

Radiological changes in maxillary sinus morphology after lateral sinus floor augmentation

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SUMMARY:

Background: Restoration of the masticatory function in patients with edentulous posterior maxilla is often challenging due to the severe atrophy of the alveolar ridges and proximity of the maxillary sinus, resulting in insufficient bone quantity for implant-supported dentures.

Aim: The purpose of this study was to analyze the changes in Schneiderian membrane thickness after lateral sinus floor augmentation (LSFA) using cone beam computed tomography (CBCT).

Material and methods: W LSFA procedures using different bone grafting materials were performed in 87 patients, operated on in two clinical institutions from 2016 to 2018. CBCT examination was performed in all patients before the LSFA procedure, at 1 month after surgery, and after 6 months, before implant placement or loading.

Results: Minor radiological changes in mucous membrane morphology were observed preoperatively in 17.1% of patients. Postoperative CBCT in the early postsurgical period demonstrated that the number of intact non-specific sinuses decreased significantly, i.e. from 86.7% to 26.7%. The number of cases with local hypertrophy of the mucous membrane increased from 20.3% to 26.7%. Mucosal thickening was observed in 41.7% vs 7.5%. The number of intact sinuses increased to 57.8%. The number of cases with local membrane hypertrophy also increased – to 37.4%. The number of cases with mucosal thickening or fluid accumulation decreased significantly to 11.8 and 5.3% respectively. In 2 cases the development of chronic sinusitis required secondary surgeries.

Conclusion: The present retrospective study revealed that minor radiological changes in the morphology of the maxillary sinus mucosa were observed preoperatively in 17.1% of patients who underwent LSFA procedures. In the early and late postoperative period their frequency increased to 68.5% and 47.1%, respectively. However, the clinical signs of sinusitis developed only in 19.26% of patients. No significant correlations were found between the frequency and severity of postoperative radiological changes and residual bone height, sinus anatomy, initial state of the mucous membrane and type of the grafting material.

KEYWORDS:

computed tomography, implantation, lateral sinus floor augmentation, membrane thickness

ABBREVIATIONS

CBCT – cone beam computed tomography

ITI – International Team of Implantology

LSFA – lateral sinus floor augmentation

INTRODUCTION

The proximity of the maxillary sinus limits the possibility of implant placement in an optimal position and increases the risk of complications, arising from surgery in patients with edentulous posterior maxilla. The standard technique for achieving sufficient bone volume and quality is augmentation of the maxillary sinus floor (sinus lift) [1, 2], a technique introduced by Tatum (1977), and modified by Boyne and James (1980). This surgical procedure

is performed through osteotomy of the lateral sinus wall, followed by careful elevation of the sinus membrane, and creation of a space that is filled with bone graft or bone substitute material, sometimes, simultaneously with implant placement. Different bone replacement materials were used for sinus floor augmentation [3], such as autogenous bone [4], demineralized bone matrix [5], synthetic hydroxyapatite [6], beta tricalcium phosphate or bioactive glass particles. In comparison to other augmentative procedures, sinus lift proved to be a “safe and predictable” procedure for increasing alveolar bone volume and further placement of dental implants with a comparably low complication rate [7].

However, some recent studies have reported that the incidence of complications, associated with sinus lift procedure is gradually increasing. The main postoperative risks reported in literature include Schneiderian membrane perforation [8] with penetration

of the grafting material into the sinus cavity [9], cyst formation, wound dehiscence [10], graft exposure or failure, chronic or acute sinusitis. The last one is the most challenging problem as its clinical management is complicated and often associated with additional surgery, prolonged recovery time, significant discomfort for the patient, negative impact on the quality of life and legal issues.

The current literature indicates an incidence of 10–26% of acute sinusitis among patients who underwent the LSFA (lateral sinus floor augmentation) procedure [11–13]. Chronic sinusitis is less common and constitutes 1.3–5% [8, 14–16]. However, the number of studies on LSFA complications and long-term outcomes is limited and their results are controversial. Moreover, according to the last data the incidence of significant morphological and radiological changes of the sinus membrane can be higher as in many cases these changes develop with no clinical manifestations. The treatment strategy and the protocol for implant placement and loading in such a situation are under debate.

