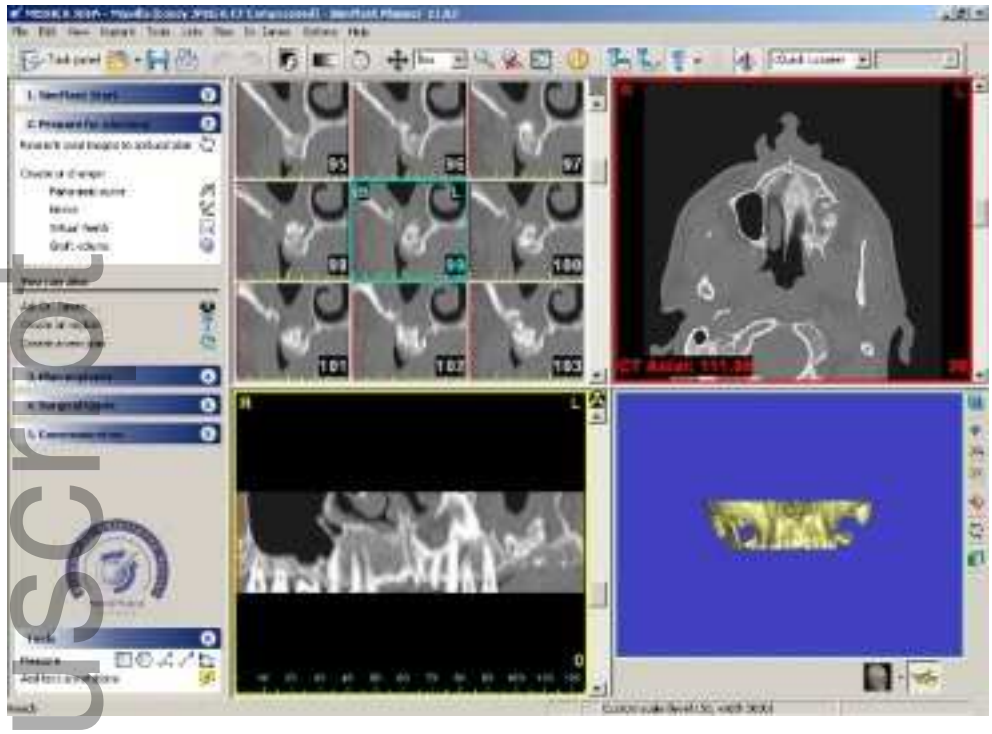

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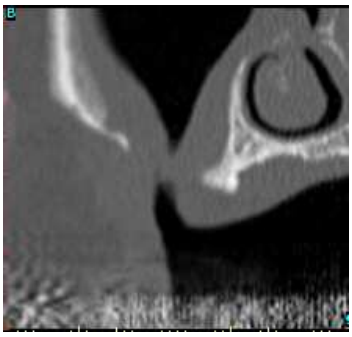

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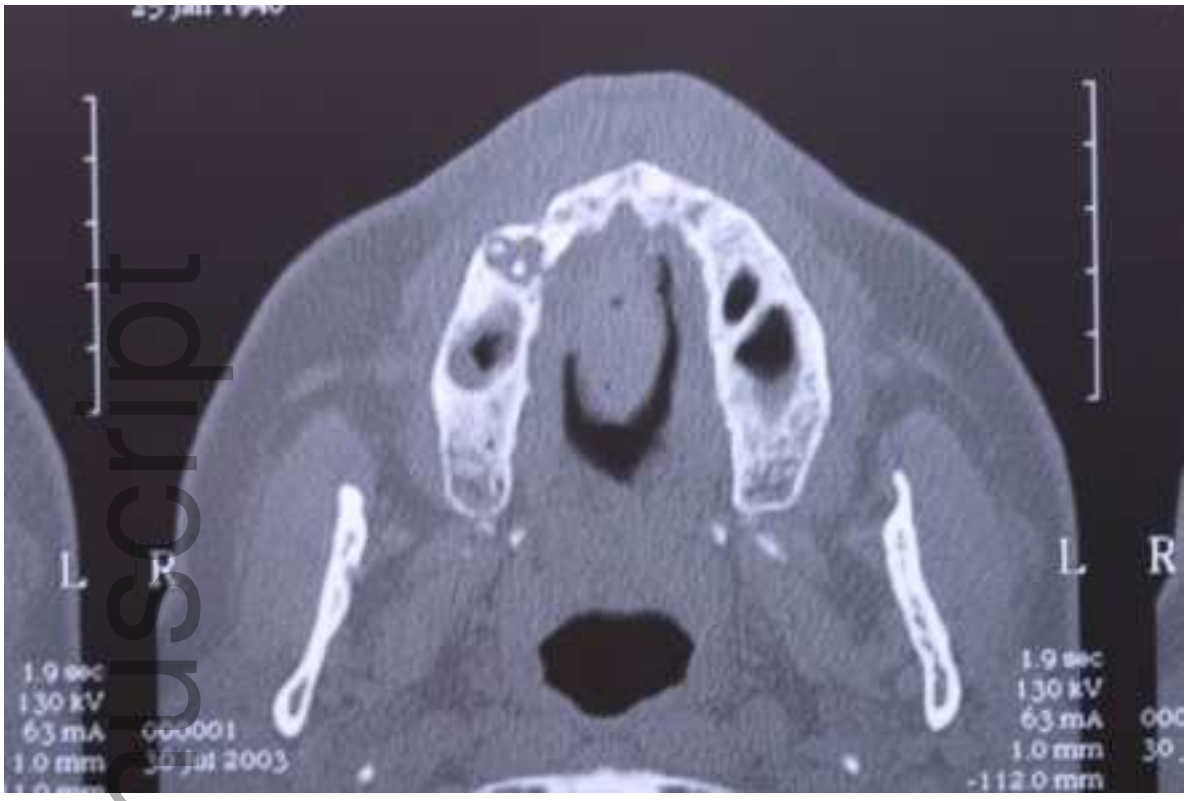

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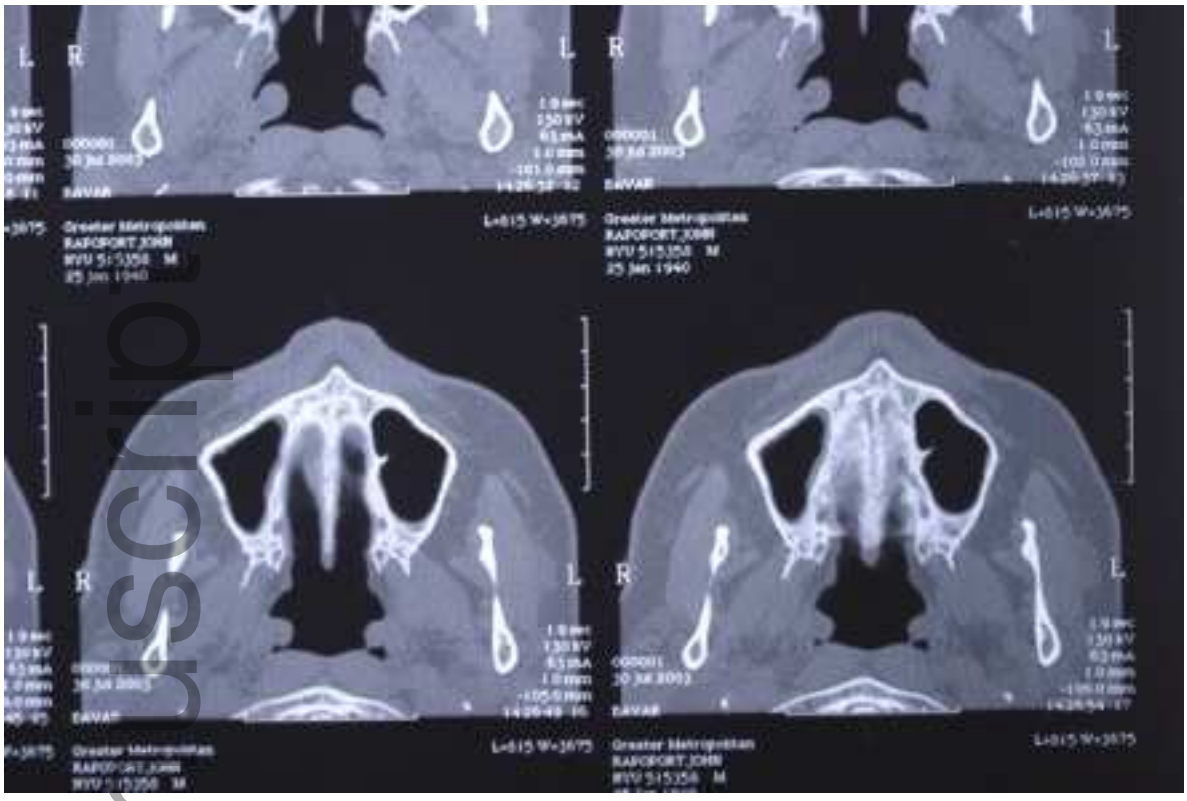

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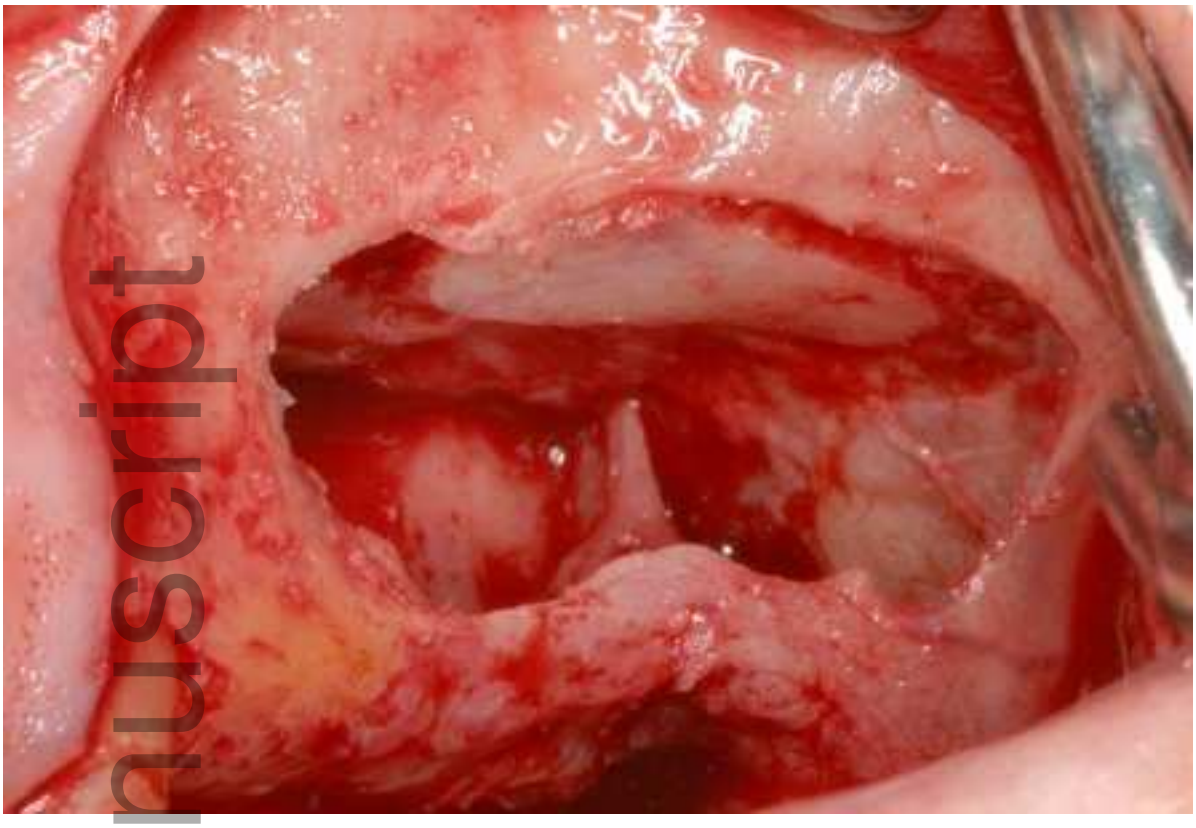

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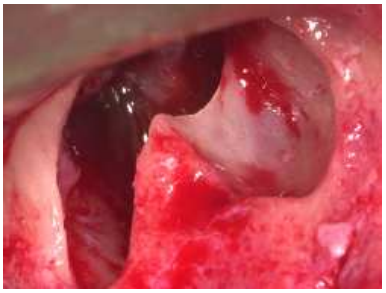

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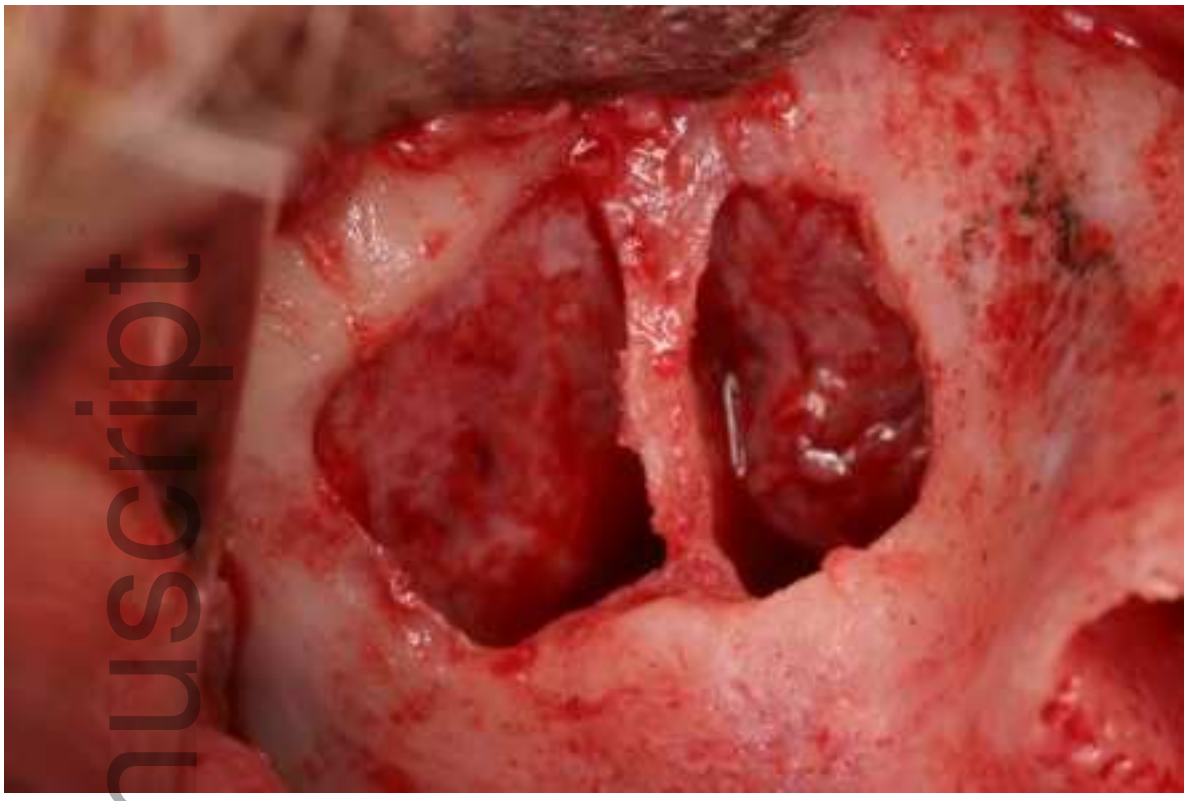

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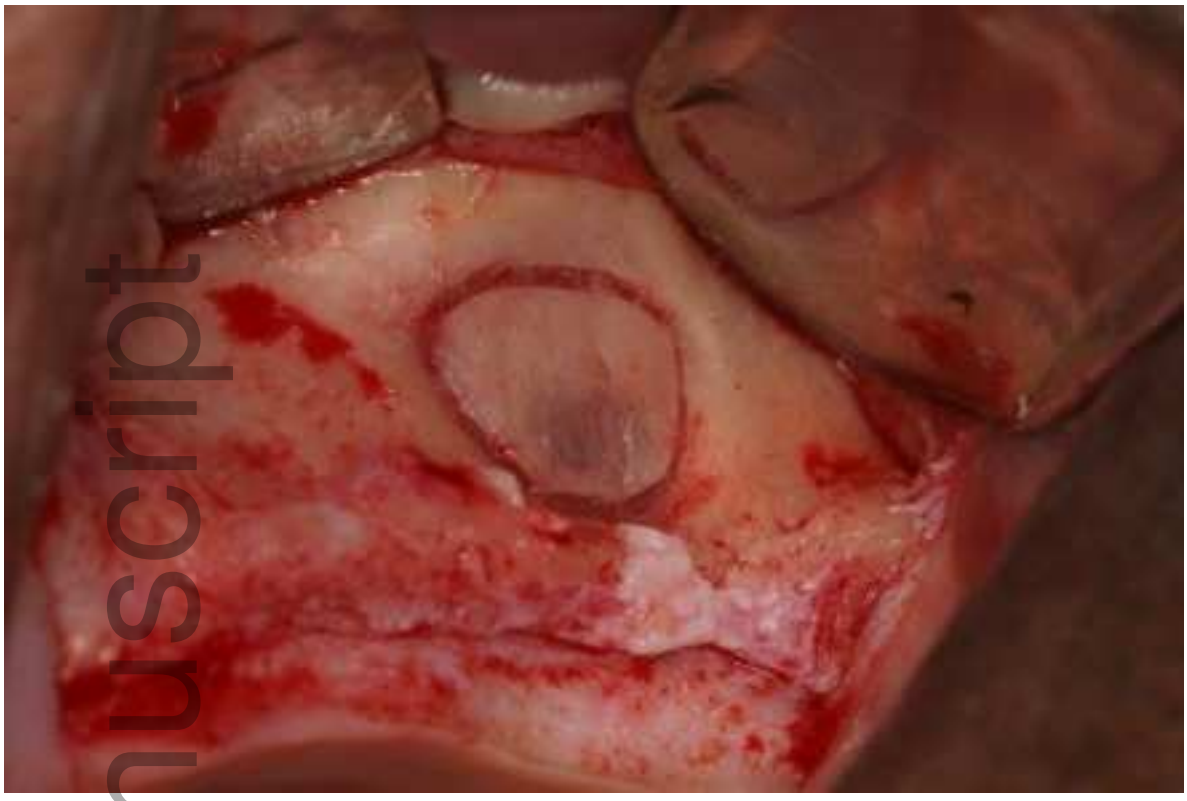

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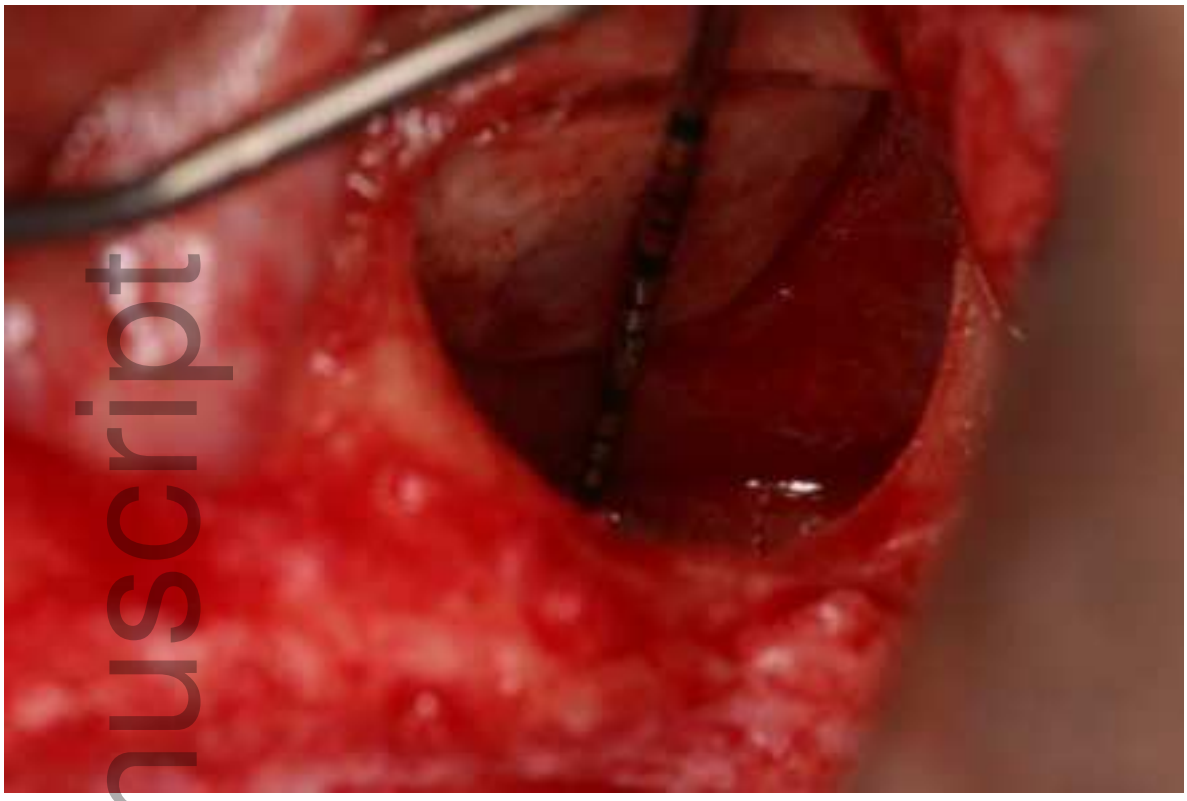

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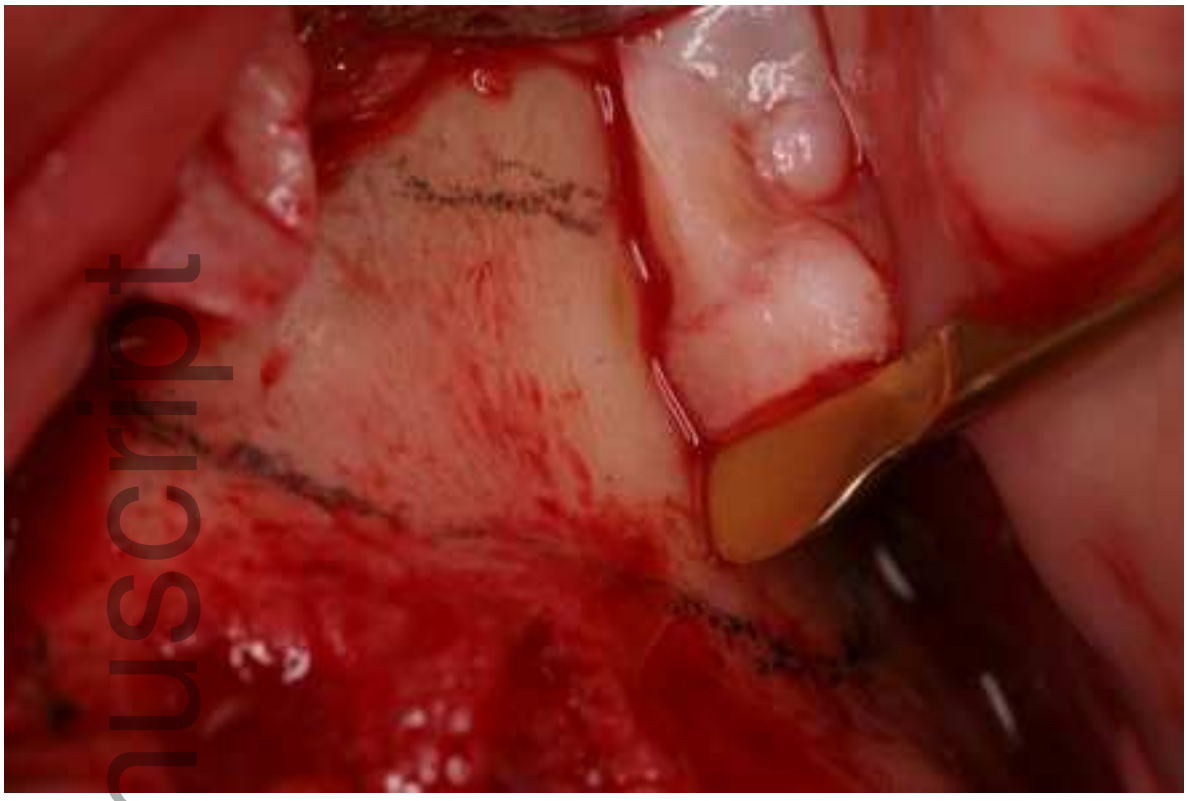

