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Uses of maxillary sinus lateral wall bony window in an open window sinus lift procedure: literature review

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SUMMARY

Aim. To review all of the possible uses for maxillary sinus lateral wall bony window in an open maxillary sinus lift procedure and to evaluate the influence of each method to the rate of sinus membrane perforations.

Methods. A systematic literature review was performed of randomized control studies in English identified in MEDLINE (PubMed) and Cochrane online databases, published between 2007.09.01 and 2017.09.01. Surgeries had to be performed in vivo, for patients over 18 years old. A study had to have at least 10 sinus lifting procedures, had to detail how the bony window was used and had to report the number of Schneiderian membrane perforations.

Results. 922 publications were found, out of which 68 were selected for qualitative assessment. 29 of them were selected for quantitative assessment. 4 distinct uses for bony window were found: bony window is elevated into the sinus cavity under the membrane; removed and discarded; repositioned to its original position after the surgery; used as a graft material for sinus lift.

Conclusions. there is a statistically significant difference of sinus membrane perforations between different uses of the lateral bony window of an open sinus lift procedure. However, due to the lack of publications that investigate the effects of different bony window usage methods, clinical recommendations cannot be drawn from current data.

Key words: Caldwell-Luc, sinus bony window, sinus augmentation, sinus membrane perforation, open window approach.

INTRODUCTION

In contemporary dentistry, dental implants are the best solution for the treatment of hypodontia. However, in cases when alveolar bone is atrophied, additional bone augmentation procedures such as maxillary sinus lift are needed before implants can be placed. It was first suggested by Tatum and later modified and described in detail by Boyne and James in 1980. According to the original protocol, lateral wall of maxillary sinus is fenestrated and the remaining bony window is elevated into the sinus cavity (1). Most common complications after such surgery are: bleeding from the nose, post-operative sinusitis, post-operative pain, perforations of the Schneiderian membrane (2). The latter is the most common complication of the sinus floor augmentation procedure, that is present in 19,5% (varies from 0% to 58.3%) of clinical cases (2). There are a lot of factors that can influence the prevalence of intraoperative and postoperative complication rates. However Schwartz-Arad *et al.* noticed that intraoperative and postoperative complications of sinus augmentations are scarcely mentioned and analyzed in a scientific literature (3). The authors of our study hypothesised that different methods of bony window usage have influence on Schneiderian membrane perforation rates. Our aim was to compare different uses for sinus bony window in the open window sinus augmentation procedure and their potential influence to the rate of Schneiderian membrane perforations.

METHODS

This review is registered in "PROSPERO", registration number: CRD42016036535 (4). A systematic literature search was performed according to PRISMA guidelines in search of clinical trials published between 2007.09.01 and 2017.09.01 in MEDLINE (PubMed) and Cochrane online databases (5). Search keywords: Maxilla Maxillary, Upper Jaw, Upper Jawbone, Sinus Caldwell, Luc procedure, Lateral

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window, Lateral window, osteotomy Direct lift, bone grafting, Bone augmentation, Lift, Elevation Supplementary search was performed in Google Scholar database. Publications that met inclusion criteria were drawn to the qualitative analysis study pool. From this, publications that met quantitative assessment criteria were selected into quantitative analysis (Figure).