The aim of the present retrospective study was to identify the radiological state of the maxillary sinus before and after sinus lift procedures as well as to evaluate the incidence of early and late complications with special attention to the risk factors of their development.

MATERIALS AND METHODS

This study met the requirements of the Declaration of Helsinki and was approved by the Ethics Committee of the Bogomolets National Medical University. All personal cone beam computed tomography (CBCT) data were used anonymously, with informed consent of the patients. Patients were recruited at the Stomatological Medical Center of the Bogomolets National Medical University and Kyiv Regional Center for Maxillo-facial Surgery and Stomatology (Kyiv, Ukraine). The present retrospective clinical and radiological study reports the outcomes of standard LSFA procedures, with special attention to the factors that compromise the functional state of the maxillary sinus in the early and late postoperative period.

Patients with edentulous posterior maxilla who underwent the unilateral or bilateral sinus floor elevation procedures via a classic lateral approach during the period from 01.2016 to 12.2018 were included in the study. The indications for LSFA based on ITI recommendations included the presence of alveolar ridge atrophy with residual bone heights less than 5 mm, determined by preoperative CBCT.

Exclusion criteria were the following: age below 18 years; the period from tooth extraction or any surgeries performed in the area of the maxillary sinus to the LSFA procedure of less than 4 months; a history of radiotherapy or chemotherapy for malignant tumors, drug abuse, uncontrolled systemic diseases constituting contradiction to surgery, systemic bone disorders (e.g. osteoporosis), aggressive forms of periodontal disease, clinical and radiological signs of acute or chronic rhinosinusitis, low quality of CBCT data, patient non-compliance or rejection to participate in the study.

The medical records and CBCT data of 87 patients who met the inclusion criteria (50 females and 37 males) were analyzed. The youngest patient at the moment of the operation was 20 years old, the oldest was 63 years old (mean age 32 + 11.2 years). Sinus floor augmentation procedures were unilateral in 67 patients, bilateral in 20; altogether 107 LSFA operations were performed. Sixty (56%) procedures were performed on the left sinus, 47 (44%) on the right. In total, 183 implants were placed into the operated areas. Among them, 38 implants were installed according to the immediate implantation protocol, and 145 according to the protocol of delayed two-stage implantation.

Based on the surgeons' preferences and patients' demands, the following implant systems were used: MIS (Medical Implant System, MIS Implant Technologies Ltd, Shlomi, Israel), MegaGen (MegaGen, Gyeongsan, Daegu, South Korea), B.&B. Dental s.r.l, Italy or Straumann (Straumann Holding AG, Switzerland) with diameters varying from 3.0 to 5.0 mm and length from 7.5 to 13 mm. However, the differentiation of particular implant types was not the subject of this study.

The following data was collected from the patients' medical records: medical history, general health state of the patient, age at the time of augmentation, dental and periodontal status, ENT anamnesis, smoking habits, grafting material used, implant placement and loading protocol. CBCT was performed preoperatively in each case, in order to determine the exact amount of the residual bone and the morphological state of the nasal cavity and paranasal sinuses. The postoperative CBCT was used to evaluate the morphological changes in the maxillary sinus, caused by the operation in the early (up to 1 month) and late (6 month) postoperative period.

Surgical protocol and post-surgical procedures

In all the patients, the standard protocol of LSFA was applied according to the ITI recommendation. After disinfection of the operation area with povidone Betadine solution (Betadine, Egis Pharmaceuticals PLC, Budapest, Hungary) or chlorhexidine, local anesthesia was induced by 4% articaine solution with adrenaline 1:200000 (Ubistesin, 3 M-Espe, St Paul, MN, USA). Then, an incision on the top of the alveolar crest was performed in the posteroanterior direction, followed by vertical releasing incisions in the canine and the third molar areas.