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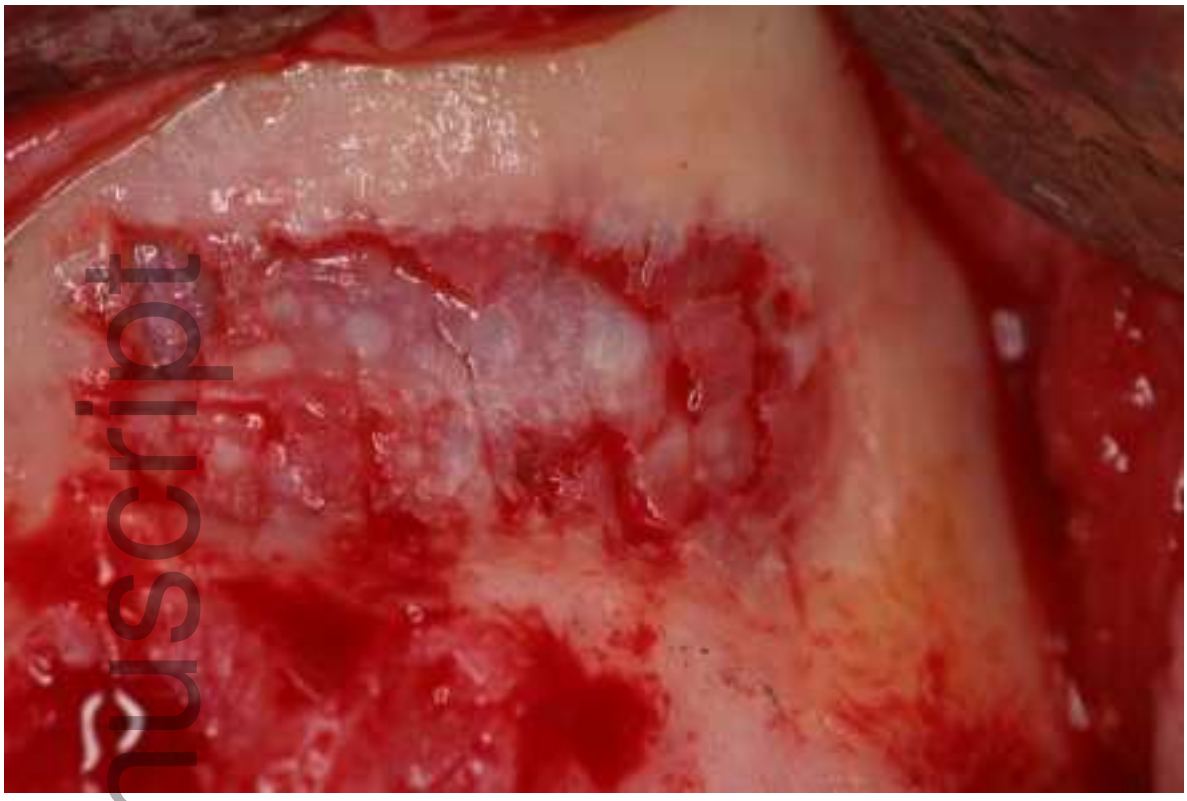

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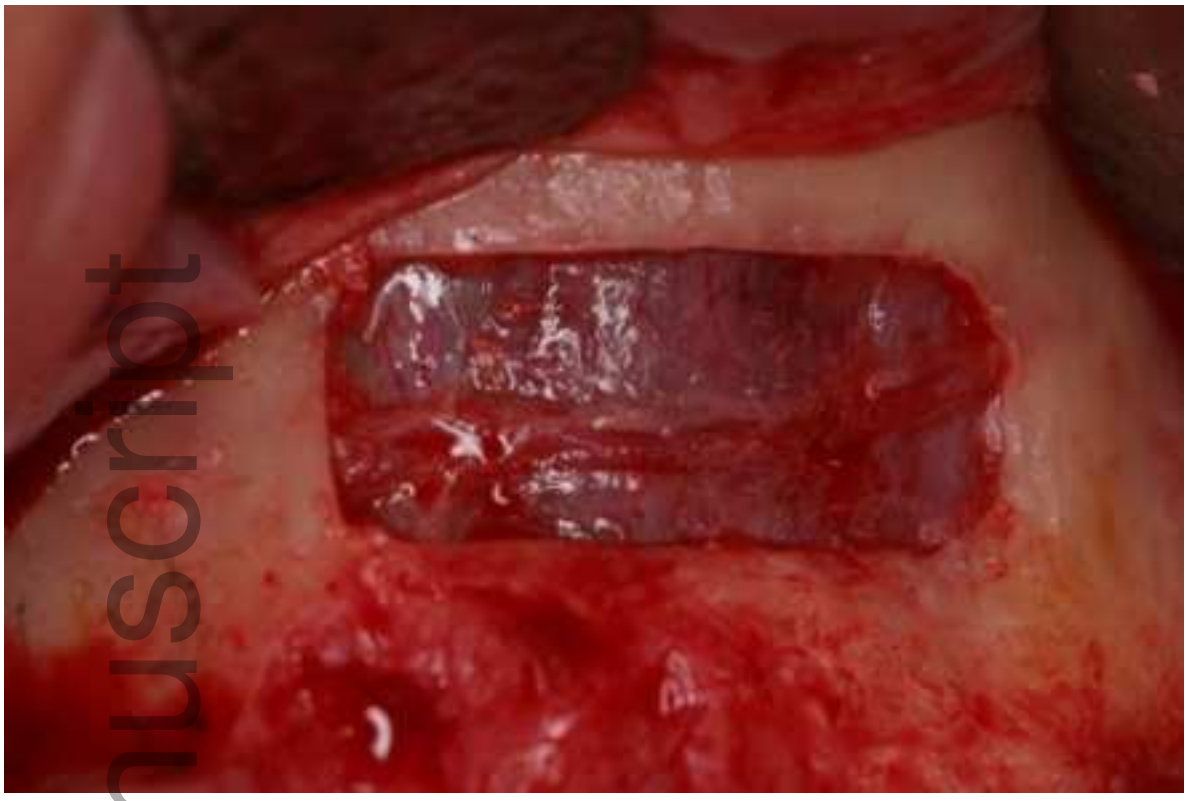

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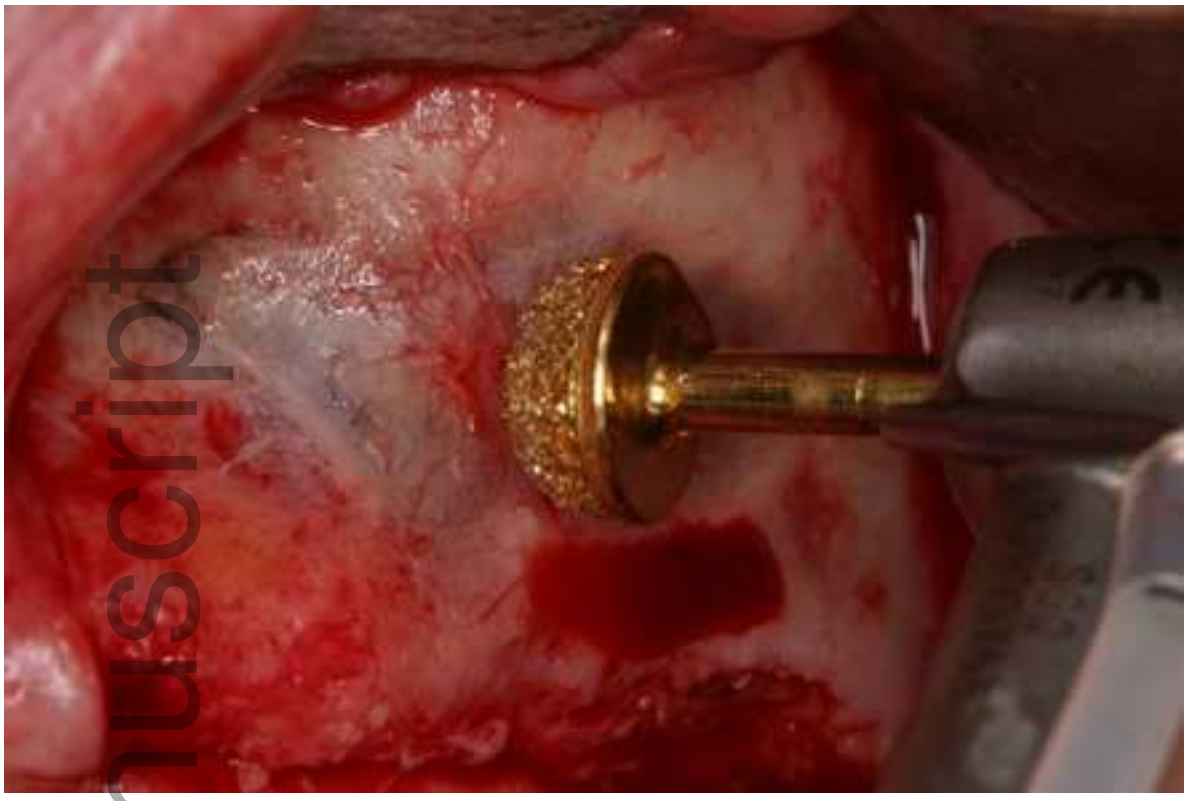

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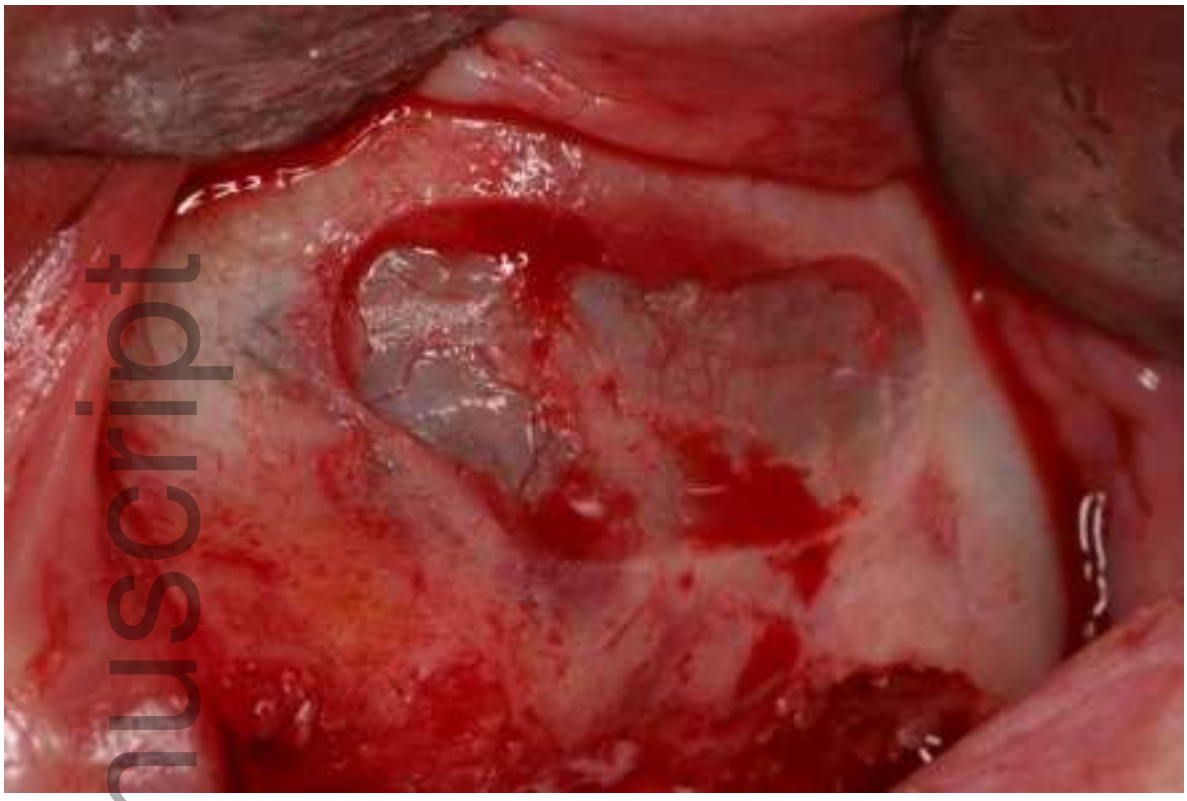

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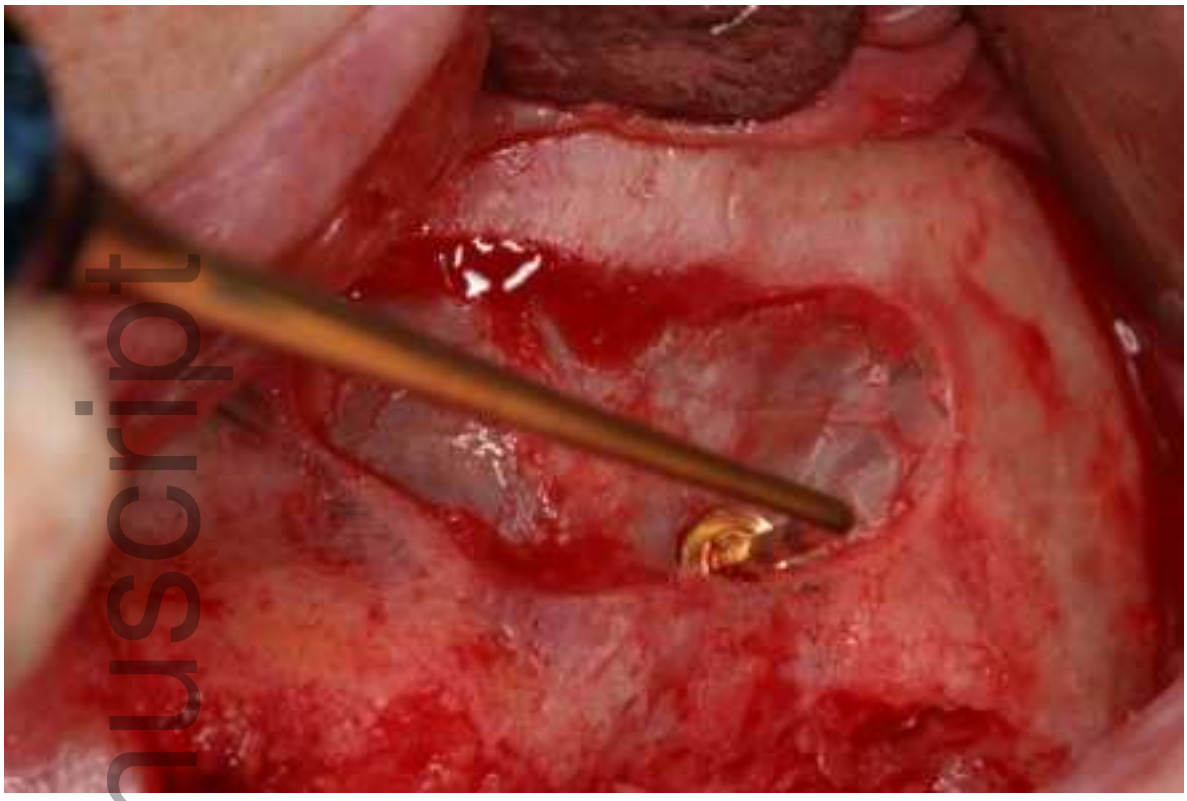

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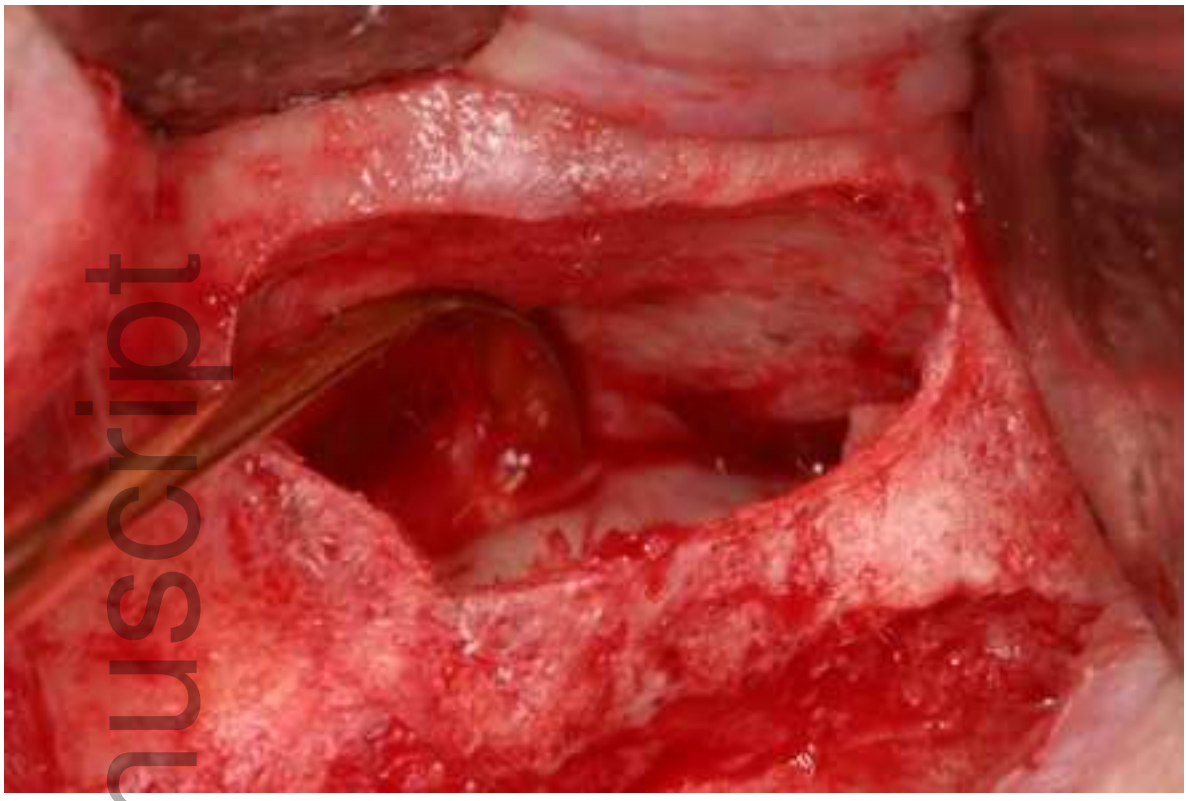

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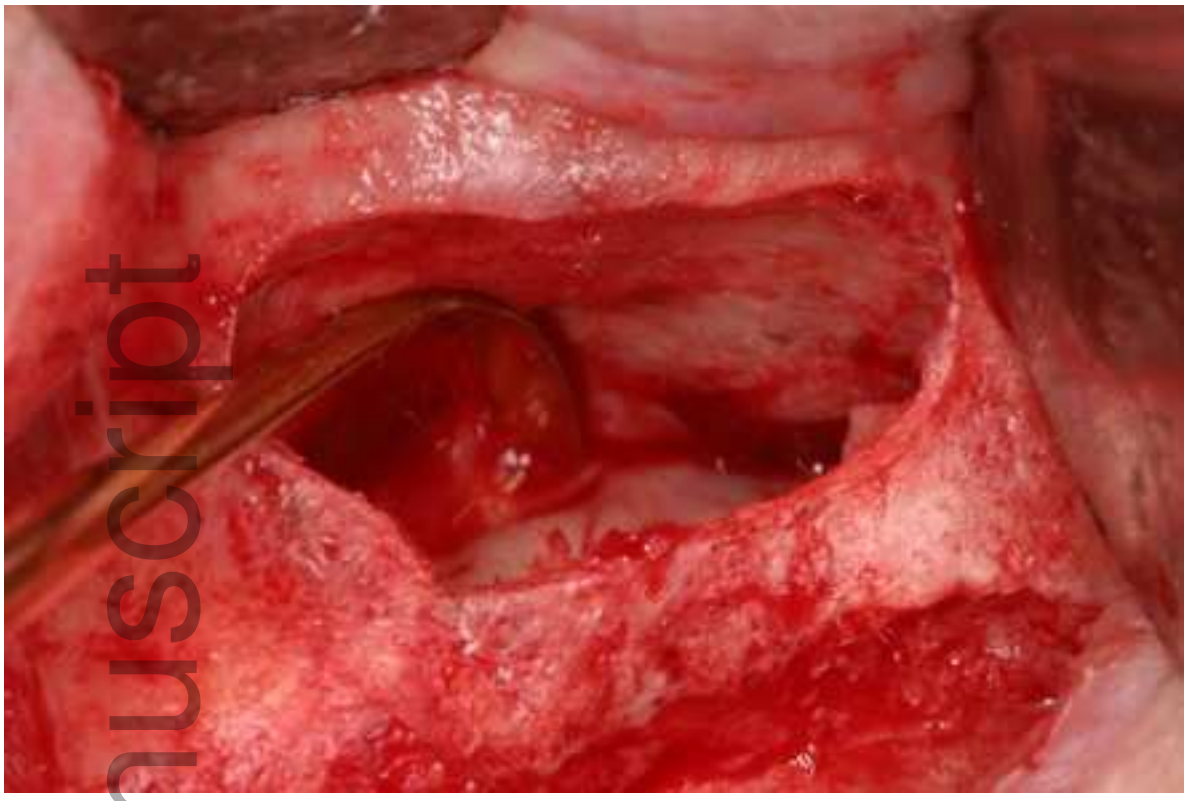

