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CONE BEAM COMPUTED TOMOGRAPHY EVALUATION OF MAXILLARY SINUS BEFORE AND AFTER SINUS FLOOR ELEVATION

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Sinus lift surgery elevation is a procedure that requires radiological maxillary sinus evaluation and procedure planning. The condition of the maxillary sinus before and after sinus lift surgery was assessed. Sixty-five sinuses of 49 patients were included in the study. Preoperative and postoperative cone beam computed tomography (CBCT) scans were performed. The sinuses were analysed radiologically for pathological changes: mucosal thickening, ostia obstruction and accessory opening. The presence of concha bullosa in nasal cavity and septa in the maxillary sinus were recorded. The sinus volume also was measured before and after surgery. Thickened mucosa was found more often in postoperative scans than in preoperative scans (63.1% and 67.7%, respectively). Concha bullosa was found in 30 preoperative scans and in 33 postoperative scans. A correlation between mucosal thickening and ostia obstruction was found. The mean sinus volume decreased after surgery and the changes were statistically significant. In conclusion, changes of the maxillarysinus and nasal cavity can be detected with CBCT. Sinus lift surgery does not excacerebate the existing conditions of the maxillary sinus; however, there is a tendency for pathological features to increase after surgery. Sinus lift surgery is a safe surgery with regard to the maxillary sinus if performed with care.

Key words: *CBCT, maxillary sinus, sinus lift.*

INTRODUCTION

Dental and maxillofacial imaging has progressed over the past 20 years due to the arrival of new imaging modalities, digital sensors, along with a better understanding of anatomy and pathologies. Cone beam computed tomography (CBCT) has gained the leading position in imaging for its abiltity to aid in sophisticated diagnosis in the maxillofacial region. CBCT is often used before maxillofacial surgerys to plan the operative course. In 2012, the European Commission issued Evidence-Based Guidelines for Cone Beam CT for Dental and Maxillofacial Radiology. When planning difficult surgical cases, such as sinus lift surgery, where many anatomical structures are involved, three-dimensional (3D) scanning is invaluable. Due to its volumetric aptitude, CBCT is superior to two-dimensional modalities (Anonymous, 2012; Tadinada *et al*., 2015). The dimensional accuracy for CBCT is sufficient for linear measurements. Further, CBCT gives fewer metal artefacts, an important issue in dental and maxillofacial radiology and surgery (Hodez *et al*., 2011). It has also been reported that visualisation of important structures is easy with CBCT images (Loubele *et al*., 2007). In sinus lift planning, residual alveolar bone and the maxillary sinus can be evaluated radiologically.

Computed tomography (CT) is considered to be the first imaging approach for visualisation of paranasal sinuses because of the method's superior osseous delineation. CT is used for evaluation of inflammatory processes in the maxillary and all other paranasal sinuses. The method is useful for determining the extent of disease, for surgical planning, and also intraoperative guidance (Harnsberger *et al.*, 2011). Lately, CBCT has been considered to be an alternative imaging modality for paranasal sinus evaluation due to its reduced radiation dose, image precision, spatial resolution, and ease of image acquisition (Hodez *et al.*, 2011). However, there are limitations for the use of CBCT in the visualisation of paranasal sinuses in cases such as invasive tumours, blood effusion, and others. CBCT is helpful in the diagnosis of acute and chronic inflammatory diseases of the sinuses, mucus retention cysts, mucocele, antrolith, and trauma (Hodez *et al.*, 2011; Rege *et al.*, 2012; Mossa-Basha *et al.*, 2013).

The aim of the study was to radiologically evaluate the condition of the maxillary sinus before sinus lift surgery and to study how sinus lift surgery affects the condition of the maxillary sinus.

MATERIALS AND METHODS

The study sample was composed of 49 patient records of CBCT undertaken at the Department of Oral and Maxillofacial Diagnostic Radiology of the Institute of Stomatology, Rīga, Latvia. The research protocol was approved by the Local Ethics Committee.