A full-thickness mucoperiosteal flap was raised, and the lateral wall of the maxillary sinus was exposed. At this level a round or oval osteotomy was created with intensive saline irrigation using low-speed diamond burs to minimize the risk of Schneiderian membrane perforation. The Schneiderian membrane was carefully elevated using special curved mucosal elevators from the floor and from the anterolateral and the medial walls of the maxillary sinus until sufficient space for the bone grafting material was created. Membrane perforation was assessed by the Valsalva maneuver. Schneiderian membrane perforations of less than 5 mm were directly sutured with 6.0 sutures or covered with a collagen membrane (Bio-Gide, Geistlich Biomaterials, Wolhusen, Switzerland, or BioMend® Zimmer Biomet, Munich, Germany), PRGF or PRF fibrin membranes. Then the grafting procedure was completed.

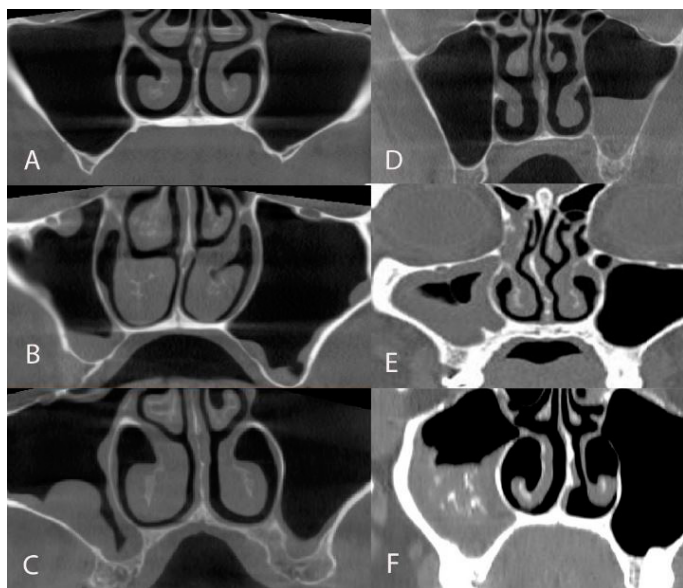


Fig. 1. (A) Nonspecific finding, (B) solitary polyp or cyst, (C) mucosal thickening, (D) air–fluid level or fluid accumulation (most often indicating acute infection or inflammation), (E) near-total opacification of the maxillary sinus or other paranasal sinuses (most often indicating chronic rhinosinusitis), and (F) calcification spots in the maxillary sinus (most often indicating fungal sinusitis). Classification by Chen Y.-W. and al.

In cases of larger perforations the procedure was cancelled and postponed for 1.5–2 months. If no perforation occurred, the bone grafting material was placed under the elevated sinus membrane. The amount and type of grafting material used varied depending on the amount of available residual bone, sinus anatomy, preexisting clinical conditions and surgeons' preferences. Care was taken not to obstruct the middle nasal meatus to allow free sinus drainage.

The following grafting materials or bone grafts were used: iliac crest bone block – 5.7%, xenogenic grafts (Cerabone, Botiss biomaterials GmbH, Gerlingen, Germany or Gen-Os, Osteobiol, Tecness Dental, Torino, Italy, Tutogen Medical GmbH™ 0.25–1.0 mm or 1–2 mm; Germany) – 85.2%, and a mixture of autologous bone with xenogenic materials – 9.1%. Autologous bone blocks were fixed with titanium screws (length 14 mm, diameter 1.6 mm; Titanium Alloy Bonescrew, Titamed).

Postoperatively the patients were instructed not to blow their nose, to sneeze with their mouth wide open in order to control the air pressure inside the maxillary sinus and to avoid any physical stress. Smokers were informed of increased risks of surgery and were advised to stop smoking. Post-operatively, patients were instructed to rinse their mouth 4 times a day with chlorhexidine 0.05% for over 2 weeks. Antibiotics – clindamycin 300 mg orally every 8 h or amoxicillin with clavulanic acid 500 mg 2 times a day, non-steroid anti-inflammatory drugs and analgesics were prescribed for 5 days after the LSFA procedure. The sutures were removed 10 to 14 days postoperatively.