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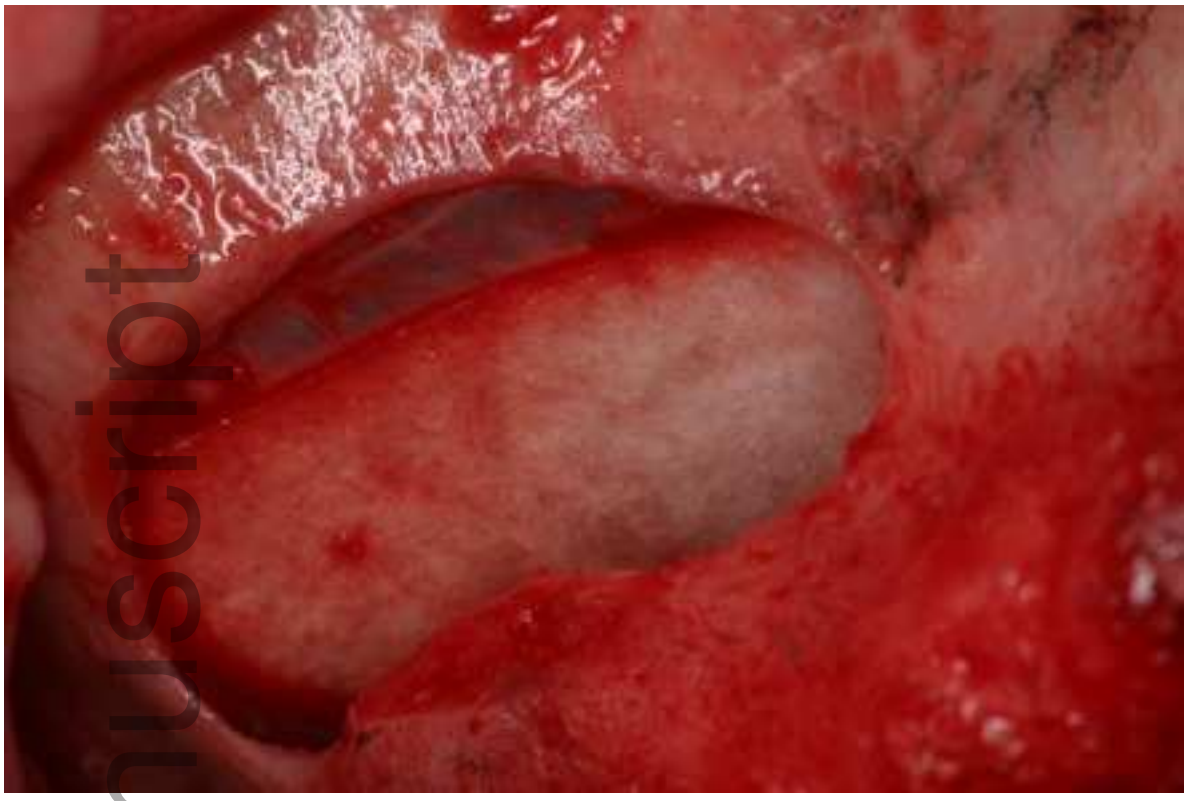

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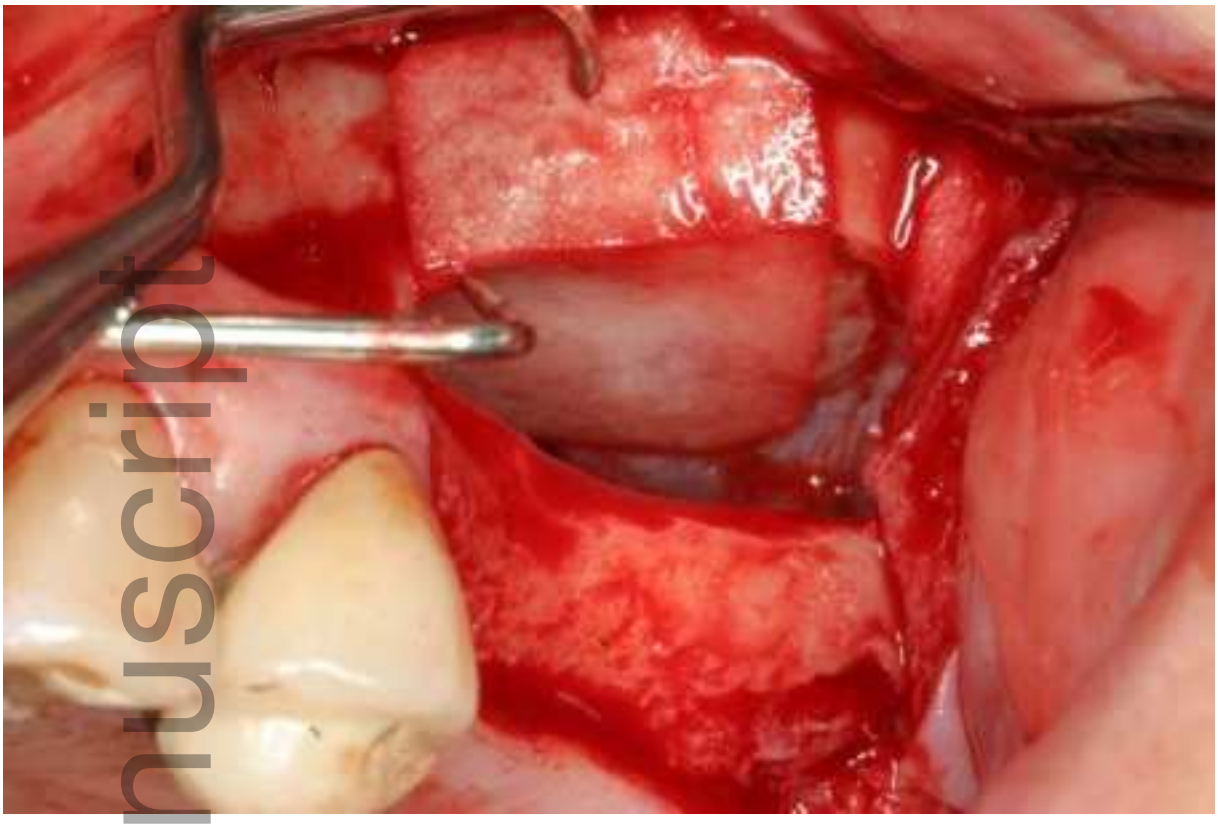

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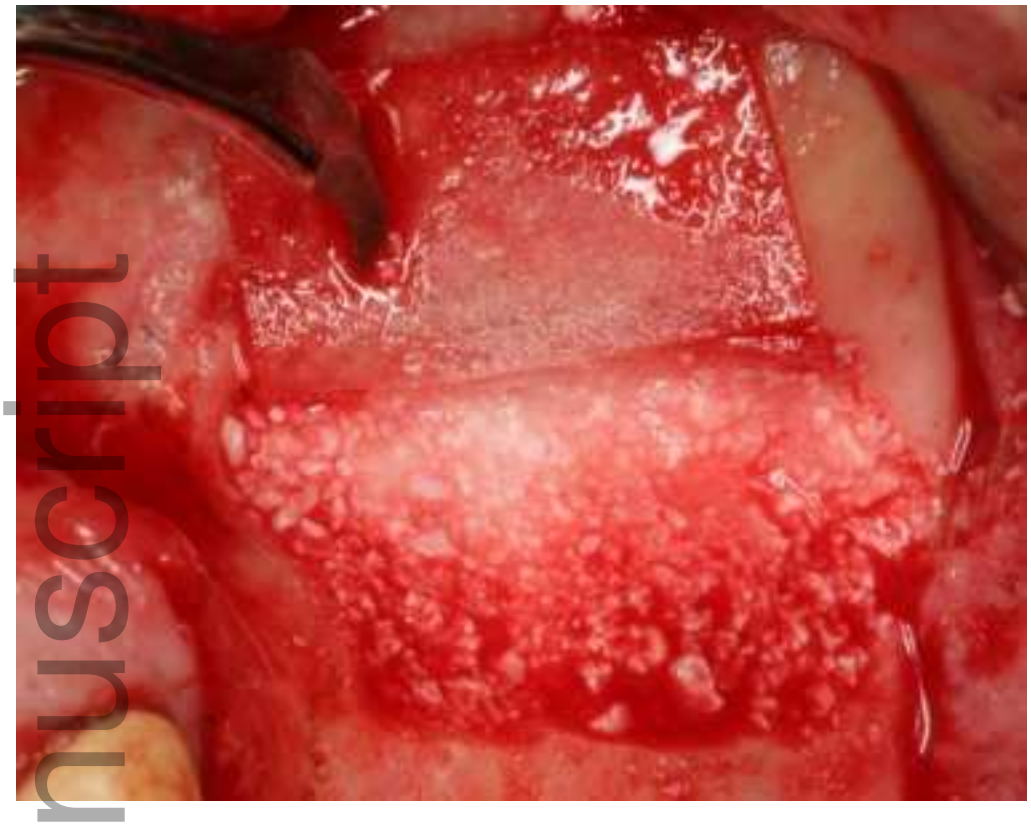

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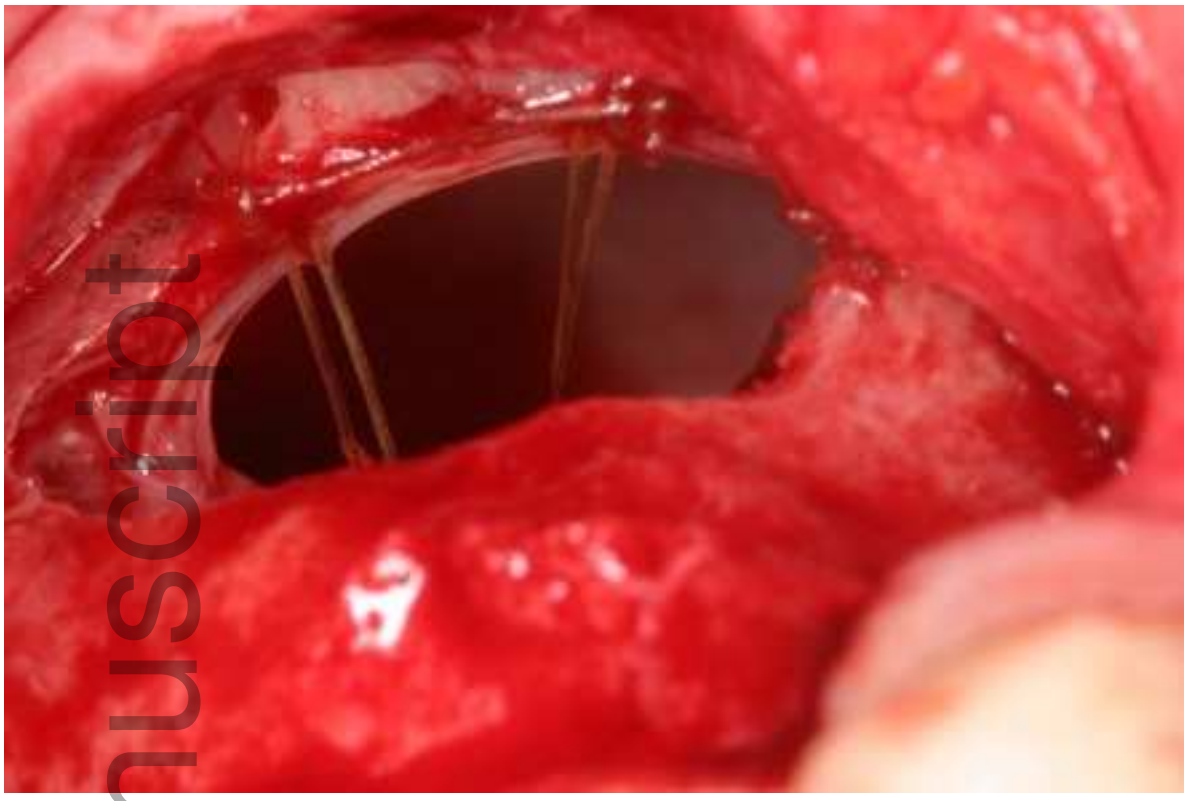

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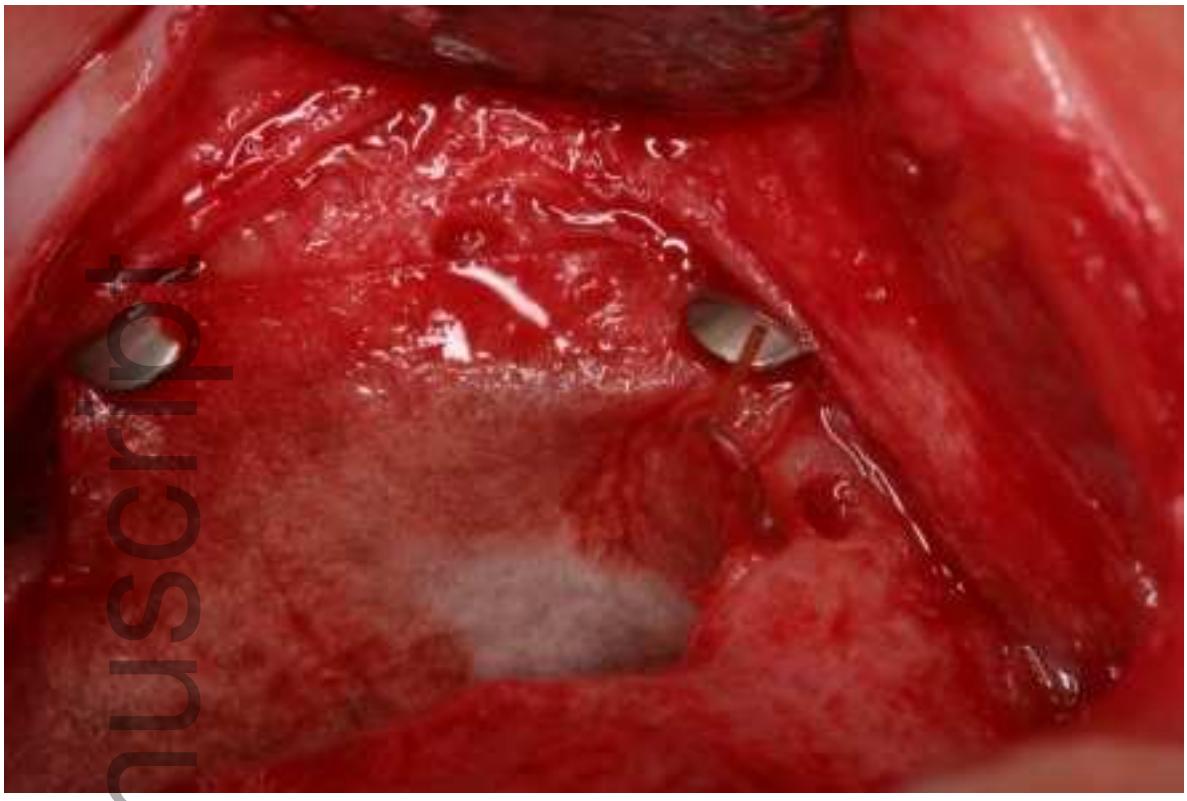

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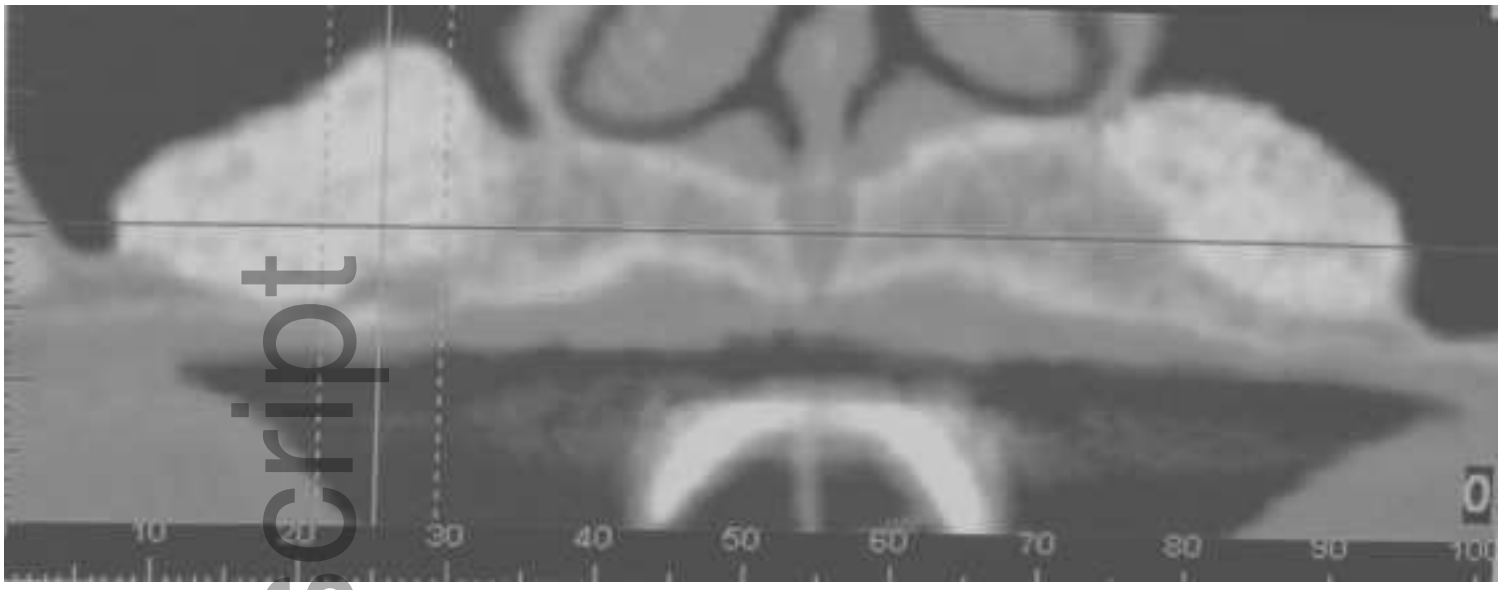

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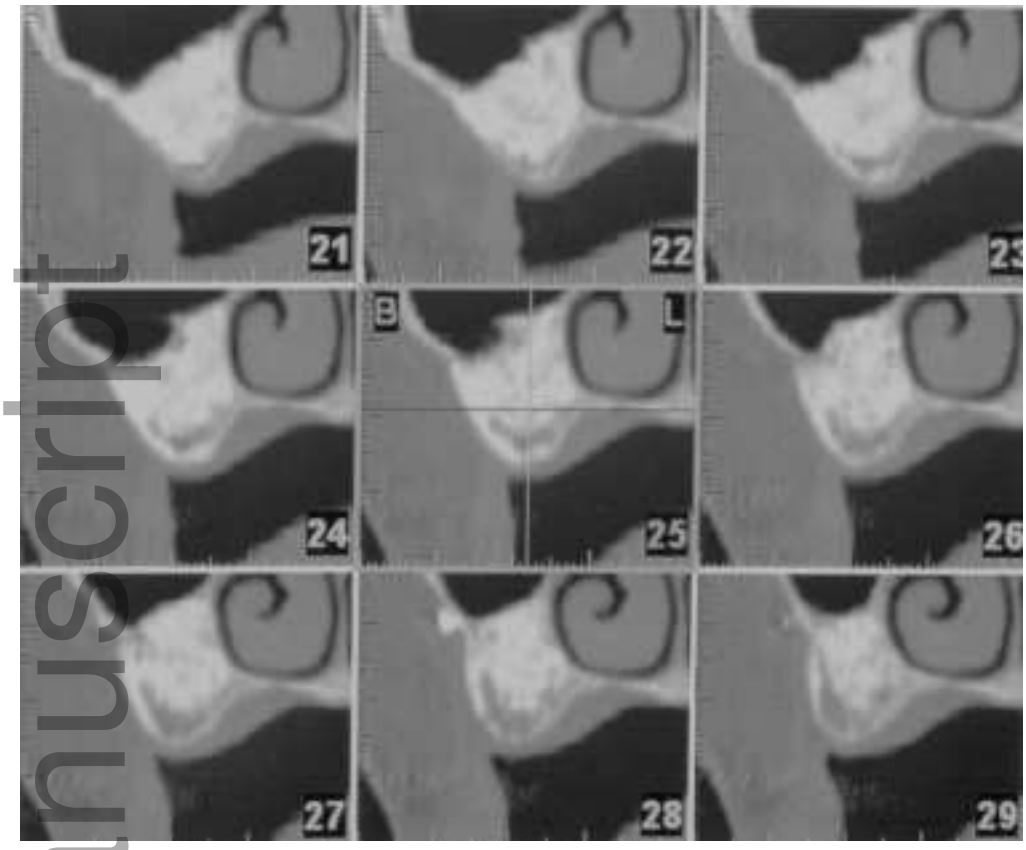

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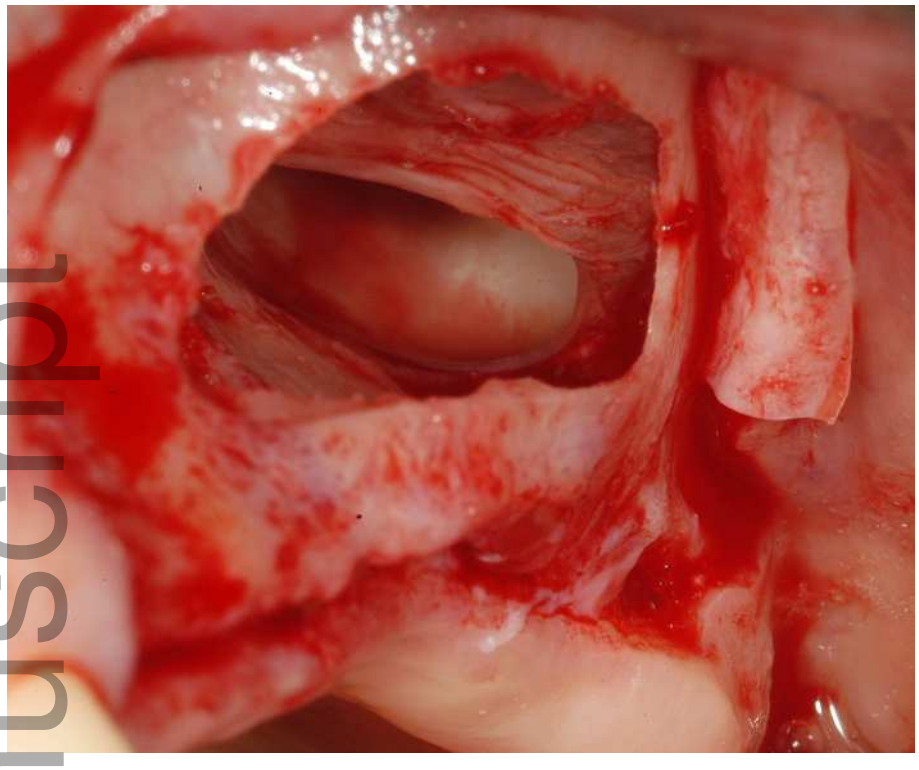