All patients were referred for CBCT diagnosis and treatment planning for maxillary sinus lift surgery with enforcement with biomaterials. None of the patients were primarily referred for radiological investigation due to sinus symptoms. In total, 65 sinuses were included in the study. At least one year after sinus lift surgery, a second CBCT scan was performed. Sinus lift surgery was done via the lateral window approach under local anaesthesia. The opened sinus floor was augmentated with different granules of calcium phosphate bone substitutes. Before the second scan, none of the patients had complaints about sinus problems.

Only those CBCT scans in which the entire maxillary sinus and physiological ostia could be seen were included in the study. All CBCT images were taken using the i-CAT Next Generation CBCT imaging system (Imaging Science International, Hatfield, USA). Image volume was reconstructed with a 0.3 mm voxel size. The tube voltage was 120 kVp, the tube current was 5 mA, and the exposure time was 20 seconds.

Images were stored and converted into the DICOM file format using the acquisition software integrated into the equipment (examVison 1.9, Hatfield, USA). The image files were examined using the examVision programme in three orthogonal slice views: axial, coronal, and sagittal. ExamVision measuring tools were used to measure mucosal thickening. The sinus volume was calculated by Dolphin Imaging 3D (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) software.

The CBCT scans were analysed by the radiologist. The pathological findings were as follows: thickening of mucosa (Fig. 1), obstruction of ostia (Fig. 1), posterior accessory opening (Fig. 2), and pneumatised middle turbinate concha bullosa (Fig. 3) on the sinus lift side. In the postoperative scans, the pathological findings were thickening of the mucosa, obstruction of the ostia, presence of concha bullosa, and presence of posterior accessory opening. The presence

Fig. 1. Mucosal thickening and ostia obstruction in the left maxillary sinus.

Fig. 2. Accessory opening in medial wall of the right maxillary sinus.

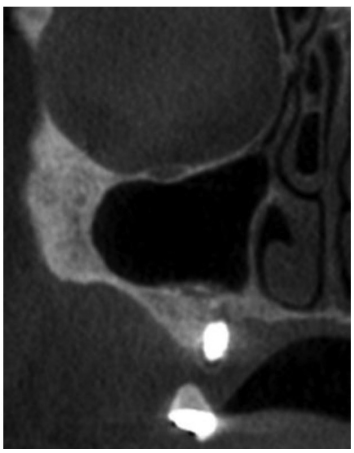

Fig. 3. Right side middle turbinate concha bullosa.

or absence of bony septa in the maxillary sinuses was determined in the preoperative scan. The integration of the maxillary bony septa in sinus lift was evaluated by postoperative radiological examination. The sinus volume was measured before and after surgery.

Mucosal thickening was measured in millimeters (mm). Ostia obstruction, posterior accessory opening, and presence of concha bullosa were identified as present (yes) or absent (no). The presence of the bony septa was also identified as present (yes) or absent (no). The integration of the bony septa into the sinus lift was determined as followed: integrated and not integrated. The maxillary sinus volume was calculated and measured in square millimeters (mm^3).

The data were analysed using SPSS 16.0 software (SPSS, IBM, New York, USA). Descriptive statistics, the Wilcoxon test, analysis of variance (ANOVA), and correlation analyses were applied for data analysis. A p-value < 0.05 was considered to be statistically significant.

RESULTS

The CBCT examinations of 65 maxillary sinuses before sinus lift surgery were included in the study. The time from sinus lift surgery to postoperative scan was as follows: the longest time after surgery was 3 years and 11 months, and the shortest time was 1 year and 2 months (mean 2.1 y; standard deviation (SD) ± 0.64 y).

Mucosal thickening in sinuses was found in 41 (63.1%) preoperative scans. The maximal thickening was 20 mm. The distribution of different mucosal thickenings in the first radiological examination is presented in Figure 4. In the postoperative radiological examinations, maximal thickening of mucosa was 26 mm. After surgery, no mucosal thickening was found in 21 (32.3%) sinuses. Mucosal thickening of the maxillary sinuses after sinus-lift surgery is presented in Figure 5. No statistically significant difference of mucosal thickening was found before and after sinus lift surgery (p = 0.502). However, there was a positive correlation between mucosal thickenings between the two investigation results (Table 1).