Radiographic examination and measurements

CBCT examination was performed before the LSFA procedure in all patients, then in the early postoperative period: up

to 1 month after surgery, and after 6 months, before implant placement or loading (if immediate placement protocol was applied). Images were acquired using Planmeca ProMax 3D. The scanning parameters were as follows: 120 kVp, 5 mA, 5-s acquisition time, 0.3-mm-thick axial slice, isotropic voxel size, and 20 × 17-cm image area. All images were recorded in the Digital Imaging and Communications in Medicine format (DICOM). The entire data constituted of 0.3-mm-thick axial slices as single DICOM files. Axial images were exported with a 512 × 512 matrix as a single frame per DICOM file. The CBCT images were transferred to SimPlantPro 11.04 (Materialize) software for further visualization and analysis [2]. An expert radiologist and maxillofacial surgeon evaluated the morphological changes and anatomical structure of the maxillary sinus before and after surgery. Craniofacial CBCT images were carefully assessed for the mucous membrane condition in paranasal sinuses, anatomical changes such as septal deviation and concha bullosa, patency of the maxillary sinus ostium, presence of fluid inside the maxillary sinus etc. After that all cases were categorized into six groups (A to F) according to Chen et al. (Fig. 1.): those with (A) nonspecific findings, (B) a solitary polyp or cyst including local hypertrophy of the mucous membrane, (C) mucosal thickening, (D) air–fluid level or fluid accumulation (indicating acute infection or inflammation or haemosinus in most of the cases), (E) near-total opacification of the maxillary sinus (most often indicating chronic rhinosinusitis), and (F) calcification spots (intensive radio-opaque infusions) in the maxillary sinus (most often associated with migration of the graft material into the sinus or fungal infection).

Statistical analysis

For statistical analyses, IBM SPSS Statistics software (version 22, IBM, Armonk, New York, USA), was used with the level of significance set at $P < 0.05$. Sample distribution was tested using the Kolmogorov-Smirnov test. Descriptive analysis of patient characteristics was performed using mean and standard deviation for continuous variables and percentage for categorical variables. Spearman analysis and chi-square test were used to calculate the correlation coefficients between clinical and radiological parameters.

RESULTS

A total of 87 patients with 107 LSFA procedures were included in the study. Among them, 16 (18%) patients were smokers and 71 (82%) were non-smokers. As many as 91.3% had no episodes of acute or chronic sinusitis in anamnesis, 8.7% patients were previously operated on maxillary sinuses with endoscopic sinus surgery or traditional antrotomy.

Preoperative CBCT Findings

Radiographic changes of the sinus mucosa in the study group are presented in the Fig. 1. Preoperative CBCT findings revealed that 66 (75.8%) patients had normal anatomy of the sinus with no changes in mucosal morphology or signs of ENT pathology (nonspecific findings – type A by Chen et al.). Solitary polyps, cysts or local

Class	Description	Images	Risk degree (score)
I	Single basal perpendicular septum		Low risk (0)
II	Multiple (2 or more) basal perpendicular septa		Low risk (0)
III	Single long partial perpendicular septum that is not limited to the base of the sinus.		Moderate risk if not considered (1)
IV	Multiple (2 or more) long partial perpendicular septa that are not limited to the base of the sinus.		High risk and relative contraindication for sinus surgery (2)
V	Partial horizontal septum		Low risk (0)
VI	Complete perpendicular septum that divides the sinus into separate anatomic cavities		Low risk (0)
VII-divI	Complete horizontal septum placed inferiorly		Moderate risk if not considered (1)
VII-divII	Complete horizontal septum placed superiorly		Low risk (0)

Fig. 2. The bony architecture of the sinus floor.

hypertrophy of the mucous membrane (type B) were observed in 15 (17.3%) patients; mucosal thickening (type C) in 6 (6.9%) patients. There were no cases with D, E, F mucous membrane types (fluid accumulation in the maxillary sinus, total or sub-total opacification, etc.) in the initial examination: such radiological findings were considered as contraindications for LSFA procedures.