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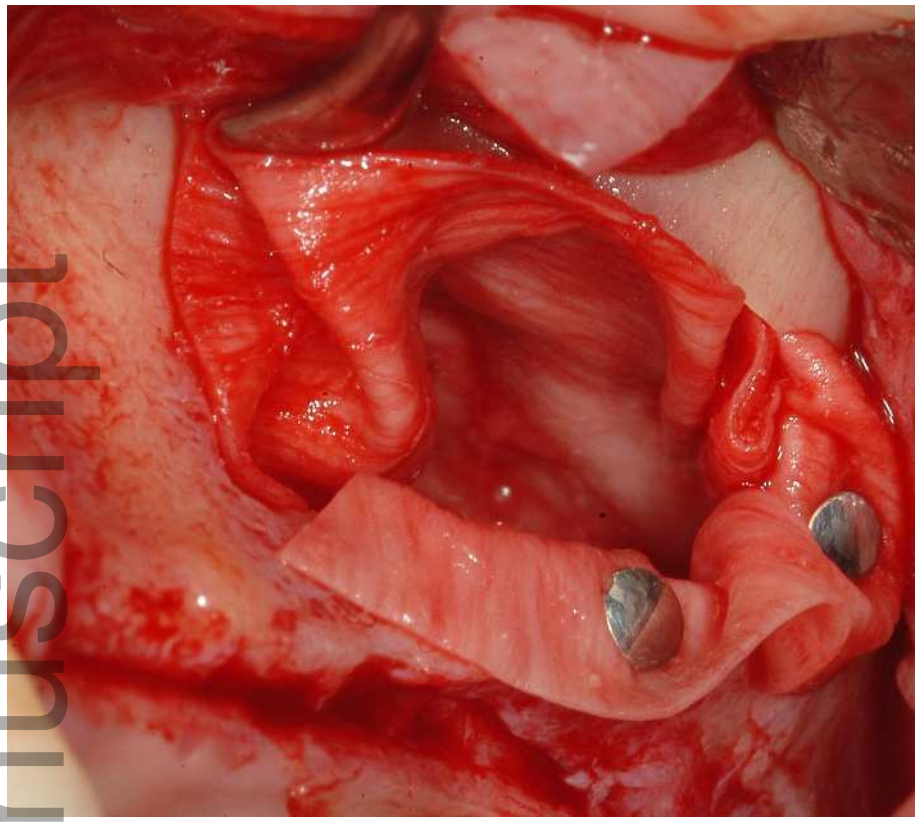

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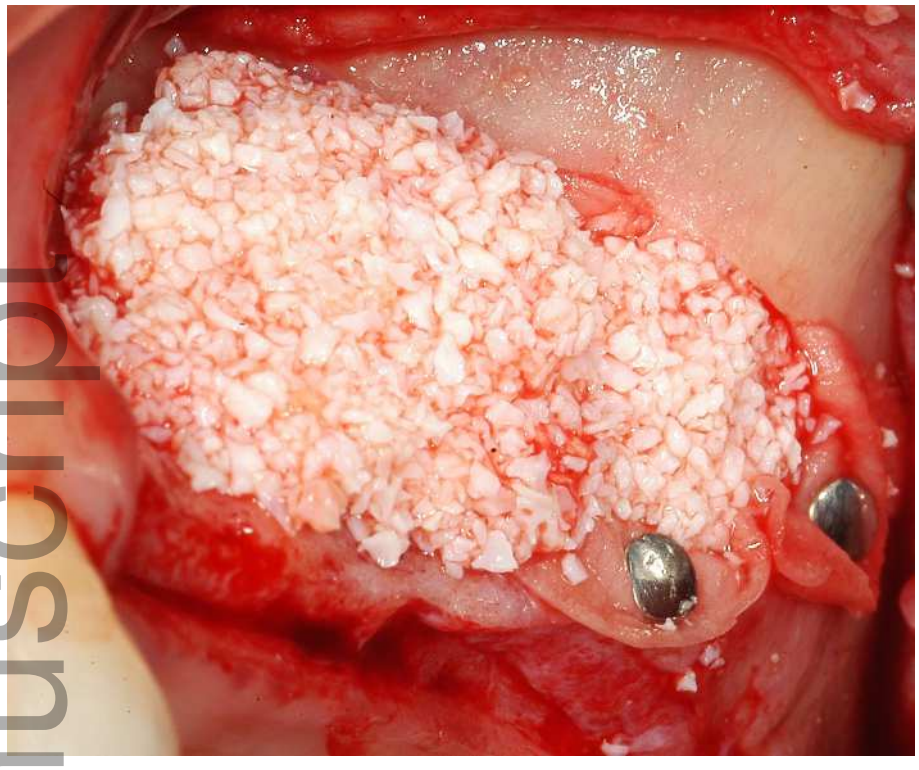

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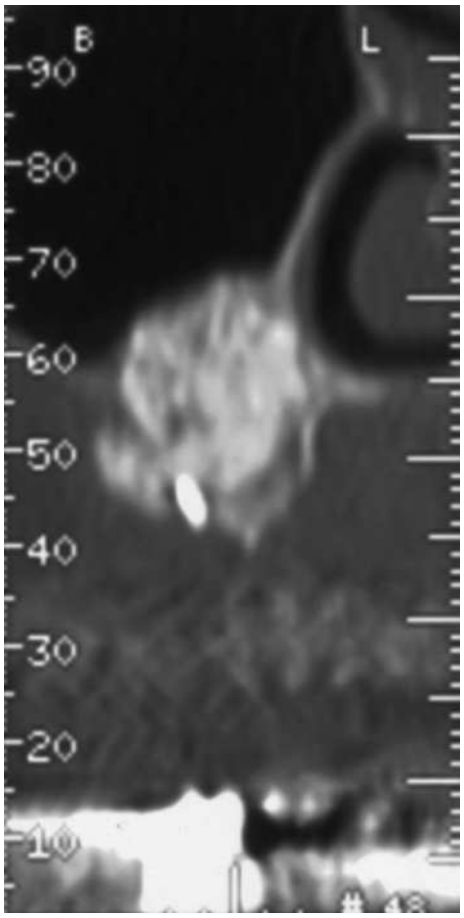

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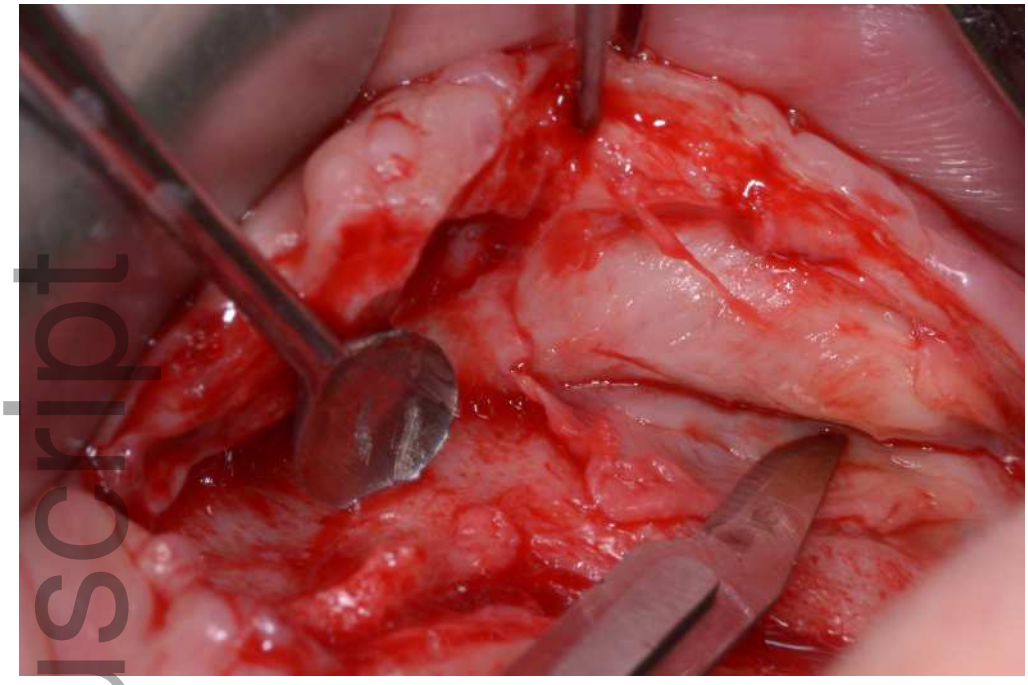

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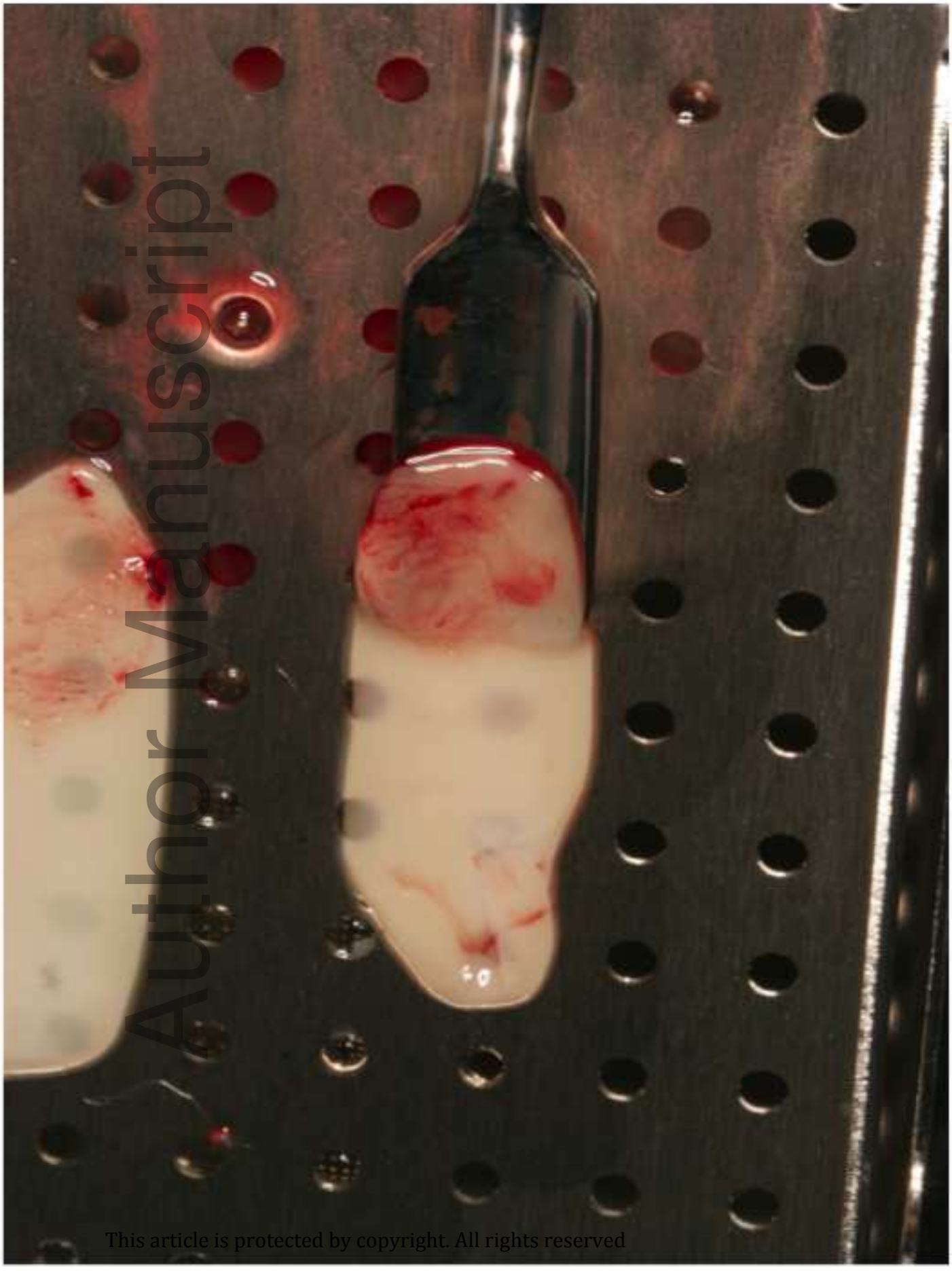

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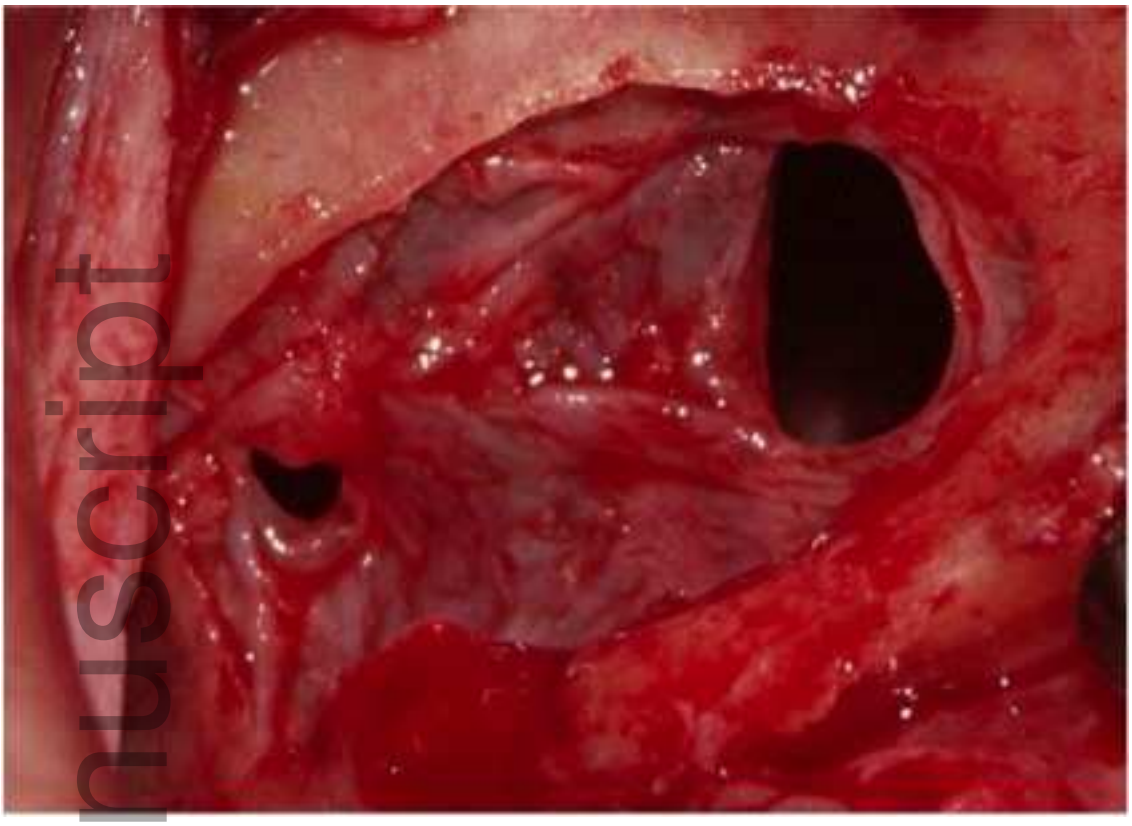

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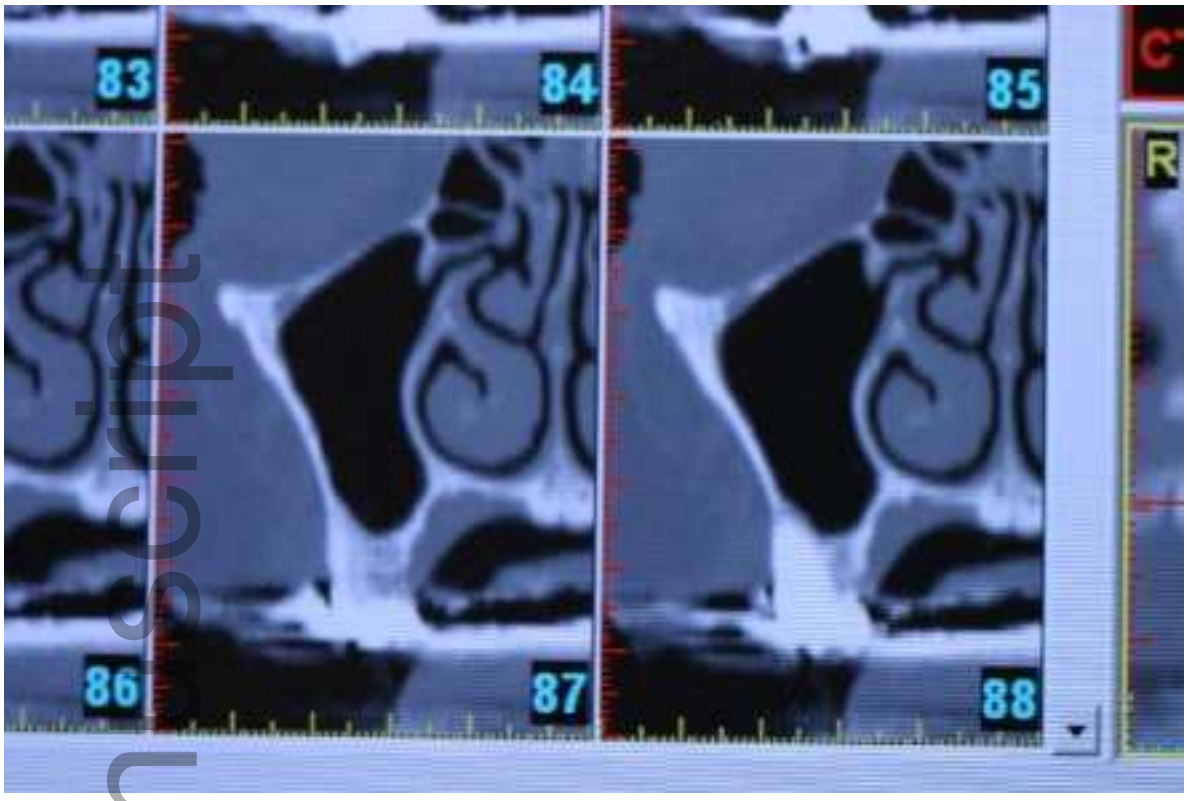

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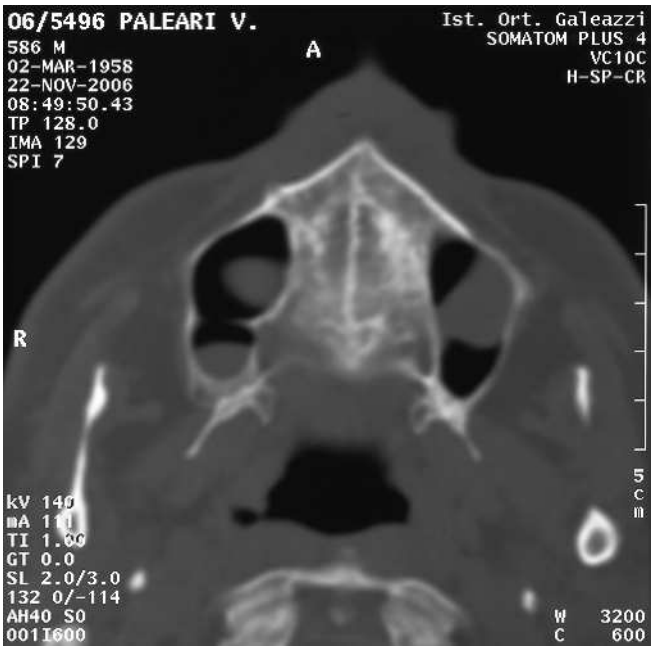

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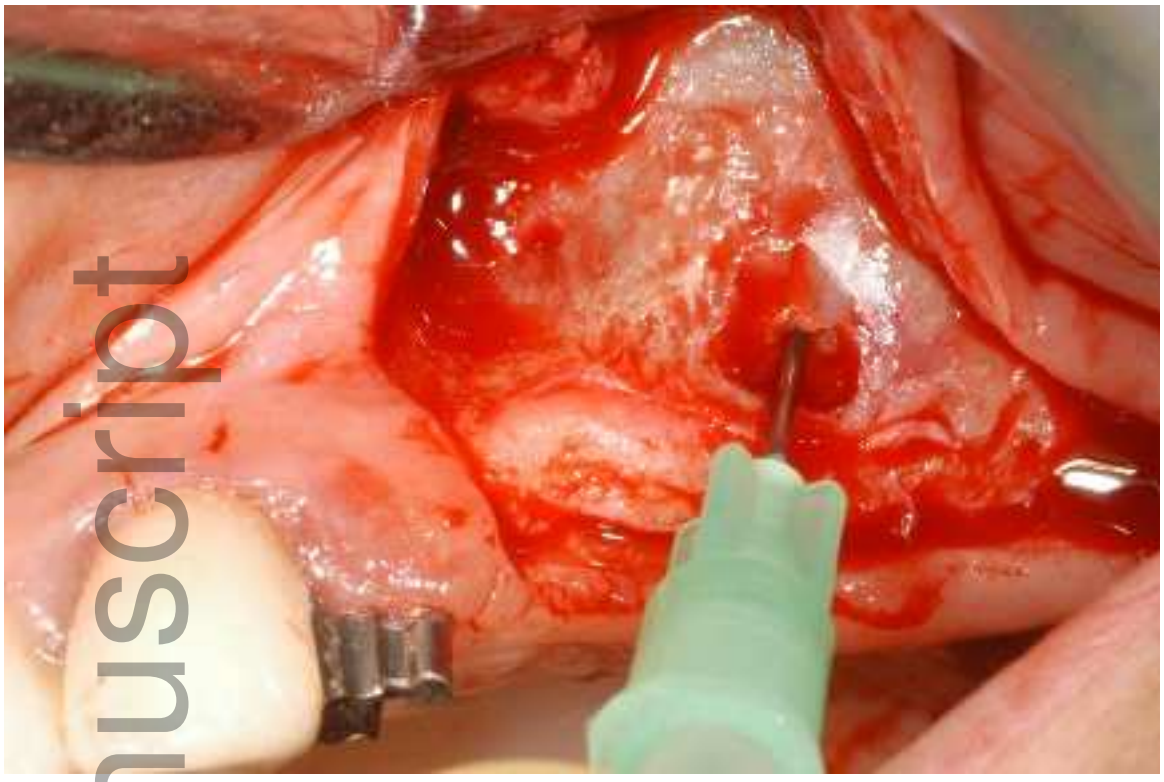

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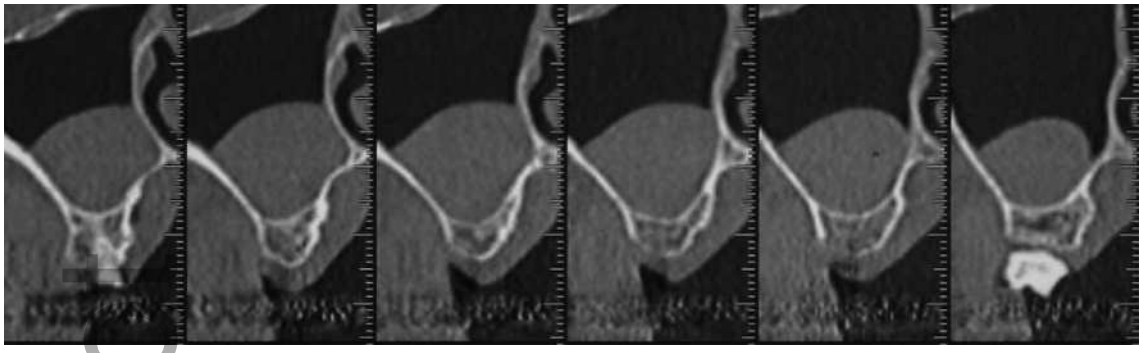

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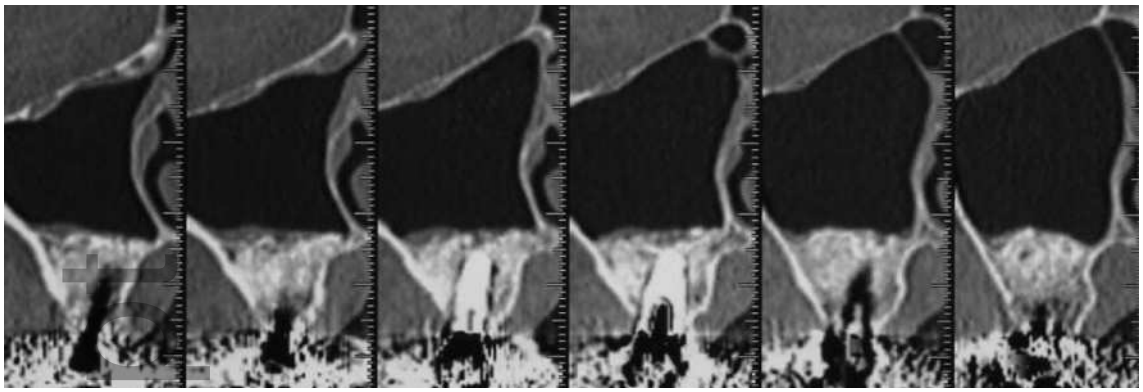