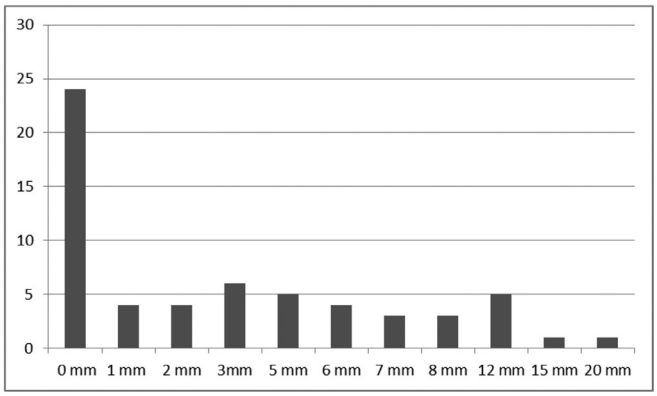

Fig. 4. Mucosal thickening before sinus lift surgery.

Table 1

CORRELATIONS OF RADIOLOGICALLY DETECTABLE SIGNS

		Mucosa before operation	Mucosa after operation	Ostia before operation	Ostia after operation
Mucosa before operation	Pearson Correlation	1.000	0.309*	0.117	–0.048
	Sig. (2-tailed)		0.012	0.353	0.707
	N	65.000	65	65	65
Mucosa after operation	Pearson Correlation	0.309*	1.000	0.304*	0.357**
	Sig. (2-tailed)	0.012		0.014	0.004
	N	65	65.000	65	65
Ostia before operation	Pearson Correlation	0.117	0.304*	1.000	0.474**
	Sig. (2-tailed)	0.353	0.014		0.000
	N	65	65	65.000	65
Ostia after operation	Pearson Correlation	–0.048	0.357**	0.474**	1.000
	Sig. (2-tailed)	0.707	0.004	0.000	
	N	65	65	65	65.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

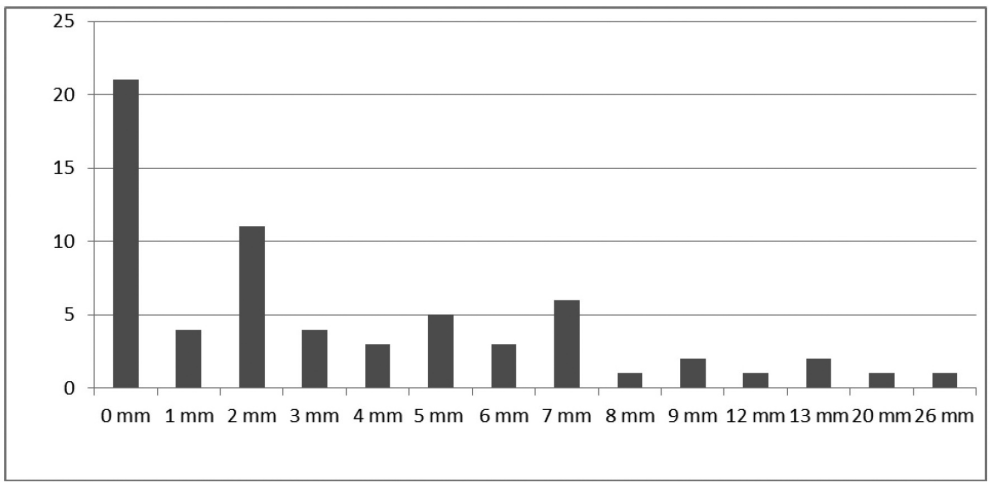

Fig. 5. Mucosal thickening after sinus lift surgery.