The bony architecture of the sinus floor was the following (Fig. 2): in 72 sinuses (67.2%) there were no septa, 35 patients had septa with a different risk of membrane perforation. In 22 patients (20.5%) – type 1, 3 (2.8%) type 2, 3 (2.8%) type 3, 4 (3.7%) type 4, 3 (2.8%) – type 5. Type 2 to 5 were associated with a higher risk of Schneiderian membrane perforation [17].

The residual bone height in operated patients (Fig. 3.) was 1 mm or less in 19 cases (17.7%), 2 mm in 45 cases (42%), 3 mm in 33 cases (30.8%), 4–5 mm in 10 cases (9.2%). The mean height of the residual bone was 2.36 + 0.8 mm. It was strongly associated with the time from tooth extraction ($P < 0.05$). In patients with residual bone height less than one mm the mean time from extraction was 14.3 + 2.2 years, 1–3 mm – 12.8 + 1.8 years, 3–5 mm – 5.5 + 1.4 years.

Postoperative CBCT Findings

Postoperative CBCT performed in the early postsurgical period (before 1 month) demonstrated that the number of cases with no changes in the mucous membrane (type A) decreased significantly from 86.67 to 26.75%. The number of cases with type B radiological picture increased from 20.33% to 26.75%. Mucosal thickening (type C) was observed in 7.5 patients vs 41.73% before surgery. Fluid accumulation (type D) and subtotal or total opacification of the sinus (type E) were observed in 13.91 and 2.14% respectively. However, the clinical signs of acute sinusitis or specific complaints were recorded only in 2 cases (1.8%). In 3 cases (2.7%) radiological

findings resembled the F type. All those cases were associated with graft failure and migration of the particles into the sinus. Those cases were considered as complications, all the patients underwent secondary endoscopic surgeries.

Six months after surgery, the radiological status improved in 42 patients. The number of type A patients increased to 57.8%. The number of cases with local membrane hypertrophy or solitary polyps in the sinus also increased to 37.4%; in this group of patients there were no complaints associated with the maxillary sinus or nasal function. The number of cases with mucous thickening or fluid accumulation decreased significantly to 11.8 and 5.3% respectively. In 2 cases (1.8%), total opacification of the sinus (type E) and signs of chronic sinusitis were observed. These cases were considered as an indication for the secondary surgery (Fig. 4.).

In the present study there were no statistically significant correlations ($P > 0.05$) between radiological changes in the maxillary sinus in the postoperative period and residual bone heights, sinus anatomical structure, initial state of the mucous membrane, type of bone grafting material and smoking habits. The radiological findings in the early postoperative period did not correlate ($P > 0.05$) with the state of the mucosa in the long-term follow-up either.

Complications of LSFA

Facial edema, oral erythema, nasal congestion, ecchymosis, and hemosinus were considered to be normal post-surgical conditions. They resolved in the normal course of the postoperative period of up to 14 days.

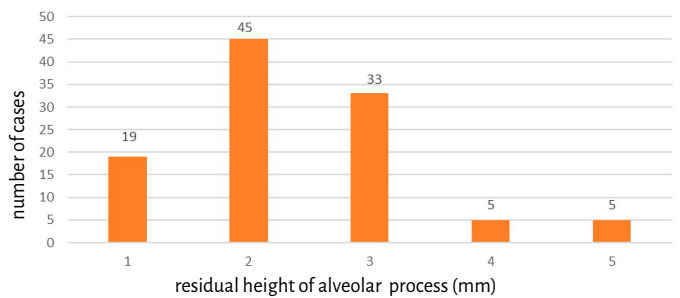


Fig. 3. The residual height of the alveolar process in relation to the number of cases.