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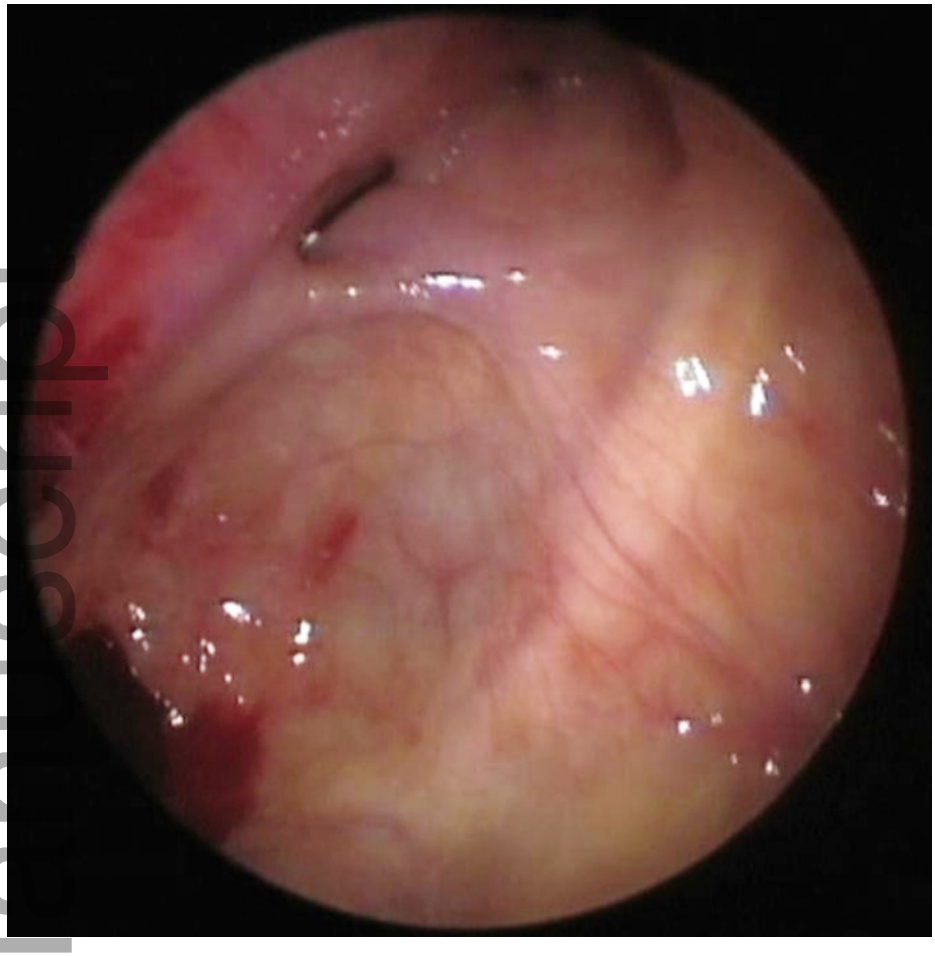

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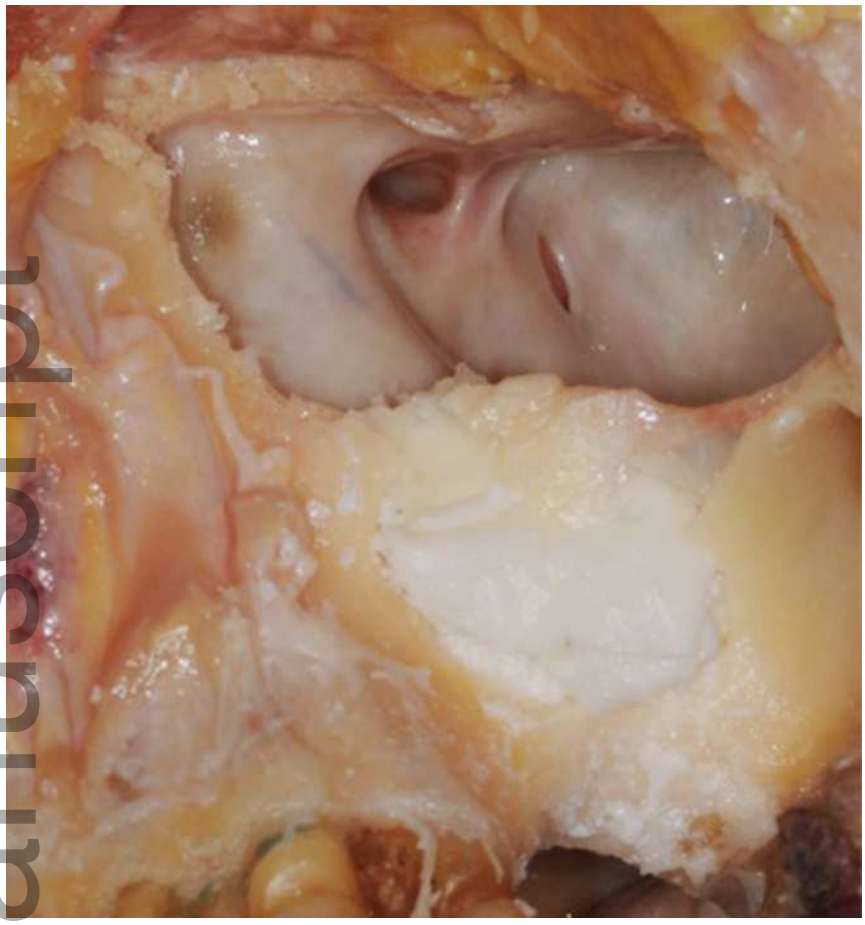

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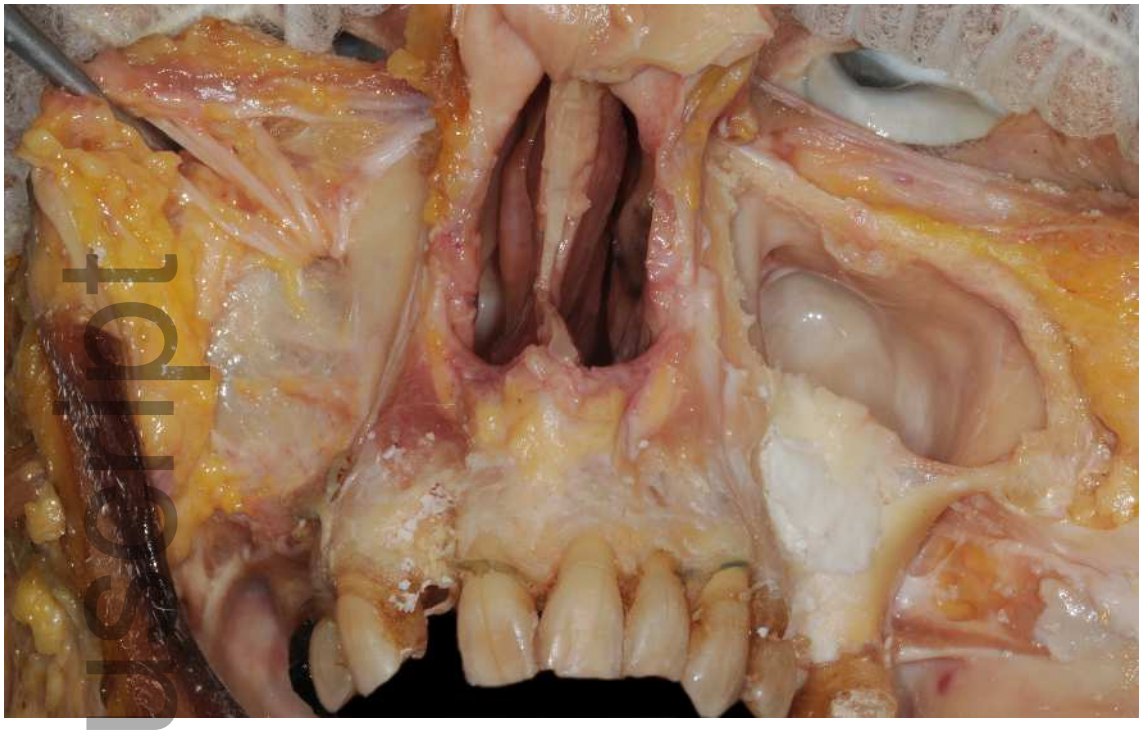

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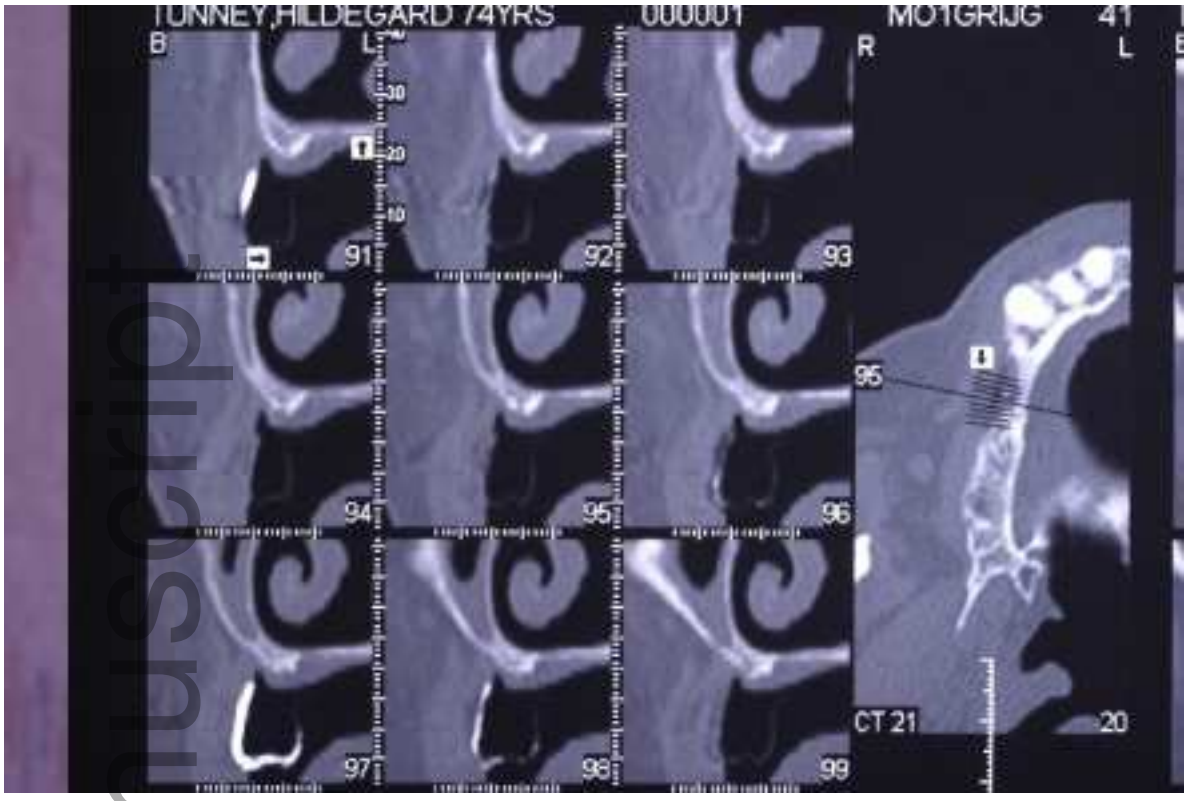

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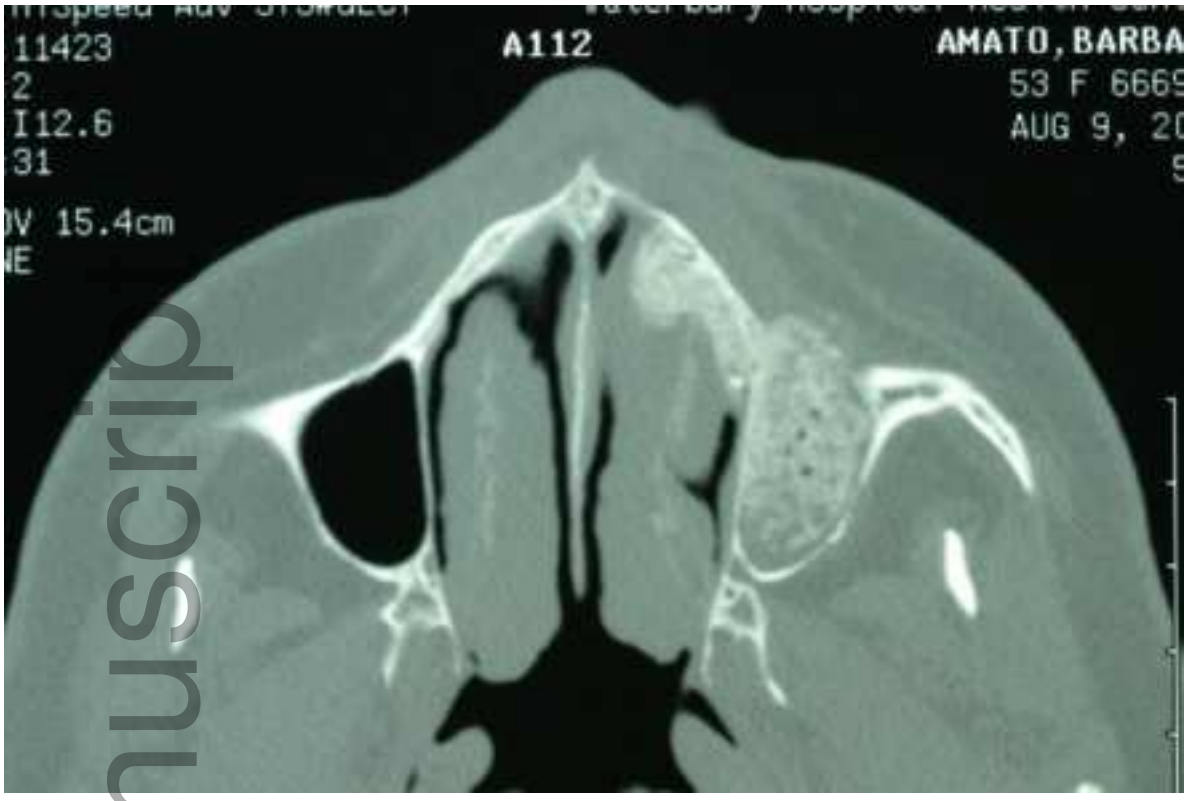

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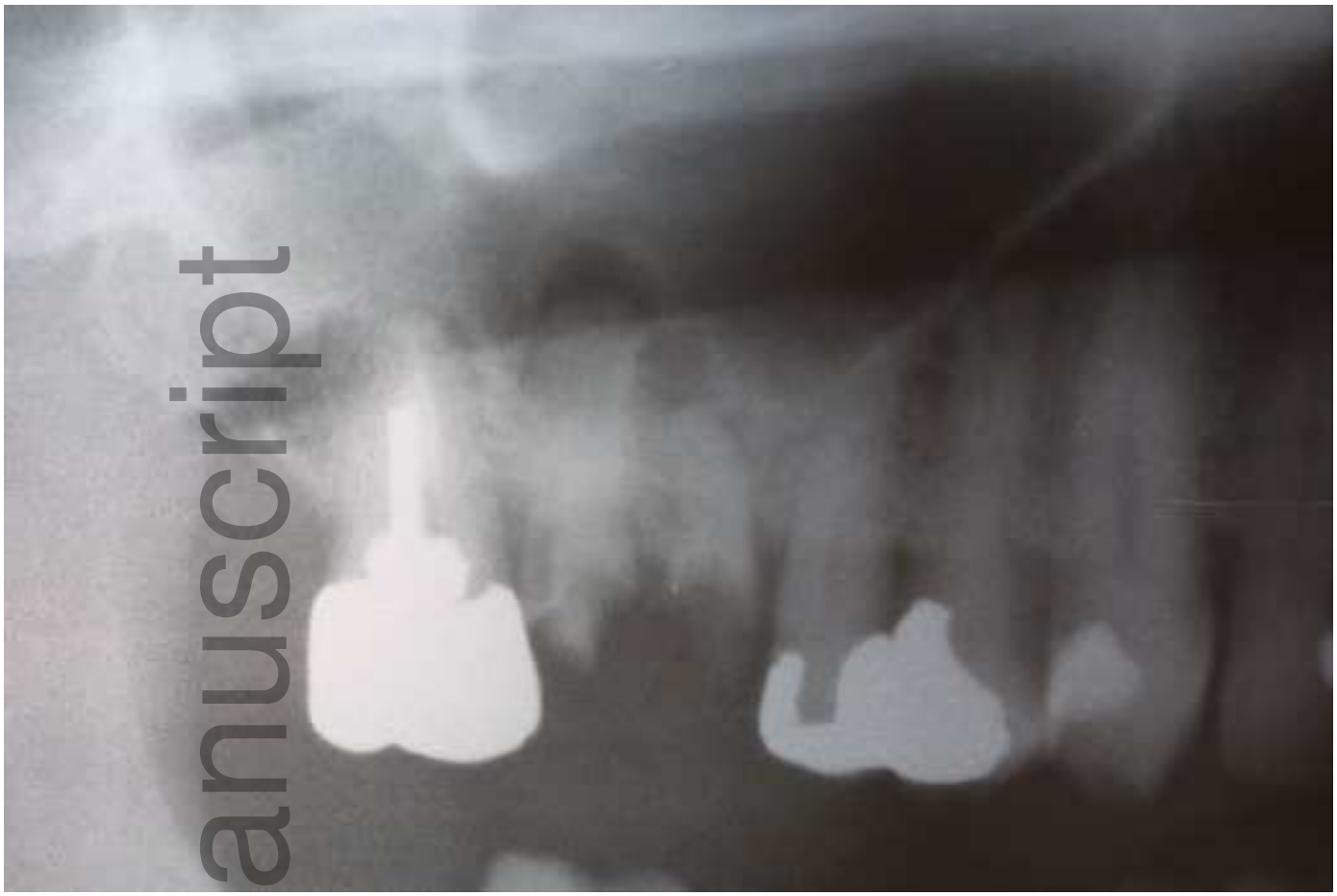

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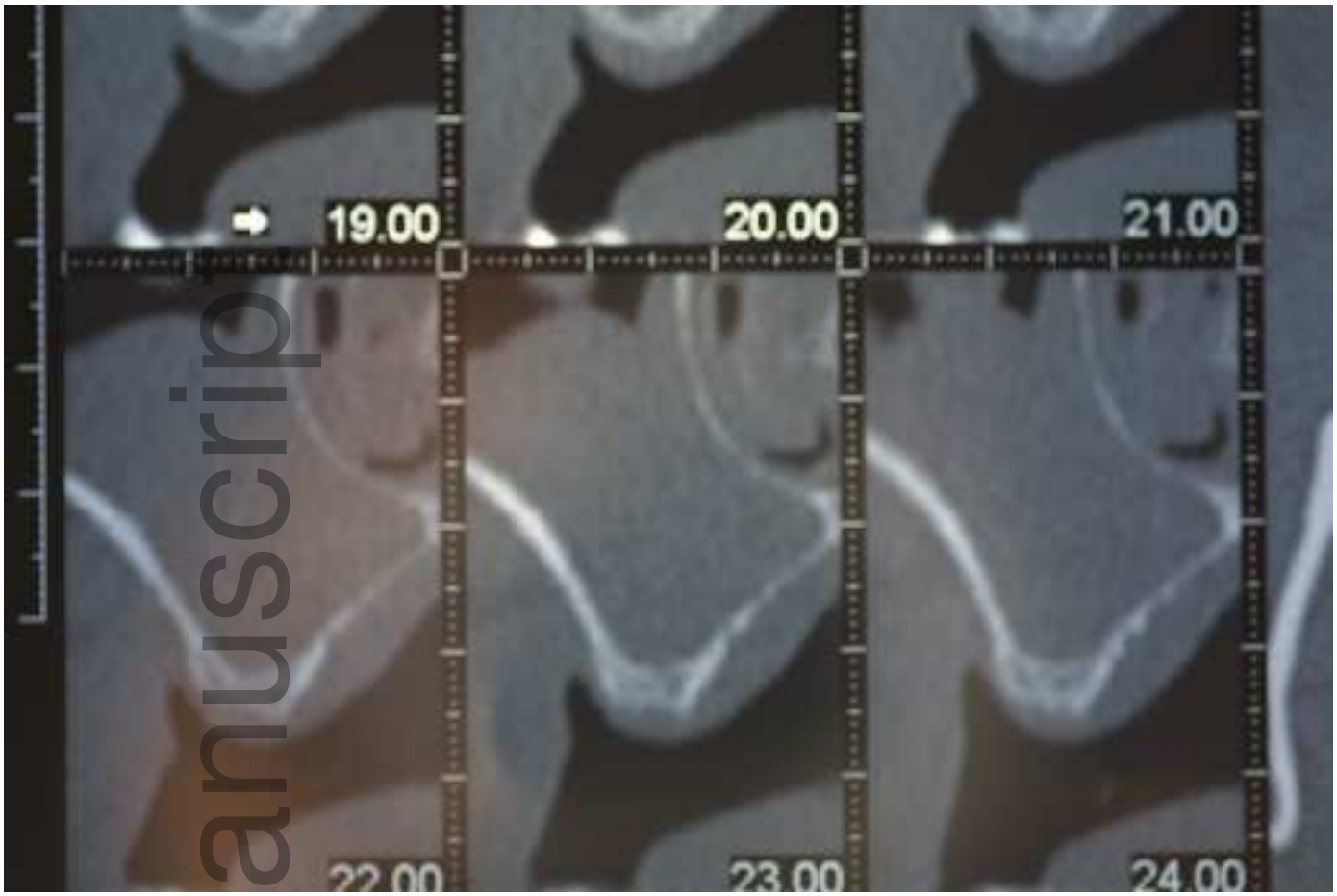