Obstruction of the maxillary ostia was defined in both scans and compared. Before surgery, ostia obstruction was found in seven (10.8%) sinuses and after surgery, ostia obstruction was observed in eight (12.3%) cases; the difference was not statistically significant ($p = 0.705$). A positive correlation was found between ostia obstruction and mucosal thickening both before and after surgery (Table 1).

A posterior accessory opening in the medial wall of the sinus was detected in 15 (23.1%) sinuses in preoperative scans were examined, compared to 15 (23.1%) in postoperative scans ($p = 1$).

In preoperative scans, nineteen sinuses (29.2%) were found to be free of any radiologically detectable signs of chronic rhinosinusitis. In postoperative scans, 18 (27.7%) sinuses were found free of any radiologically detectable signs of rhinosinusitis.

Concha bullosa was detected in 30 (46.2%) preoperative and 33 (50.8%) postoperative scans (not statistically significant, $p = 0.257$).

The difference between mucosal thickening and accessory opening, concha bullosa, and physiological opening before and after surgery was analysed. Preoperatively a statistically significant difference was found between mucosal thickening and obstruction of physiological ostia ($p = 0.023$). No statistically significant difference was found between mucosal thickening and concha bullosa ($p = 0.452$) and accessory opening ($p = 0.058$). In postoperative scans, no statistically significant difference was found between mucosal thickening and accessory opening ($p = 0.102$) and concha bullosa ($p = 0.505$). In postoperative scans, a statistically significant difference was found between mucosal thickening and obstruction of physiological ostia ($p = 0.041$).

Bony septa were present in 38 (47.5%) sinuses in preoperative scans. Of those, 33 (41.2%) were included in sinus lifts, and 5 (6.2%) were left free standing.

Volume of sinuses was calculated after detecting the borders in all orthogonal planes. The mean sinus volume before surgery was 18915.32 mm³ (SD ± 6648.83 mm³). After sinus lift surgery, the volume mean value was 16749.13 mm³ (SD ± 5672.17 mm³). There was no statistically significant difference in volume of maxillary sinuses found before and after sinus lift surgery ($p < 0.001$).

DISCUSSION

In our study, the most common radiologically detectable pathological finding in asymptomatic maxillary sinuses was mucosal thickening (63.1%). The reason for mucosal thickening usually is associated with some kind of irritation factor, including odontogenic, allergic, bacterial, or viral components (Nishimura and Iizuka, 2002; Brook, 2006). In our study, odontogenic irritants were minimised, as many teeth had been missing and sinus lift planning was the reason for radiological investigation. However, the mucosal thickening has been the major pathological finding in several studies in which maxillary sinuses were investigated, accounting for 36.1% to 66% (Ashraf and Bhattacharyya, 2001; Caughey *et al*., 2005; Smith *et al*., 2010; Carmeli *et al*., 2011; Rege *et al*., 2012; Raghav *et al*., 2014). The high values of mucosal thickening in our study can be due to the fact that we measured mucosal thickening starting from 1 mm. Mucosal thickening of 1 to 3 mm accounted for 29.3% of 63.1% of cases in this study. No consensus has been reached in the literature over what amount of mucosal thickening is considered pathological (Lund and Mackay, 1993; Lund and Kennedy, 1997; Ashraf and Bhattacharyya, 2001; Ata-Ali *et al*., 2017). Some authors consider mucosal thickening up to 6 mm to be normal (Vallo *et al*., 2010; Carmeli *et al*., 2011; Rege *et al*., 2012).

In postoperative scans, the mucosal thickening did not differ significantly from the amount found before surgery. These results indicate that sinus lift surgery was planned and performed with great caution and prudence. These results also can be explained by the fact that scans were obtained no earlier than 1 year after surgery; in addition, if there was any acute complication, it would present soon after surgery. The typical patient seeking sinus lift surgery is meticulous about their health and well-being. Nevertheless, a positive correlation between mucosal thickening before and after surgery indicates a constant, untreated presence of chronic rhinosinusitis.