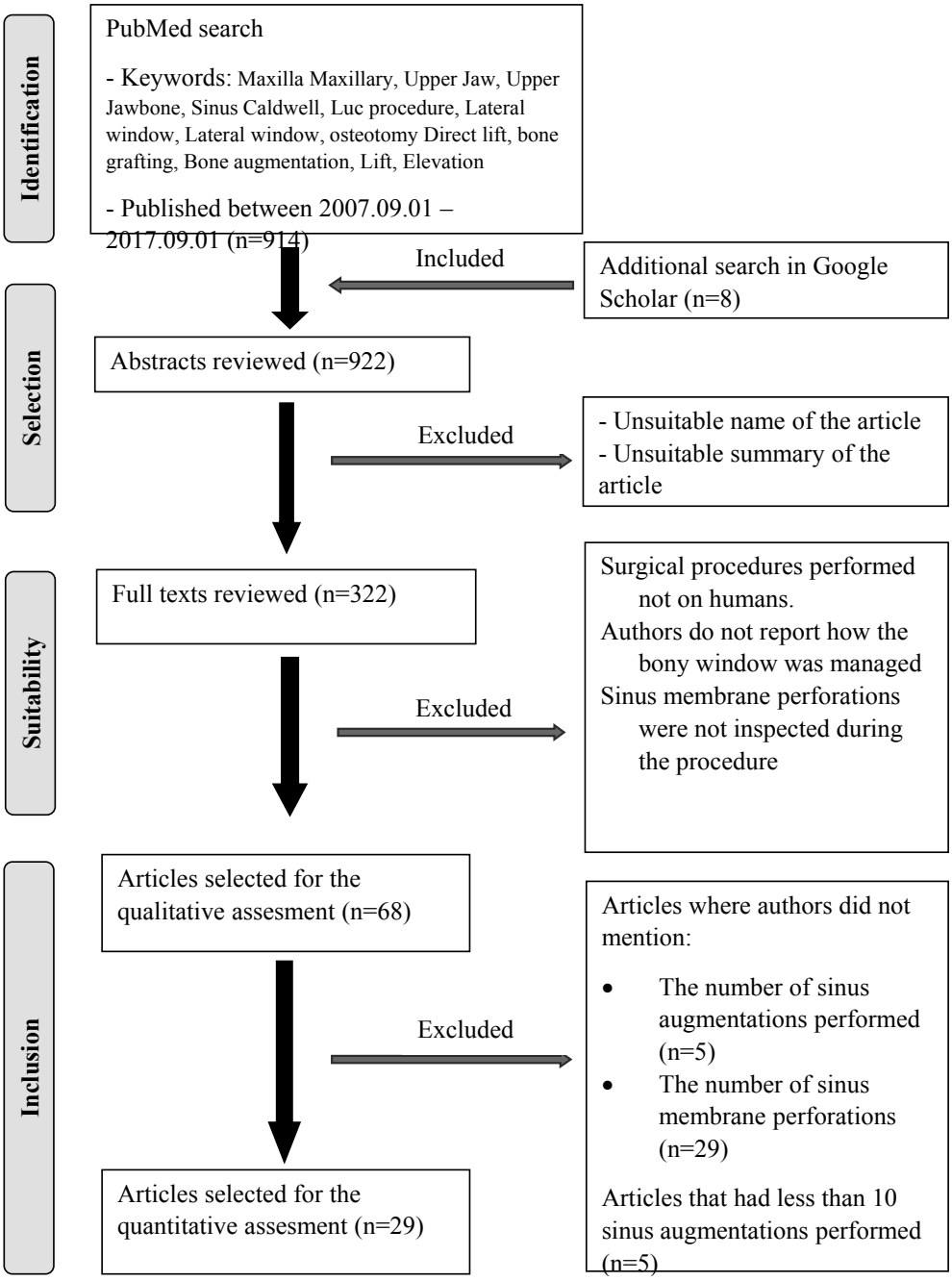

Fig. PRISMA Flowchart

Inclusion criteria:

1. Surgical procedures performed on humans *in vivo*.
2. Sinus floor augmentation performed using lateral window technique.
3. Authors report how the bony window was managed.
4. Schneiderian membrane is inspected for perforations.

Filtered articles:

1. Surgical procedures performed not on humans, *ex vivo* or *in vitro*.
2. Authors do not report how the bony window was managed.
3. Sinus floor augmentation performed using different surgical technique.
4. Schneiderian membrane was not inspected during surgery.
5. Clinical cases, pilot studies, literature reviews.

Additional quantitative assessment criteria:

1. Reported amount of performed augmentations (≥10).
2. Reported amount of sinus membrane perforations.

Statistical analysis

Statistical analysis was performed using IBM SPSS (IBM corp. 2016). Nonparametric Chi-square test was used to assess the statistical relationship between different methods of bony window usage and the rate of Schneiderian membrane perforations. For the comparison of sinus membrane perforation rates Z test was used, p values were calculated according to Bonferroni correction.

RESULTS

Systematic literature search yielded 922 results. 68 publications were included in the qualitative study and 29 publications went into quantitative study. 39 publications lacked at least one of the

required inclusion criteria.

4 different methods for the usage of bony window were found in the literature:

1. The bony window is elevated into the newly formed sinus cavity.
2. The bony window is elevated out of the surgical site and discarded.
3. The bony window is elevated out of the surgical site and repositioned after placing the bone graft.
4. The bony window is used as a bone graft.

The advantages and disadvantages for each of these surgical methods are summarized in Table 1.