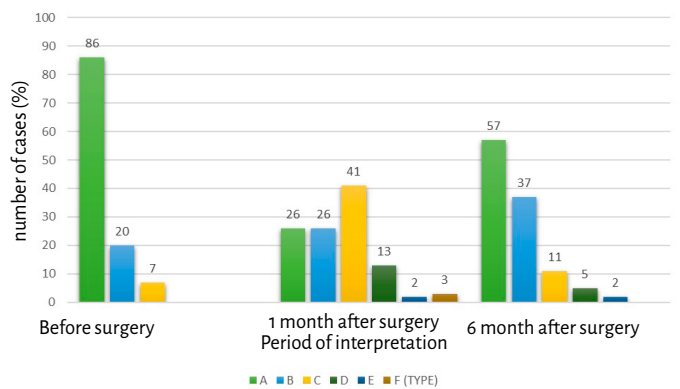


Fig. 4. Dynamics of morphological changes of the mucous membrane based on CBCT.

Of the total study population, 12 patients developed some kind of complications during surgery or in the early postoperative period. Perforation of the Schneiderian membrane was the most common complication, observed in 10 patients (12 LSFA procedures – 11.2%). These complications were observed in classes 3 and 5 [18]. Intensive bleeding during surgery was reported in 5 patients (5.7%). In 3 cases (3.5%), graft failure or migration of the material into the sinus was observed. These patients underwent endoscopic sinus surgery with partial removal of the graft material and demonstrated good recovery. Two patients developed acute rhinosinusitis after sinus augmentation. Both of them recovered completely after a conservative treatment. Two cases of chronic rhinosinusitis (2.3%) were documented in the current survey. Both cases were diagnosed in the remote postoperative period and considered as an indication for the secondary surgery. Endoscopic revision of the ostiomeatal area was performed by ENT surgeons; polyps and granulations were removed from the sinus and examined histologically. Implant placement was delayed in those cases until radiologically-confirmed recovery. Of 183 implants placed in patients after LSFA procedures, 18 (9%) were lost/disintegrated in the early postoperative period before prosthetic construction and application of functional loading. There was no statistically significant association between implant failure and radiological changes of the sinus.

DISCUSSION

According to the literature data, LSFA is a common, widely used procedure with a high predictability and success rate. However, the number of cases associated with maxillary sinus infection or functional insufficiency after LSFA procedures is still high. According to the systematic review [11], acute maxillary sinusitis occurred in 15 cases of LSFA and 12% of surgeries were associated with the development of chronic rhinosinusitis. The author reported that the percent of sinus pathologies is even higher (up to 19% and 22%, respectively) [18]. Authors assumed that the main factors to be considered is the initial state of the maxillary sinus mucosa, ostiomeatal unit as well as the surgical protocol applied (osteotomy technique, volume and type of bone graft, Schneiderian membrane injury etc.). The operations performed on compromised sinuses in patients with an existing ENT pathology or in cases with a sophisticated anatomy of the sinus floor (existing septa, irregularities or recesses) are associated with a higher risk of decompensation and development of either acute or chronic sinusitis. In the present survey, all the cases with infection development were successfully managed conservatively or by minimally invasive endoscopic approach, performed by ENT surgeons. The same multidisciplinary treatment strategy in patients with complicated LSFA is advocated by Joongmin K. and Hyonseok J. [21].

However, our data obtained on the basis of CBCT indicate that the incidence of postoperative changes of the sinus mucosa is significantly higher. Initially, 27.3% of patients had minor changes in the mucous membrane of the maxillary sinus (solitary cysts or polyps, mucous thickening etc.) but in the early postoperative period the number of cases with compromised mucous membrane increased to 68.5%; among them 19.26% had the signs of

fluid accumulation, total or subtotal sinus opacification, migration of the grafting material into the sinus. Until the 6th month the mucous status improved but still only 46% demonstrated non-specific findings. Cases with local thickening of the mucous or solitary polyps close to the operation area consisted 49.2%. At the same time, the majority of these cases were asymptomatic and not associated with any complaints or discomfort of the patients. Other studies of radiological changes in the maxillary sinus before and after LSFA reported a similar incidence of mucous membrane thickening in the early postoperative period [22–25]. However, there is limited information from follow-up at 1, 6 months or more.