The function of the mucosal ciliated epithelium is essential for the physiology of the maxillary sinus. The mucus secreted by the mucocilliar cells is constantly transported toward the physiological ostia. Obstruction of the maxillary sinus ostia has been considered to be a contraindication for sinus lift surgery. The obstruction can cause discomfort and complications postoperatively (Ozyuvaci *et al*., 2005). In our study, obstruction of the ostia was found in a small amount of sinuses both before and after sinus lift surgery. Our results agree with results of similar investigations of asymptomatic sinuses (Carmeli *et al*., 2011). We found a statistically significant difference when comparing mucosal thickening and obstruction of the ostia both in preoperative and in postoperative radiological scans. Thickening of the mucosa is a sign of an ongoing inflammatory process in the sinus. The cause of the inflammation varies amoung individuals. Nevertheless, the reaction of the mucosa can be detected radiologically. The swelling and thickening of the mucosa in the sinus can cause obstruction of the ostia, and these two conditions are commonly interrelated (Lund and Kennedy, 1997; Carmeli *et al*., 2011; Hodez *et al*., 2011;). In our study this was affirmed with correlation analysis, in which a positive relationship was found between ostia obstruction before surgery and mucosal thickening after surgery; we also observed obstruction of ostia after surgery and mucosal thickening after surgery. These results indicate that radiologically detectable obstruction of the maxillary ostia before surgery cannot be ignored, as it can result in sinus complications later.

The posterior accessory opening has been considered to be a definitive sign of chronic rhinosinusitis. This condition has been referred to as the "two holes syndrome" (Mladina *et al*., 2009; 2010). The posterior accessory opening does not serve as an additional opening for the mucus to drain from the sinus, as it is sometimes incorrectly interpreted. The cilia of the epithelium move the mucus toward the physiological opening, through to the nasal cavity and the nasopharynx, and then it is swallowed. If the posterior accessory opening exists, then mucus from the nasal cavity is drained back in to the maxillary sinus. A mucus ring is formed. This accessory opening can serve as a maintainer of a chronic inflammation in the maxillary sinus. In our study, an equal amount of accessory opening in the medial wall of the maxillary sinus was detected in pre- and post-operative scans. Our results are in line with results reported in the literature concerning the frequency of accessory opening of the maxillary sinus (Kumar *et al*., 2001; Mladina *et al*., 2009; 2010). In preoperative scans, we detected a tendency for a relation between mucous membrane thickening and posterior accessory opening; however, it was not statistically significant. It can be speculated that the tendency between these two chronic rhinosinusitis radiological signs affirms the presence of a sinus inflammatory condition (Ali *el at*., 2017). As we found no increase in the amount of posterior accessory openings in postoperative scans, it can be concluded that sinus lift surgery did not stimulate inflammatory changes in the maxillary sinuses.

The narrowing of the osteomeatal complex inhibits mucus outflow from the maxillary sinus, lessens aeration of the sinus, and increases the risk for sinus disease. One of the structures that can restrict aeration and outflow of the sinus is concha bullosa (Caughey *et al*., 2005; Smith *et al*., 2010). Concha bullosa is easily detectable on CBCT scans. We did not find a statistically significant difference in the amount of concha bullosa found in scans before and after surgery, nor did we find a statistically significant difference when comparing the presence of concha bullosa and mucosal thickening before and after surgery (Nouraei *et al*., 2009; Smith *et al*., 2010; Mossa-Basha *et al*., 2013). In our study, we did not find that the presence of concha bullosa creates a radiologically detectable maxillary sinus obstruction.