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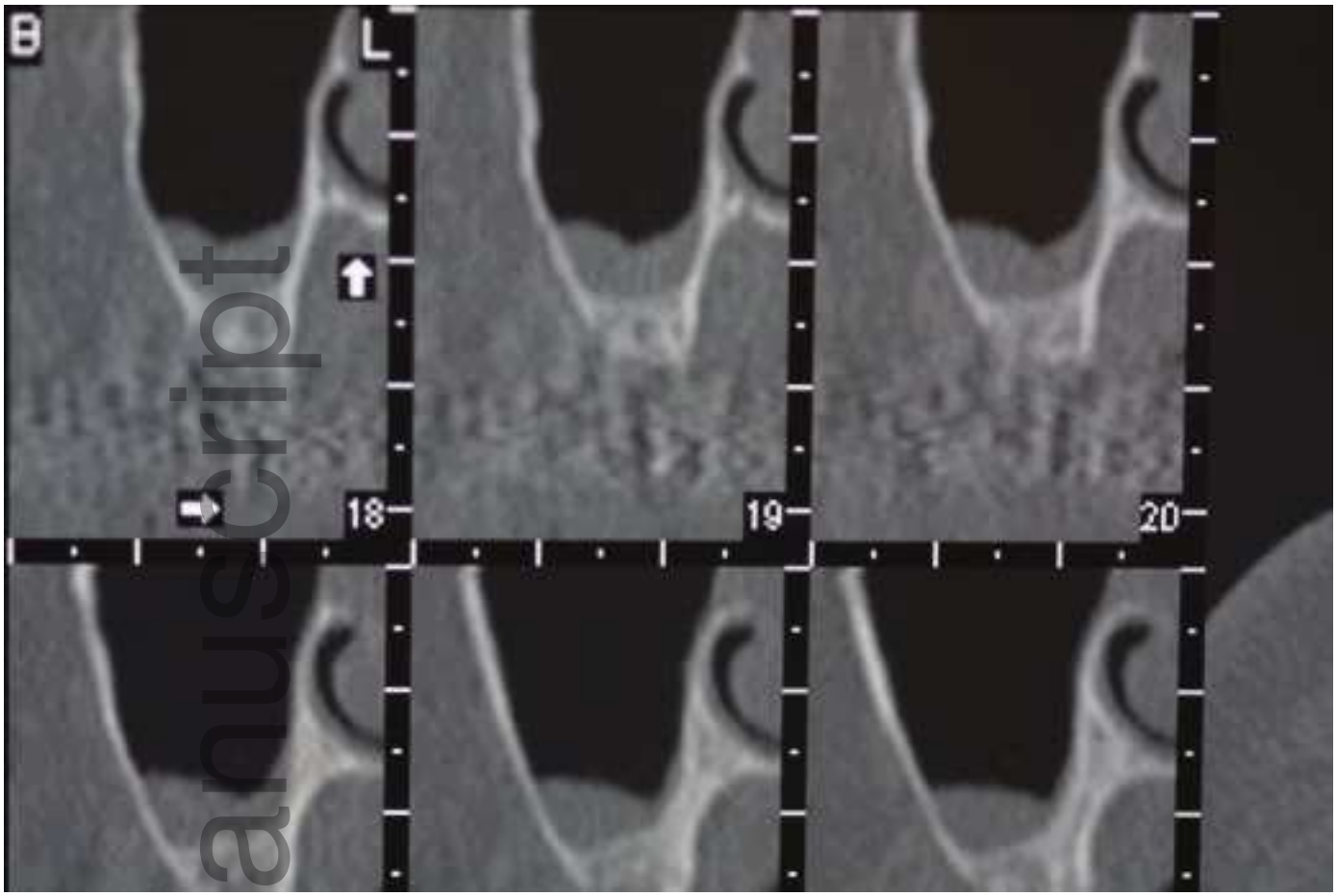

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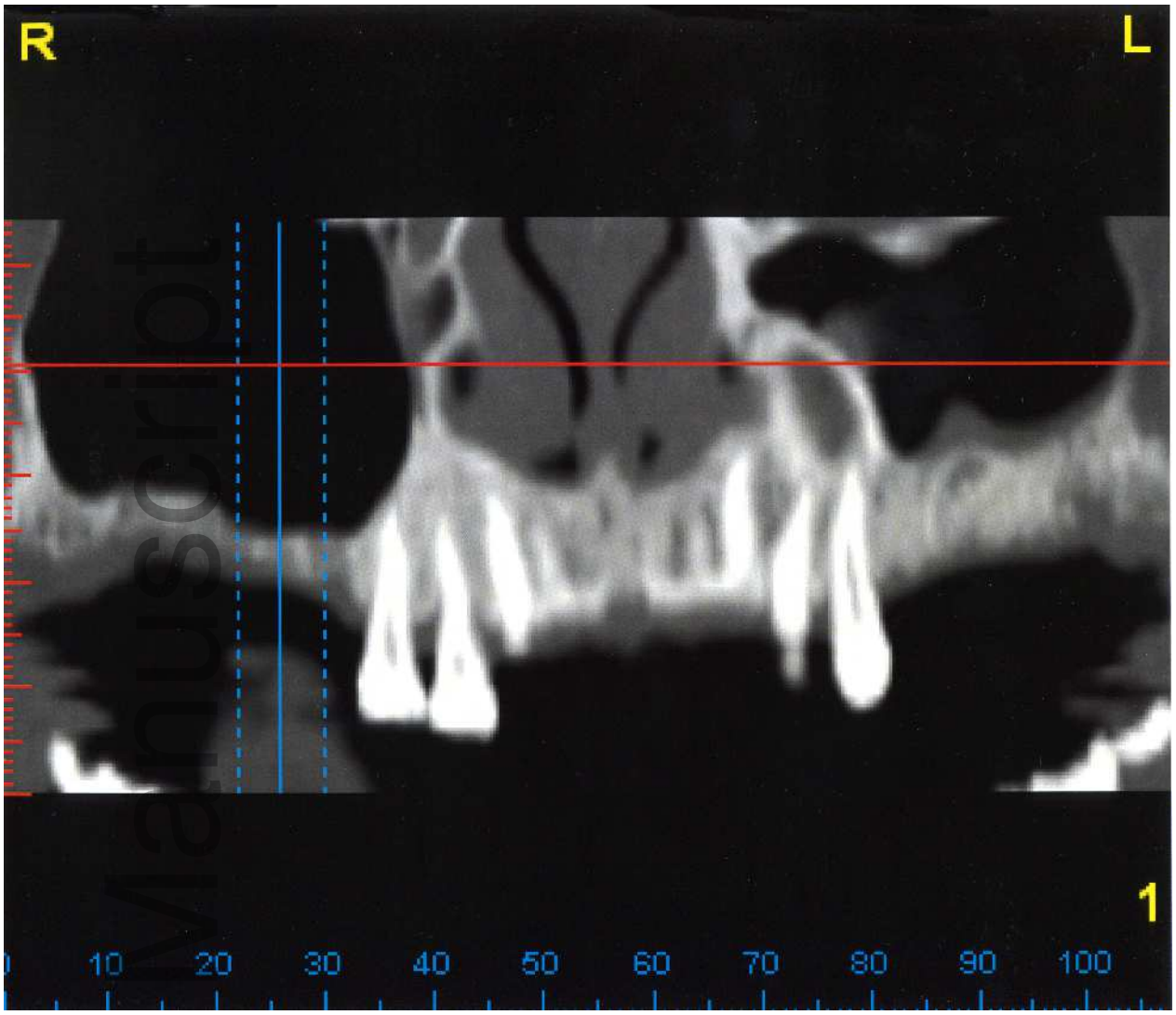

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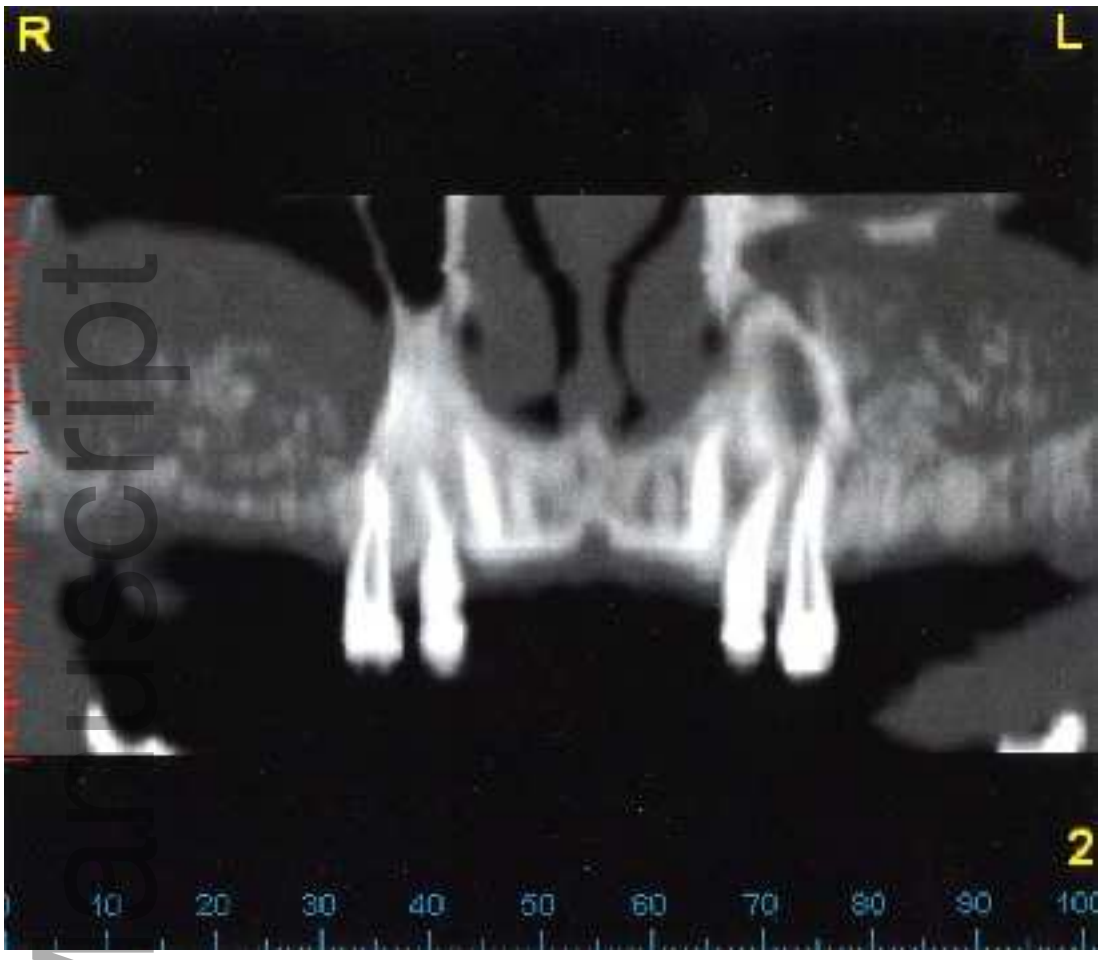

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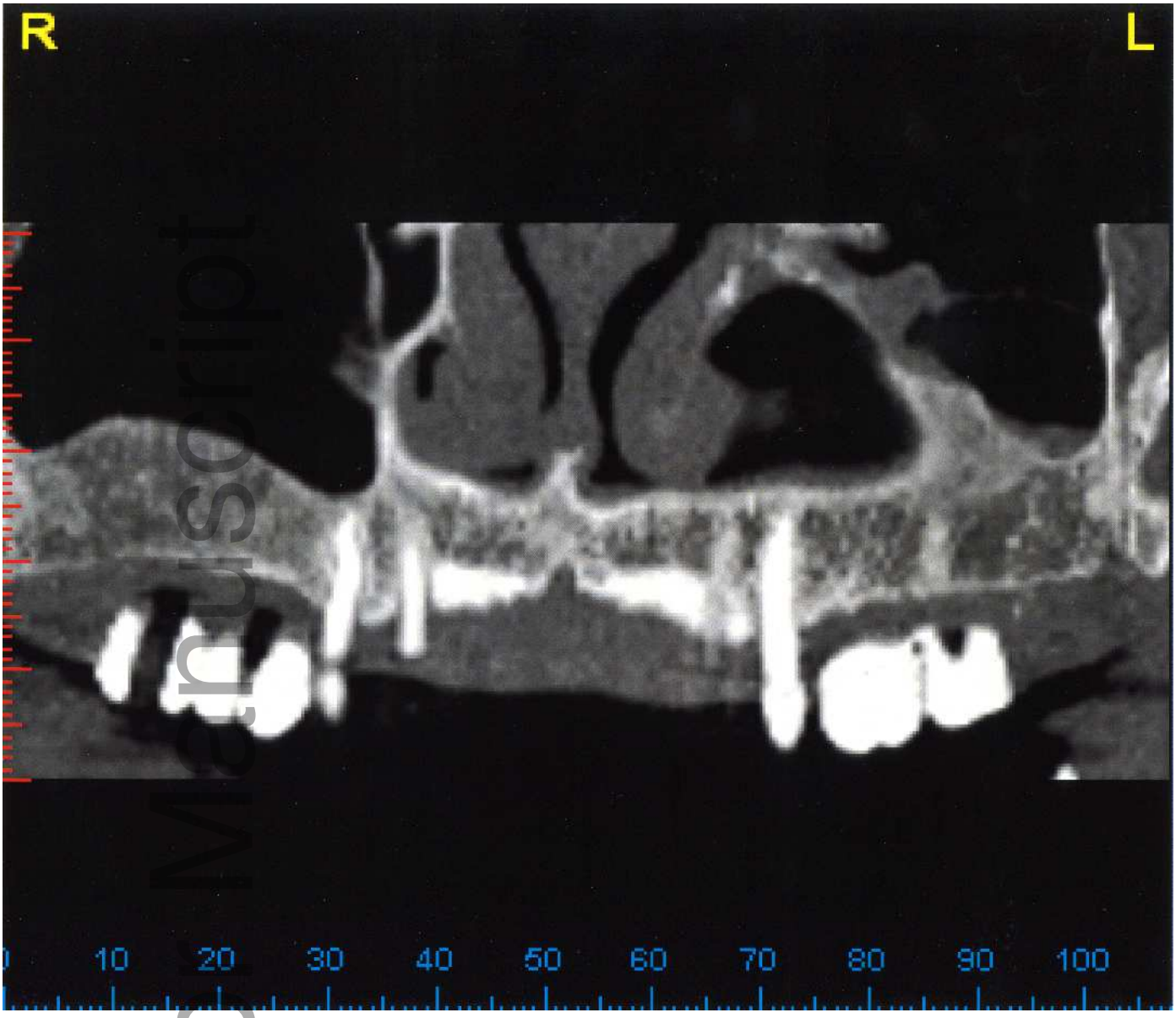

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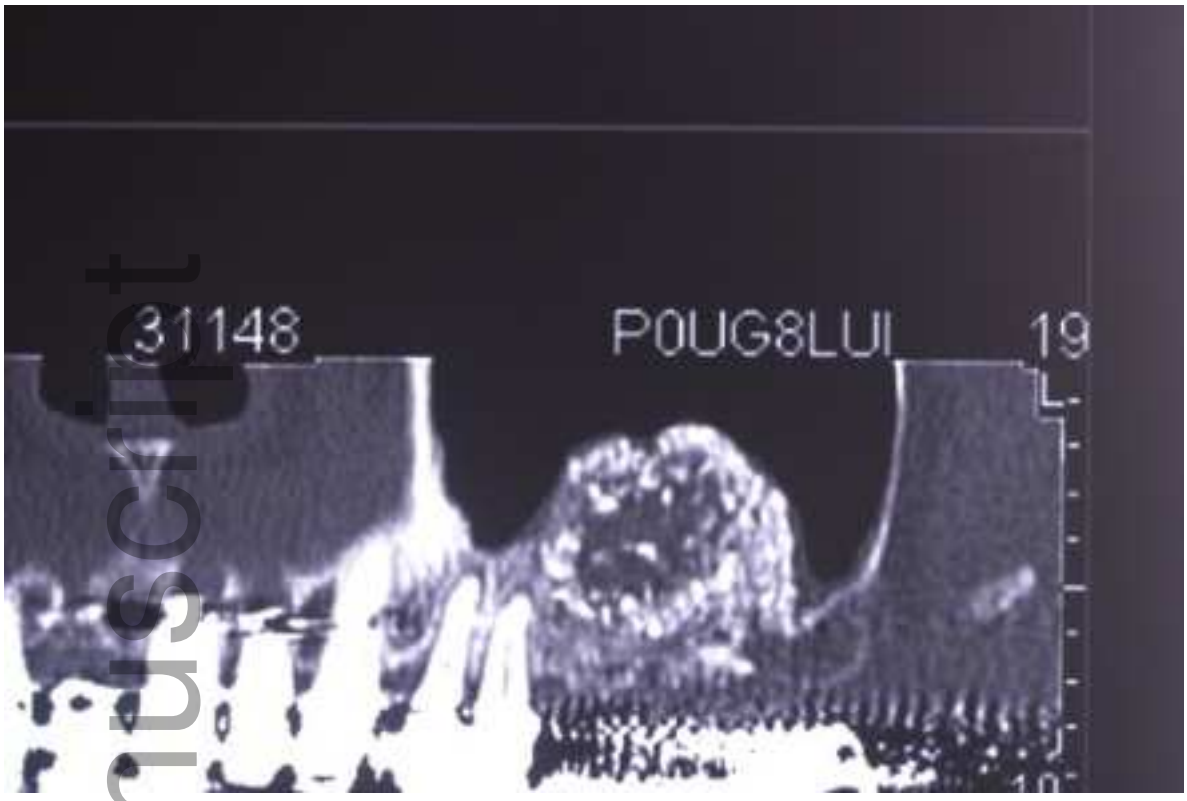

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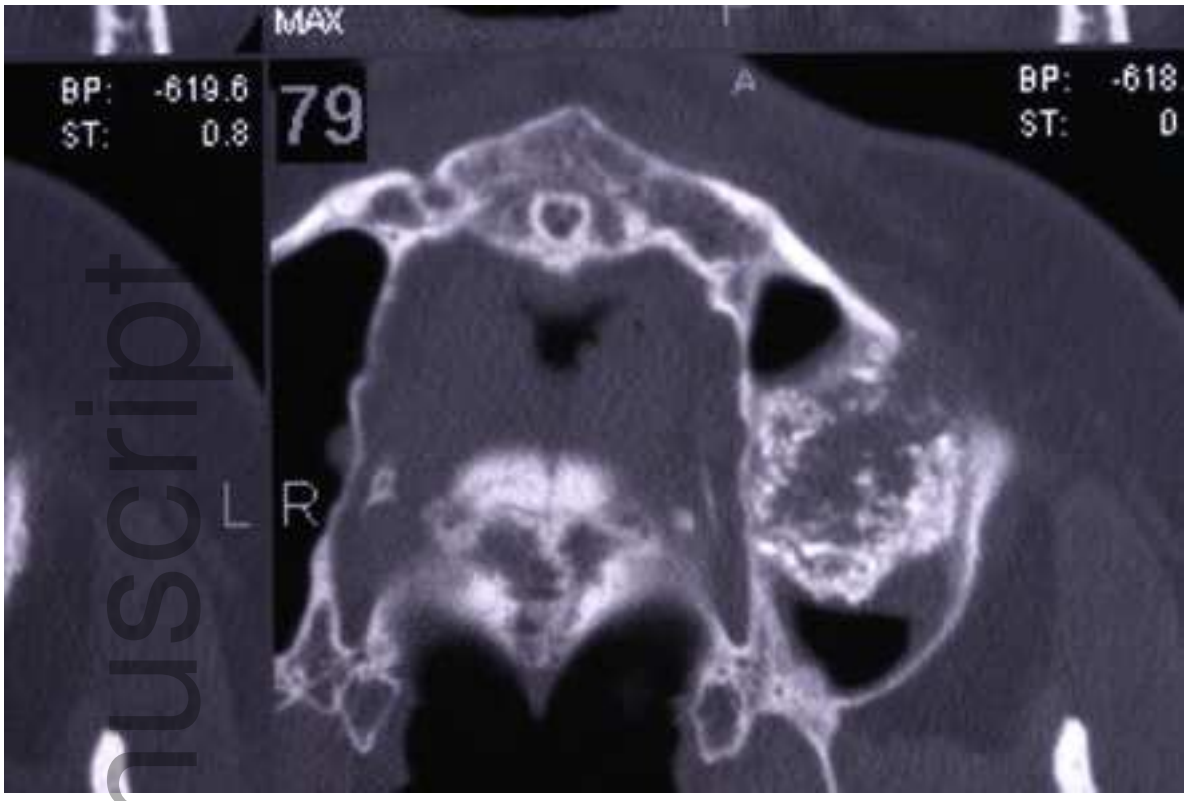

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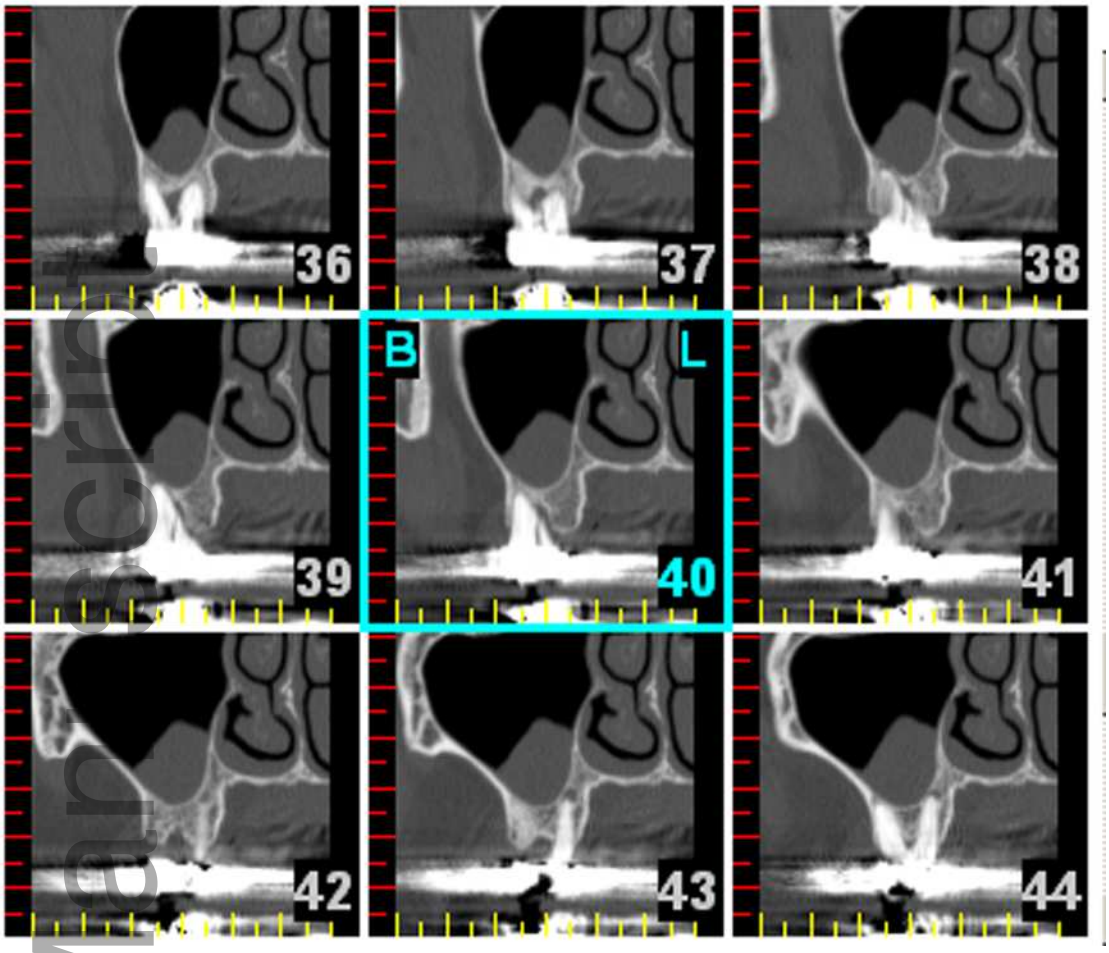