One of the main limitations of our study was the absence of long-term follow-up (more than 1 year) and endoscopic control which made the interpretation of the radiological signs ambiguous. Both in the early and in the late postoperative period it was hard to differentiate inflammatory processes from haemosinus, local hyperplasia of the mucous membrane, postsurgical edema/scarring or deterioration of the mucociliary clearance. The classification of radiological changes used in our research [26] was developed for the analysis of maxillary sinusitis and not for exact estimation of postsurgical conditions. It means that clinical decisions based only on radiological changes may be incorrect, resulting in an excessively aggressive approach to patient treatment and rehabilitation.

Interestingly, there were no significant correlations between the initial state of the mucous membrane and the severity of its postoperative changes. It supports the conclusion of [27] the study that minor changes of the maxillary sinus mucosa could not be considered as a contraindication to LSFA procedures. Chen et al. [17] reported that sinus lift can be performed in the presence of radiological changes of type B if the mucous hyperplasia or retention cyst does not exceed 17 mm, and of type C if the mucous membrane thickening does not exceed 5 mm. In type D, E and F, authors recommended the primary surgical sanitation of the sinus. The same approach was used in our patients and with good or satisfactory results.

The residual bone heights, amount and type of material used, presence of the septa and their type had no influence on the complication risks or changes in the mucous membrane. The author reported that an important factor that influences the integral result of LSFA is the presence of uncompensated disorders of mucociliary clearance and affected ostiomeatal complex [28]. At the same time, Giovanni et al. [29] proved that endoscopic examination is more informative for estimation of the maxillary sinus function in comparison to CBCT. Authors also demonstrated the clinical efficacy and importance of presurgical endoscopy of the nasal cavity and maxillary sinuses in this category of patients as well as intraoperative endoscopic control in LSFA [30].

At postoperative follow-up, endoscopy may be an important instrument for differential diagnostics of different pathological conditions if radiological changes are found. According to Hoon and Soon [31], it may be beneficial for differentiation of reactive phenomena in the postoperative period from infections and inflammatory processes and also for decision if any surgical or conservative treatment should be applied.

Postoperative changes of the maxillary sinus do not correlate with its volume and shape (architecture), but are directly influenced by the presence of septa with a possibility of membrane perforation [32, 33]. In the present study we also analyzed the incidence and risk factors for Schneiderian membrane perforations. The frequency of this complication in the present study was within the limits reported by other authors: 11.2% vs 13.3% [34], 20% [35]. With such a small number of observations we could not find statistically significant correlations between the perforation risk and residual bone heights, type of septa and smoking habits. All these factors are considered as risk factors on the basis of previously performed research [36]. However, Kim [37] found no significant correlation between Schneiderian membrane thickening and the risk of perforation or postoperative complications [38].

The presence of membrane perforation was not associated with an increased risk of postoperative infections, graft failure or severity of radiological changes. The explanation for such results may be that LSFA procedures in our survey were carried out only in cases with small perforations (less than 5 mm) which can be easily handled. In large perforations the procedure

was canceled and the patients were excluded from the study. The implants were placed in all operated cases with a good primary stability. In cases where complications followed, the implantation was almost performed after conservative or surgical treatment by ENT surgeons. The frequency of implant disintegration was within the limits reported in the literature for the maxilla and it did not depend on the severity of postoperative changes of the mucous membrane.

CONCLUSION

The present retrospective study revealed that minor radiological changes in mucous morphology of the maxillary sinus were observed preoperatively in 17.1% of patients who underwent LSFA procedures. In the early and late postoperative period their frequency increased to 68.5% and 47.1%, respectively. However, the clinical signs of sinusitis developed only in 19.26% of patients. No significant correlations were found between the frequency and severity of postoperative radiological changes and residual bone heights, sinus anatomy, initial state of the mucous membrane and type of the grafting material.

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