The bony window is elevated into the newly formed sinus cavity

This surgical method can be accomplished in two ways:

1. After the preparation of the inferior, distal and mesial bony window margins, the superior margin is prepared to a minor degree and bony window is infractured into the newly formed sinus space using hinge-like motion.
2. All of the bony window margins are prepared until the Schneiderian membrane is visible and the bony window is elevated into the sinus cavity as a free cortical bone graft.

In either case, the elevated bony window becomes the new floor of a sinus cavity. This method is called the traditional or the Tatum technique and is used the most often (6).

Aside from the simple surgical technique, another advantage of this method is the ability to automatically seal small Schneiderian membrane perforations by the elevated bony window (7). Garlini G. *et al.* Used this method extensively to close sinus membrane perforations without any sequela (7). Due to its cortical bone plate, the elevated bony window can also be used as a guide to determine

Table 1. Summary of the advantages and disadvantages of different methods for the use of bony window

Bony window usage technique	Advantages	Disadvantages
The bony window is elevated into the newly formed sinus cavity	• Elevated bony window can seal small Schneiderian membrane perforations • The easiest and the most widely used surgical technique (6) • Elevated bony window can also be used as a guide to determine the correct position of the inserted dental implant* (1)	• Two osteotomies need to be prepared if a septum is present in the maxillary sinus (1) • Supplementary membrane is needed to close the antrostomy • The elevated bony window does not increase the primary stability of inserted dental implants (1)
The bony window is elevated out of the surgical site and discarded	• When a septum is present in the maxillary sinus, only one osteotomy is needed (1) • Better visibility of the Schneiderian membrane (1) • Better visibility in case a maxillary sinus supporting artery gets severed (20)	• Supplementary membrane is needed to close the antrostomy
The bony window is elevated out of the surgical site and repositioned after placing the bone graft	• Autogenic bone window has osteoinductive properties (31) • No supplementary membranes are needed • Nonimmunogenic material (31) • Lesser probability of soft tissue migration to the sinus cavity, compared to methods, where no membrane or bony window is used to close the antrostomy (29,30) • Protects the bone graft particles from migrating to the surrounding soft tissue (29)	• Osteotomy margins need to be as thin as possible to facilitate optimal stability after repositioning (1) • In case the repositioned bony window is not stable, fibrin or cyanacrylate tissue glue is needed to enhance the stability of the bony window (30)
The bony window is used as a bone graft	• Lower morbidity and intraoperative trauma compared to other intraoral and extraoral autogenic bone grafting sites (39,40,44) • Excellent osteoinductive, osteoconductive and osteogenic properties (41) • Nonimmunogenic material (39) • Shorter postoperative healing time (39) • While gradually scraping down the bony window: • Excellent visual and tactile control (40) • Lower risk of perforating the Schneiderian membrane while performing osteotomy (40)	• The amount of harvested autogenic bone is not sufficient to be used alone (39,41) • This method takes more time compared to all the other methods (40) • Supplementary membrane is needed to close the antrostomy • Special instruments are needed in order to scrape or grind the bony window

the correct position of the inserted dental implant, although it does not influence the primary stability or the clinical success rates of implants (1).

In total, 23 studies mentioned the use of this surgical technique. 10 of those studies fit the quantitative analysis selection criteria (Tables 2 and 3).

The bony window is elevated out of the surgical site and discarded

This surgical method consists of preparation of a full thickness osteotomy margins and subsequent elevation of the bony window out of the surgical site using a special set of surgical pliers (18).

This method has more indications comparing to Tatums way:

- In case a bony septum is present in the maxillary sinus, which happens in 47% of all patients and 33.2% of sinuses, a surgeon cannot elevate the bony window inside the sinus cavity (19). In such case, by using the Tatum method, the surgeon needs to make two osteotomies on both sides of the septum. By removing the bony window one osteotomy is sufficient (1).
- In the event that any of the 3 arteries (posterior superior alveolar, infraorbital and posterior nasal) which supply blood to the maxillary sinus are damaged, the infractured bony window can obstruct the site of bleeding. This can disrupt the search for the source of bleeding (20).

In total, 24 studies mentioned the use of this surgical technique. 9 of those studies fit the quantitative analysis selection criteria (Tables 4 and 5).

The bony window is elevated out of the surgical site and repositioned after placing the bone graft

This surgical technique is similar to the previous one. The main difference is that the osteotomy margins need to be as thin as possible to facilitate optimal placement of the bony window after sinus floor grafting is carried out (1).