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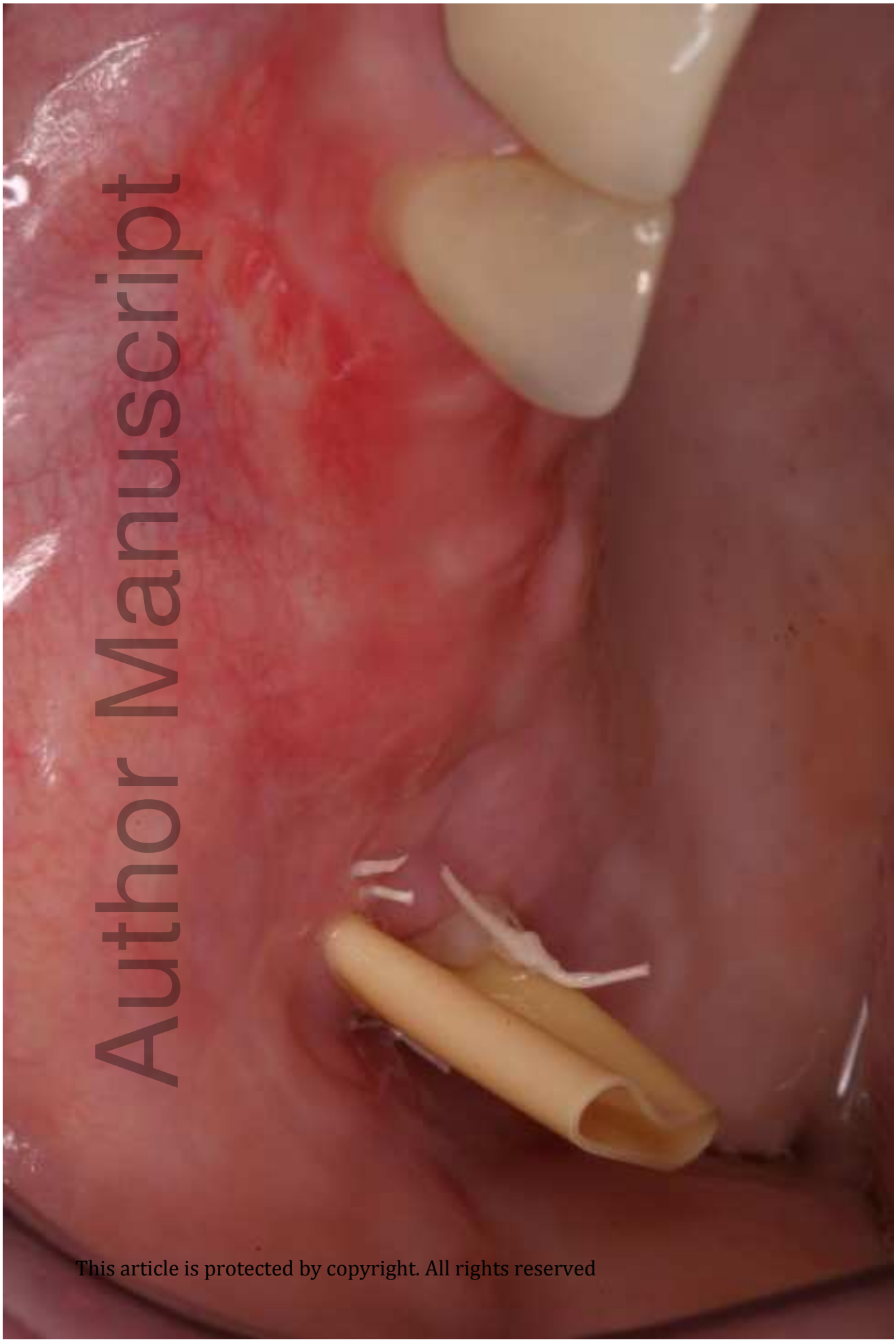

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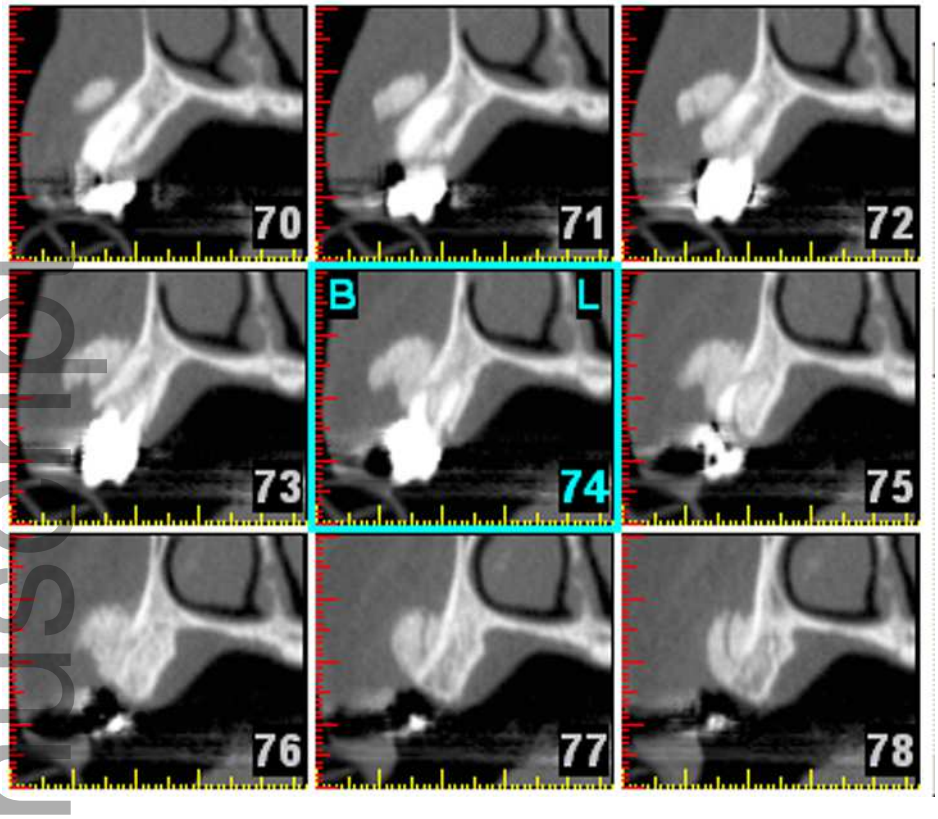

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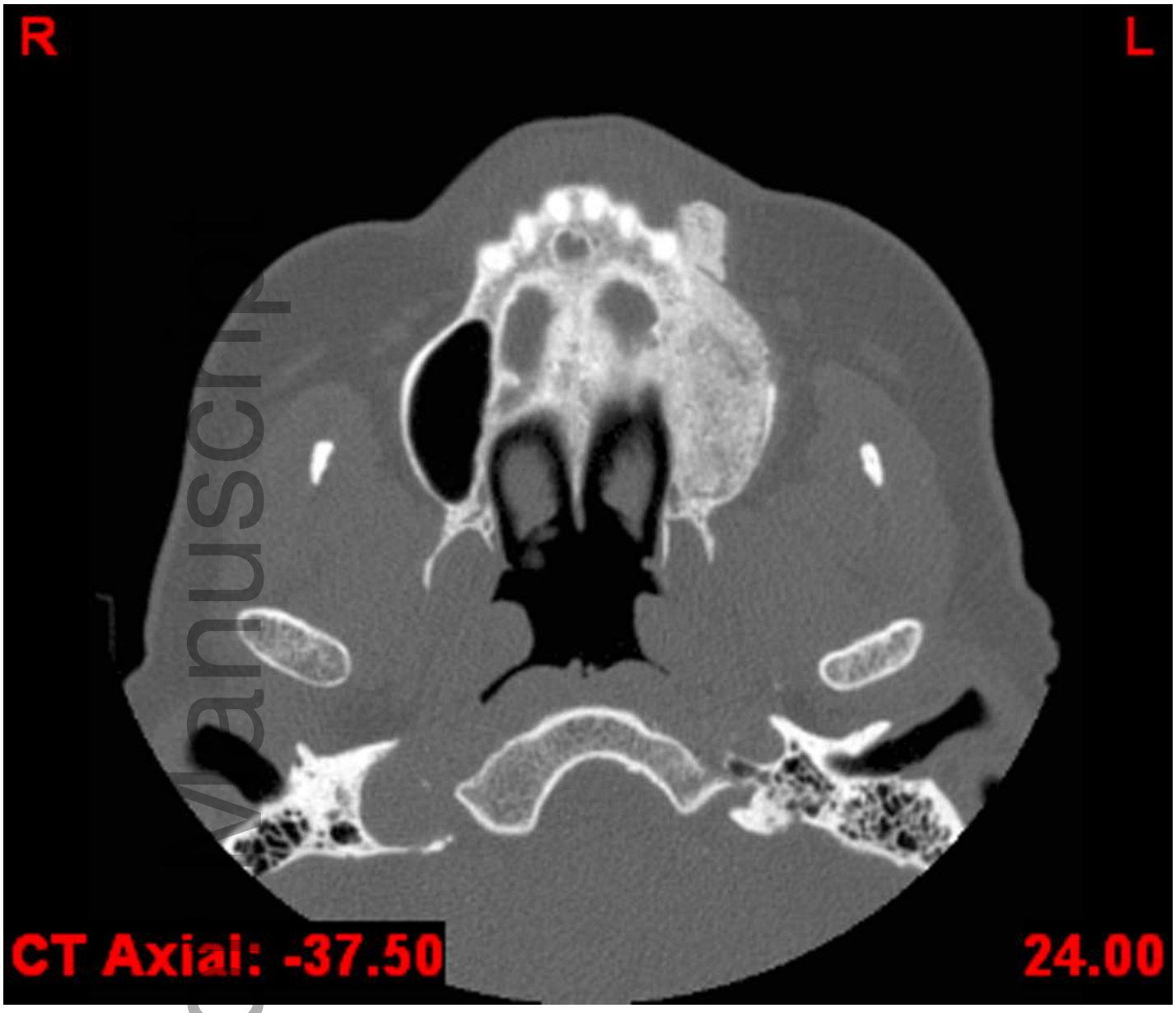

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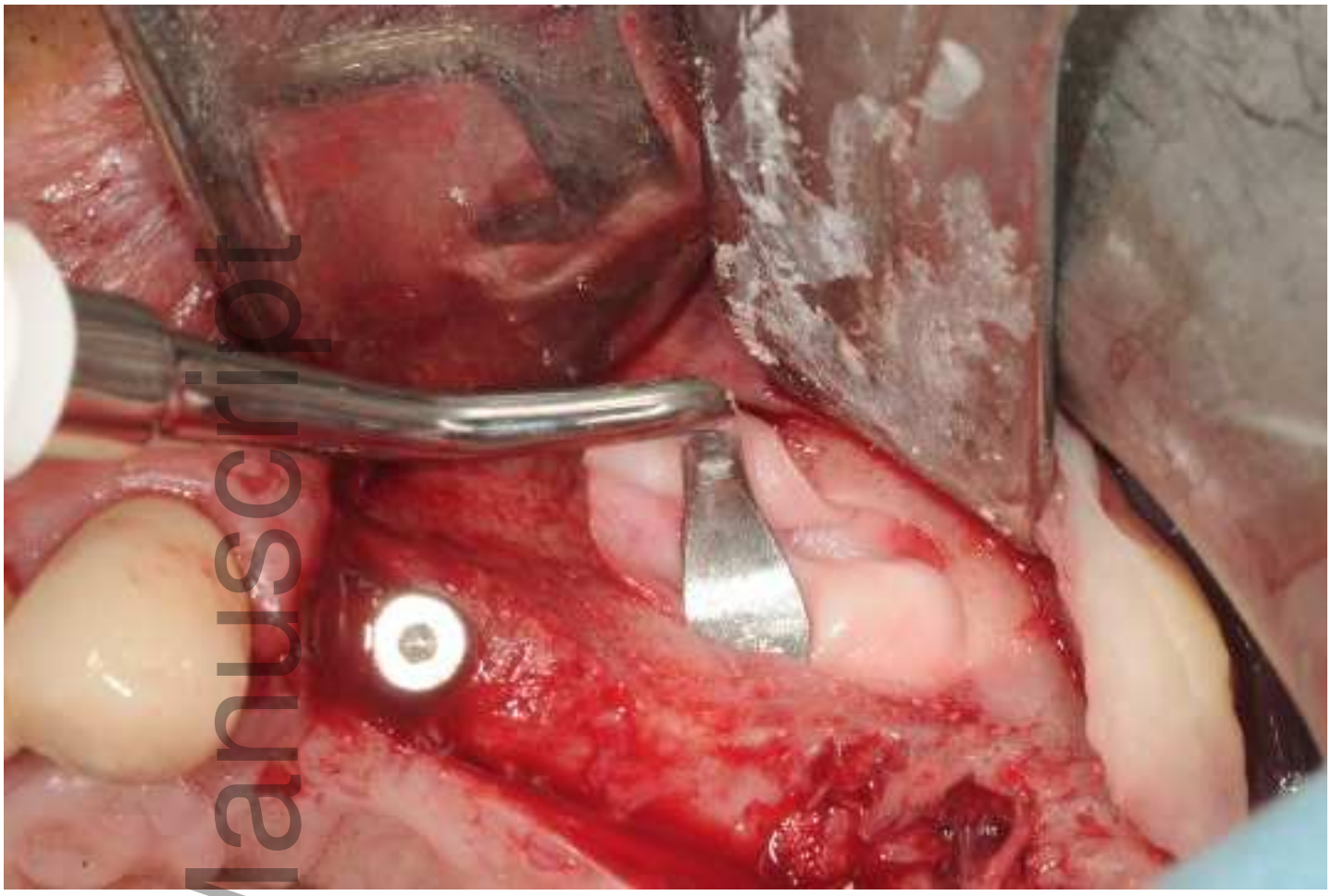

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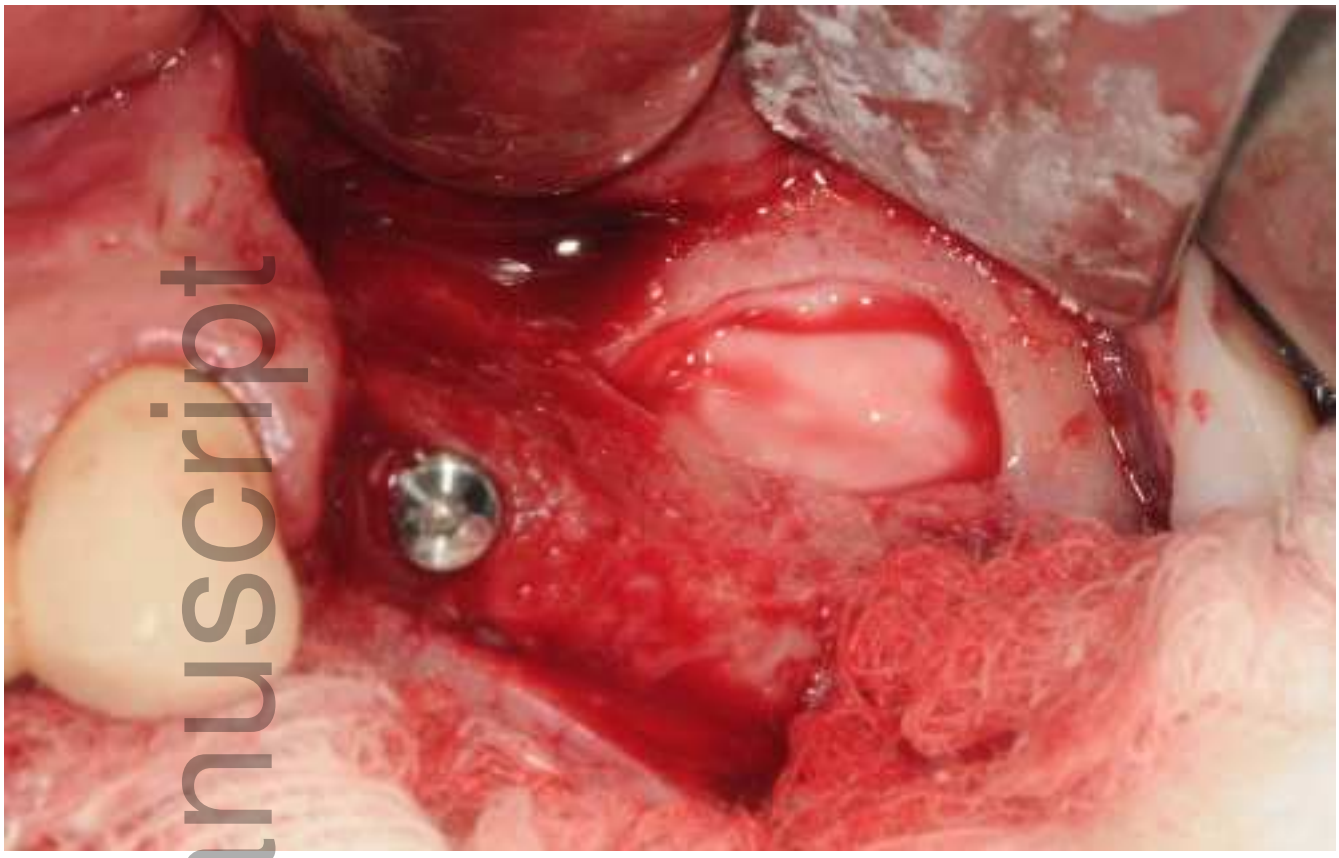

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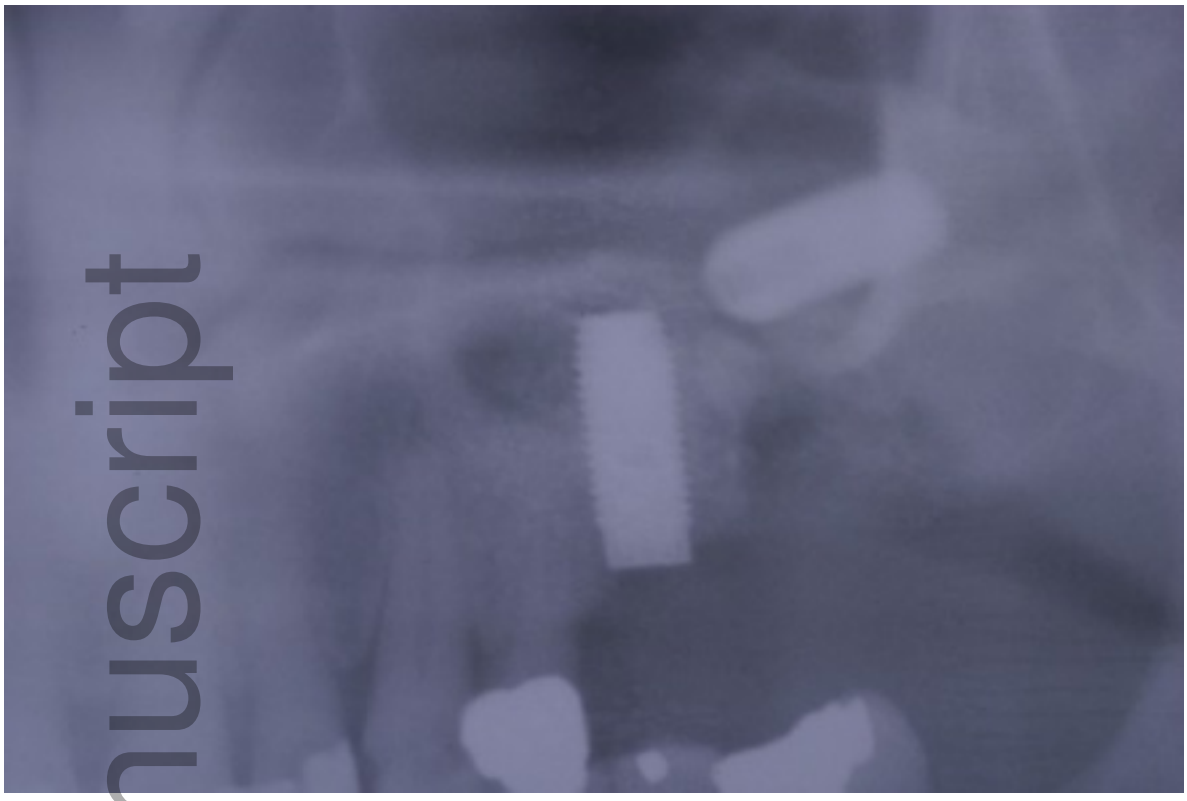

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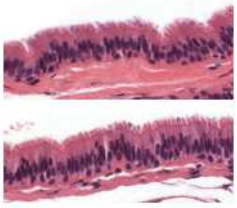

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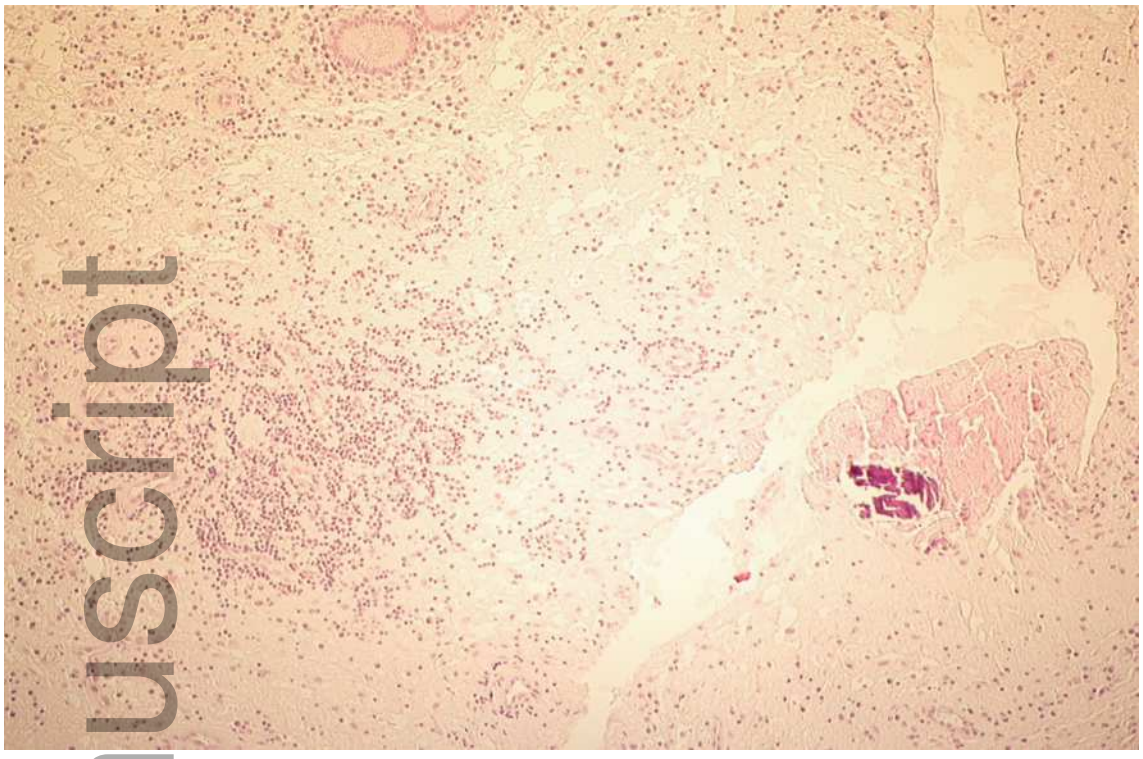