Detection of the sinus septa is important before sinus lift surgery, as their presence can change the surgical technique. Elevation of the Schneiderian membrane is more difficult around the septa. Morewover, understated sinus septa can complicate surgery because of easier mucosal perforation (Van den Bergh *et al*., 2000). The prevalence of sinus septa varies from 16% to 70% (Van den Bergh *et al*., 2000; Koymen *et al*., 2009; Van Zyl and Van Heerden 2009; Maestre-Ferrin *et al*., 2011). It has been shown that CBCT gives a clear idea about sinus anatomy, as well as the presence or absence of septa. In comparison, plain radiographs often conceal septas (Maestre-Ferrin *et al*., 2011). The CBCT investigation helps to plan sinus lift surgery with the fewest complications. Meanwhile, the sinus septa can be used as an alternative location for implant placement (Dragan *et al*., 2017). In our study, 33 septa were incorporated into the sinus lift as one border of it. We did not find radiological signs of sinus membrane perforations, such as dissemination of biomaterials or opacificiation of the sinus, which reinforces that employing 3D CBCT scan before sinus lift surgery reduces complications (Maestre-Ferrin *et al*., 2010; Maestre-Ferrin *et al*., 2011; Dragan *et al*., 2017).

Sinus volume was calculated before and after sinus lift surgery. A decrease in sinus volume of approximately 2166.49 mm^3 was found in the second scan. Nevertheless, the volume after sinus lift surgery in our study and according to data from the literature was within limits of avarage sinus volume (Uchida *et al*., 1998; Lawson *et al*., 2009; Sahlstrand-Johanson *et al*., 2011; Luz *et al*., 2018). The decrease of sinus volume should not be noticeable to the patient.

CONCLUSION

It can be concluded that a high frequency of different chronic rhinosinusitis radiological signs, such as mucosal thickening, ostia obstruction, and accessory opening, are common in asymptomatic patients investigated before sinus lift surgery. There is a correlation between radiologically detectable inflammatory pathologies before and after sinus lift surgery, signifying the need for careful investigation of the maxillary sinus before surgery, and for careful planning. The presence of concha bullosa did not influence the maxillary sinus condition after sinus lift surgery. The presence of maxillary sinus septa was not found to be problematic in performing sinus lift surgery. Vigilant planning of the sinus lift surgery in our study demonstrated the use of maxillary sinus septa in the augmented area and the operation kept away from the Schneiderian membrane's perforation.

The volume decrease of the sinus was within limits of normal maxillary sinus volume. It can be concluded that sinus lift does not cause functionally noticeable changes. Radiologically detectable changes in the maxillary sinuses were not exacerbated or afreshed after sinus lift surgery. Thus, sinus lift surgery is safe and reliable when surgery planning is done in 3D radiography.

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AUGŠŽOKĻA DOBUMA IZVĒRTĒŠANA PIRMS UN PĒC PAMATNES PAAUGSTINĀŠANAS OPERĀCIJAS AR KONISKA STARA DATORA TOMOGRĀFIJAS METODI

Augšžokļa dobuma pamatnes paaugstināšanas operācija ir bieži lietota metode zobu implantācijas pacientiem ar alveolārā kaula atrofiju. Koniska stara datora tomogrāfija mutes, sejas un žokļu apvidū mūsdienās ir galvenā trīsdimensiju izmeklējumu metode implantācijas un augšžokļa dobuma pamatnes paaugstināšanas plānošanā. Šajā pētījumā tika izvērtēti 65 augšžokļa dobumi asimptomātiskiem pacientiem pirms paredzētās pamatnes paaugstināšanas operācijas un to stāvoklis salīdzināts pēc operācijas. Tika atzīmētas vairākas paloģiskās atrades — sabiezēta gļotāda, atveres obstrukcija, papildus atvere, kā arī atzīmētas anatomiskās īpatnības, kuras varētu ietekmēt operācijas iznākumu un arī dobuma stāvokli ilgtermiņa. Pētījumā iegūtie rezultāti liecina, ka pēc operācijas patoloģisko atražu skaits palielinās. Pēc operācijas dobuma tilpums samazinās, bet tas joprojām atbilst normālam dobuma tilpuma apjomam. Šajā pētījumā netika konstatēts, ka anatomiskās īpatnības ietekmē augšžokļa dobuma stāvokli.