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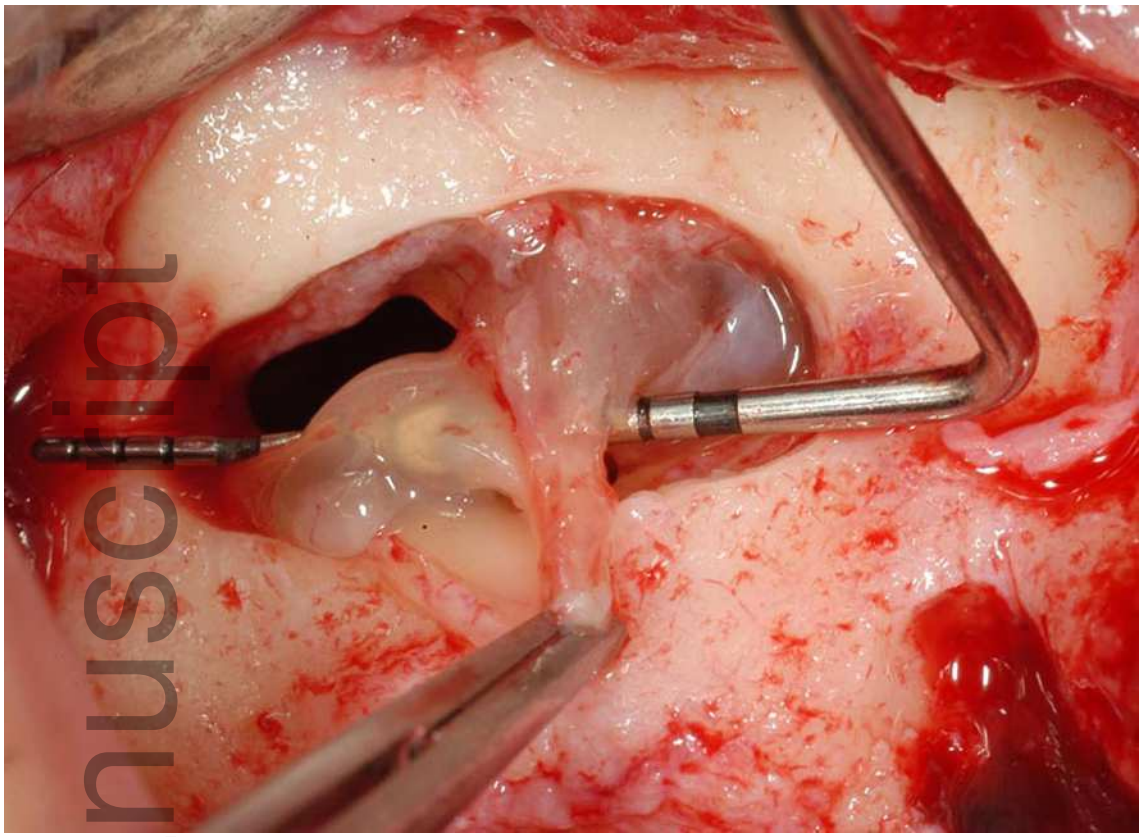

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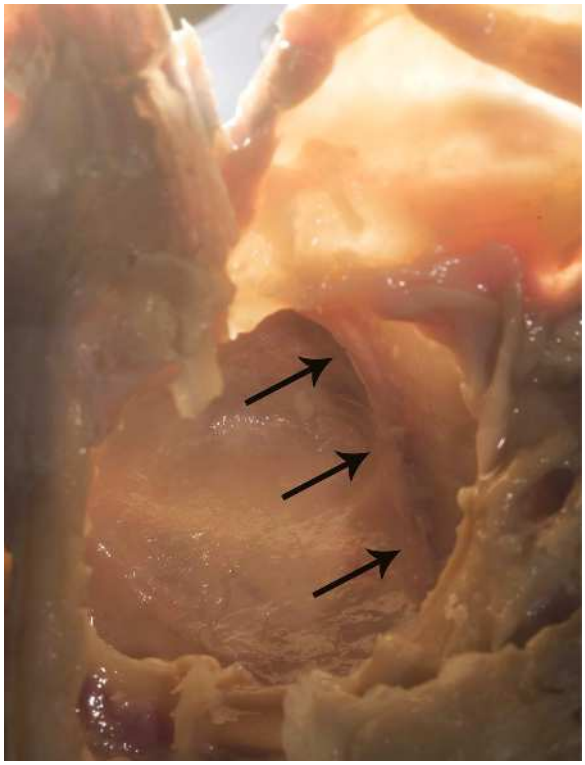

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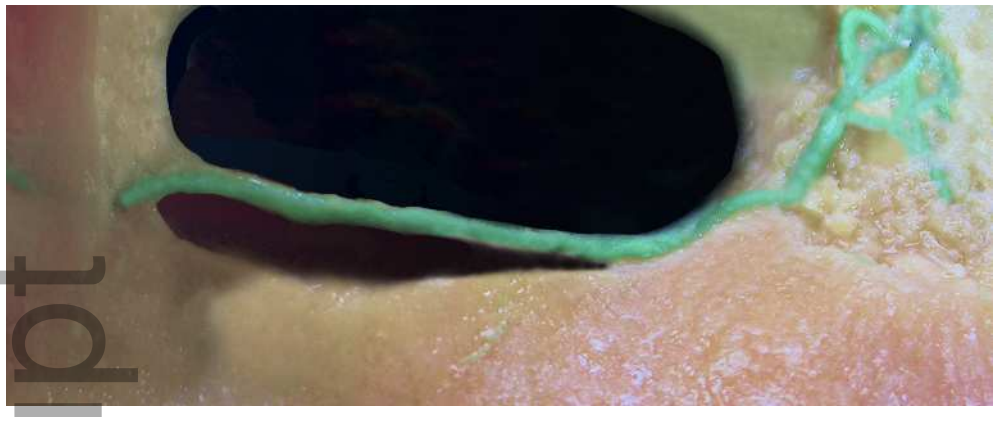

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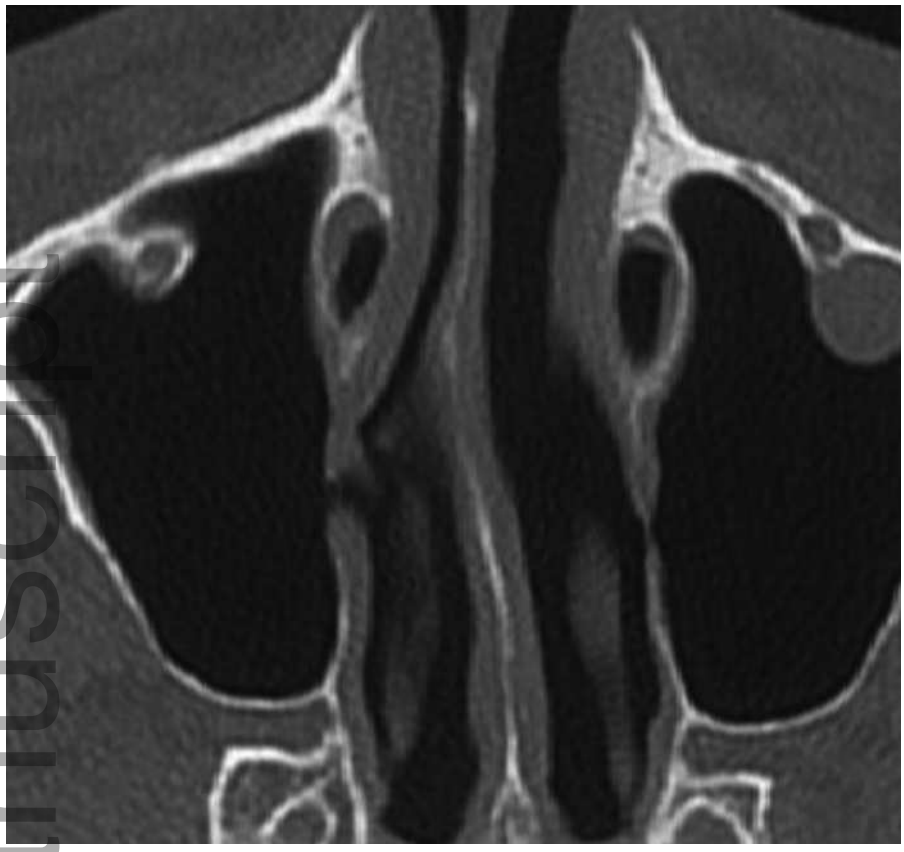

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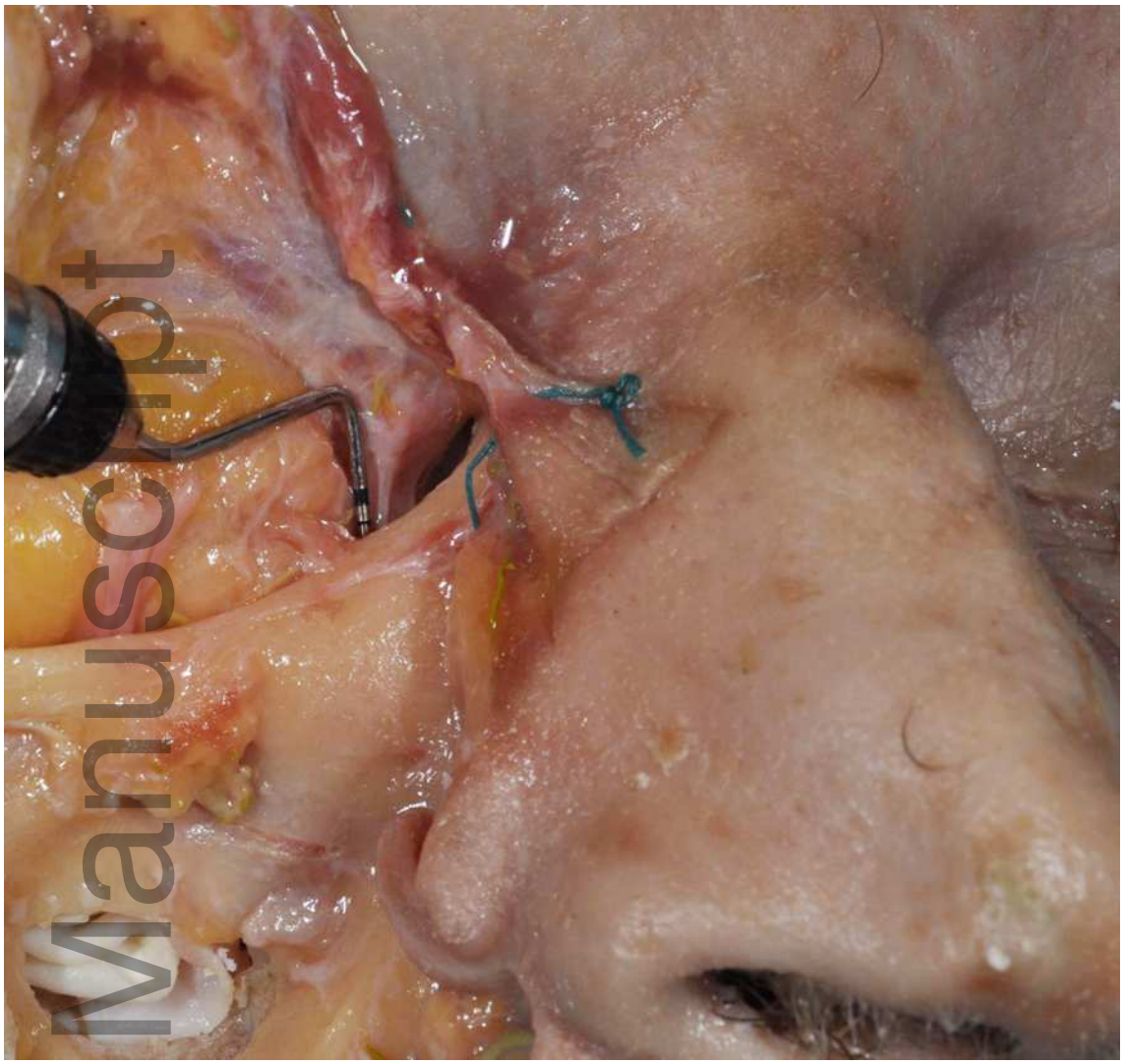

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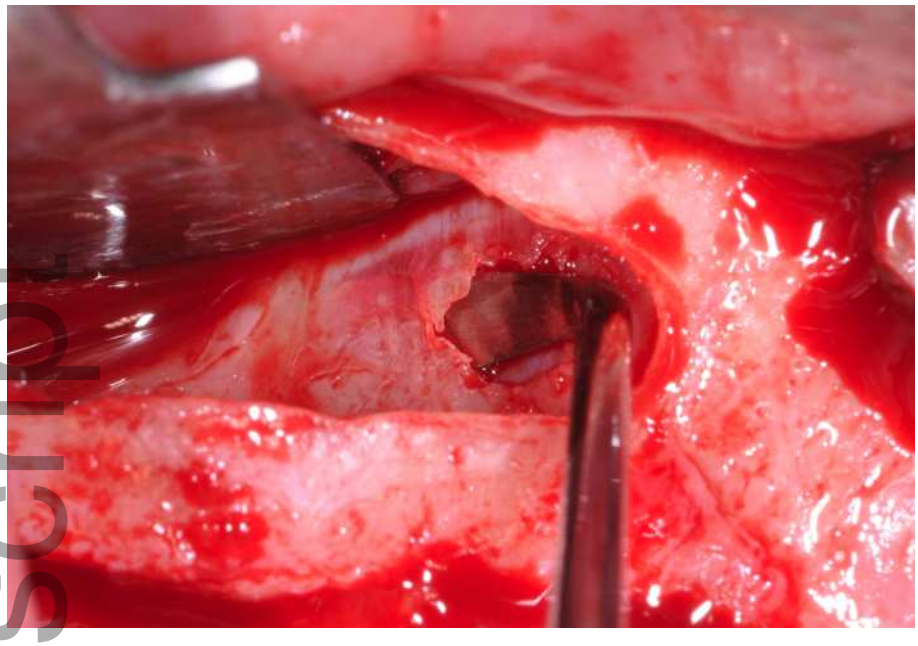

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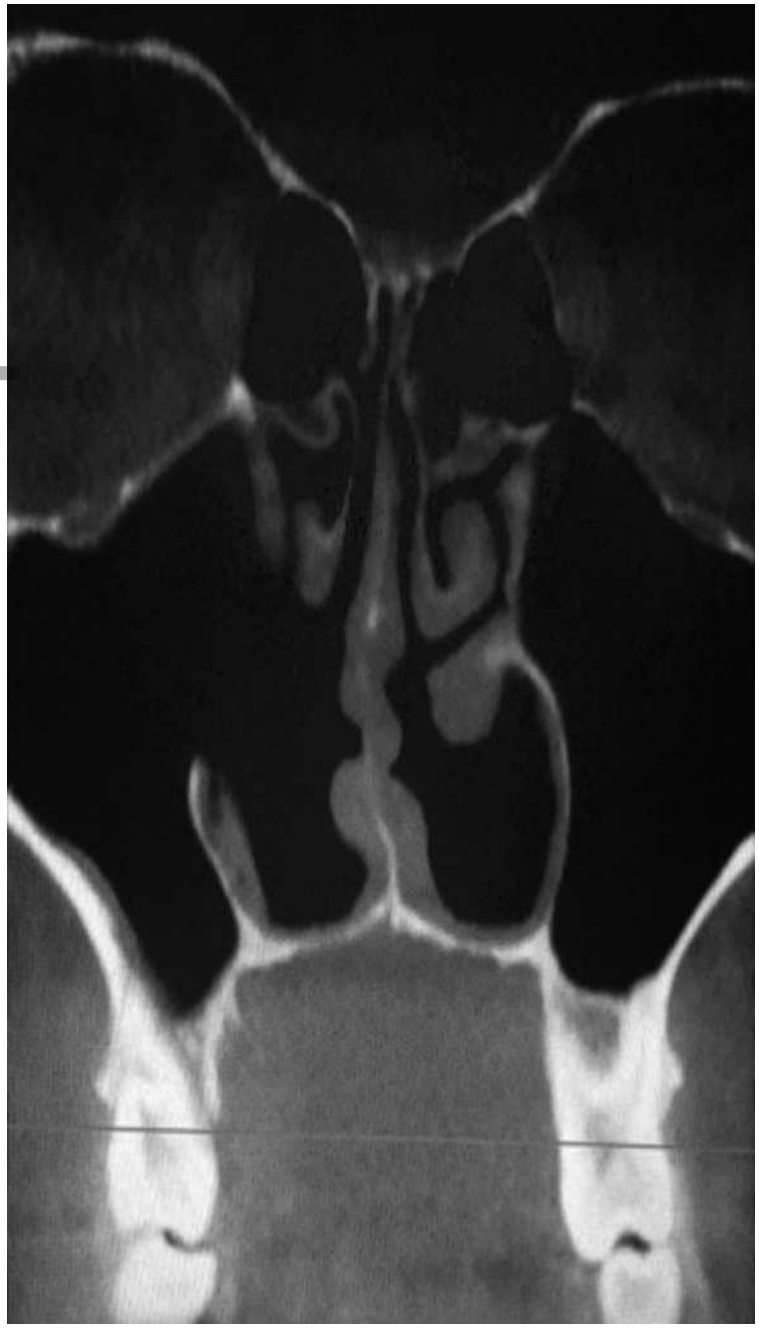

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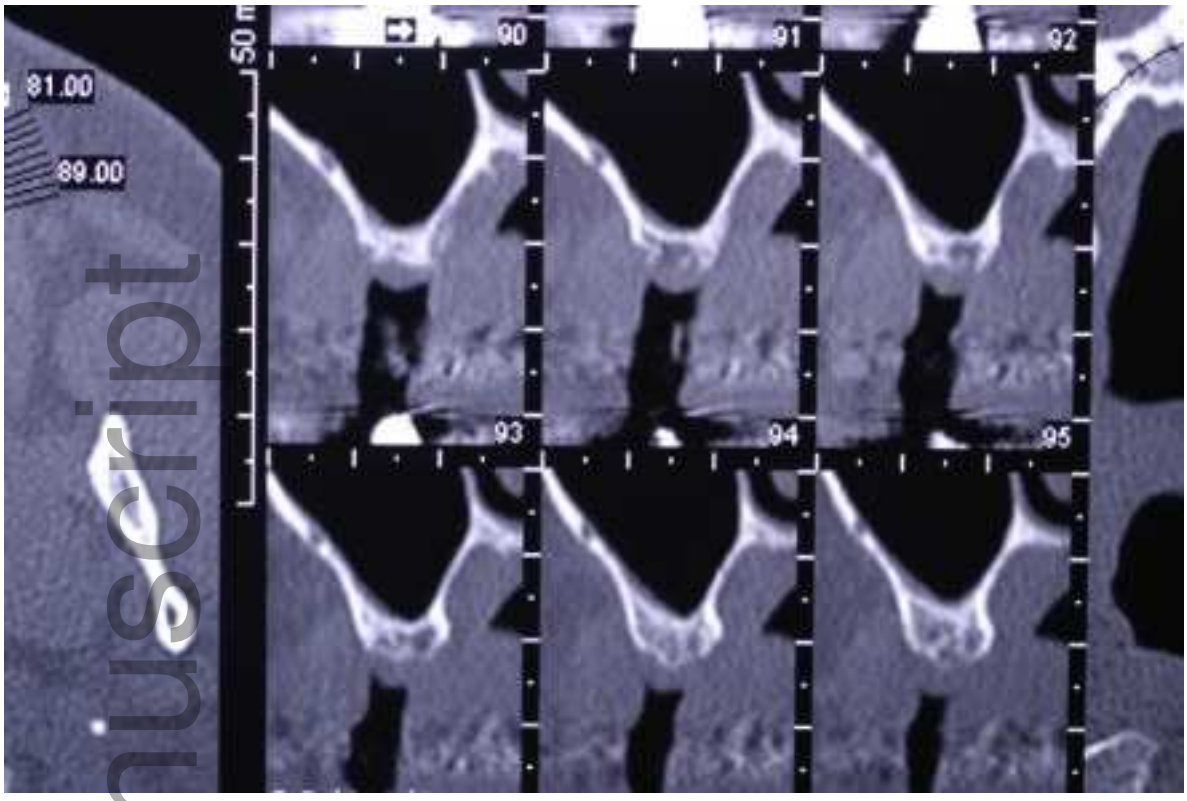

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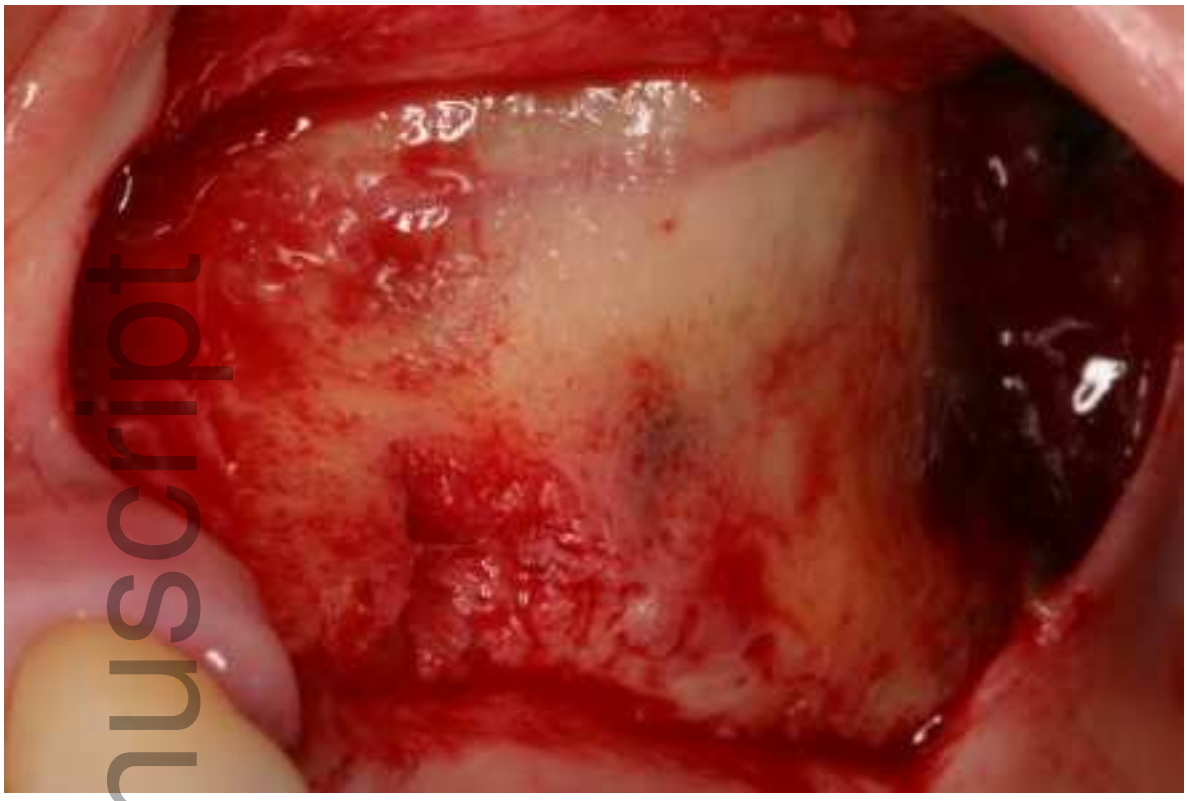

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