The repositioned bony window aids the process of pneumatisation of sinus cavity. As a result, bone graft particles cannot migrate out of the grafted site and soft tissues cannot enter the newly formed sinus cavity (29,30).

No supplementary membranes are needed to perform this surgical technique. Supplementary membranes can be immunogenic, meanwhile bony windows cannot (31). When compared to those cases, where antrostomy was closed only by suturing the subperiosteum, few authors note that the long term stability of dental implants can be enhanced due to the barrier through which no soft tissues can enter the ossification site (29,32,33)

Table 2. Publications, in which the bony window was elevated into the newly formed sinus cavity

Study	Amount of sinus augmentations	Amount of Schneiderian membrane perforations (% of perforations)
Stavropoulos *et al.* (8)	31	9 (29.03%)
Dellavia *et al.* (9)	15	0 (0%)
Peng *et al.* (10)	29	4 (13.79%)
Bornstein *et al.* (11)	59	0 (0%)
Canullo *et al.* (12)	30	4 (13.33%)
Barone *et al.* (13)	26	7 (26.92%)
Chiapasco *et al.* (14)	952	28 (2.94%)
Jurisic *et al.* (15)	12	0 (0%)
Alayan *et al.* (16)	33	0 (0%)
Park *et al.* (17)	29	0 (0%)

Table 3. The rate of Schneiderian membrane perforations across all studies

Total amount of sinus augmentation procedures	1216
Total amount of Schneiderian membrane perforations (% of total perforations; ±Standard deviation)	52 (4,28%; ±11,57)

Table 4. Publications, in which the bony window was elevated out of the surgical site and discarded

Study	Amount of sinus augmentations	Amount of Schneiderian membrane perforations (% of perforations)
Berberi *et al.* (21)	10	0 (0%)
Pasquali *et al.* (22)	16	0 (0%)
Merli *et al.* (23)	147	7 (4.76%)
Taschieri *et al.* (24)	19	3 (15.79%)
Lee *et al.* (25)	58	5 (8.62%)
Minichetti *et al.* (26)	56	0 (0%)
Zhang *et al.* (27)	16	0 (0%)
Bortoluzzi *et al.* (28)	13	0 (0%)
Torres *et al.* (29)	144	5 (3.47%)

Table 5. The rate of Schneiderian membrane perforations across all studies

Total amount of sinus augmentation procedures	479
Total amount of Schneiderian membrane perforations (% of total perforations; ±Standard deviation)	20 (4.18%; ± 5.48)

In total, 12 studies mentioned the use of this surgical technique. 5 of those studies fit the quantitative analysis selection criteria (Tables 6 and 7)

The bony window is used as a bone graft

This surgical technique has two main variations:

1. The osteotomy is prepared and bony window is removed in an identical manner to the previous two methods, subsequently followed by grinding of the bony window (38).

2. The osteotomy is prepared using special bone scraping devices. Bone particles are collected using surgical bone collectors (39, 40).

Germiani A. *et al.* concluded that preparation of the bone using bone scrapers should decrease the prevalence of sinus membrane perforation due to the increased tactile and visual control when comparing to osteotomy preparation using rotational or piezoelectric burs. However, this procedure takes more time when compared to other methods (40). Vincente J. *et al.* noticed that not a single perforation occurred during the preparation of the bony window, but rather during the elevation of Schneiderian membrane (39).

Autologic bone is considered a "gold standard" amongst bone augmentation materials (41). It is nonimmunogenic, has excellent osteoinductive, osteoconductive and osteogenic properties. A single bony window yields 0.5-2.0mg of autogenic bone graft. This amount is dependant on the thickness of maxillary sinus wall and also on the dimensions of prepared site (39). This volume of bone graft is not sufficient enough to be used alone in the sinus floor augmentation, thus, it is usually necessary to mix autologous bone with xenologous, allogenic or synthetic bone substitutes. Autologous bone vascularizes in 3-4 months, which is faster, than xenologous bone. However, autologous bone may resorb faster and more uncontrollably when compared with xenologous bone (39). The best clinical results are achieved when a combination of autologous and xenologous bone is used. While using this combination, autogenic bone shortens the healing and ossification time and xenogenic bone keeps a solid matrix which is needed for the ossification process (41, 42).

Table 6. Publications, in which the bony window was elevated out of the surgical site and repositioned after placing the bone graft

Study	Amount of sinus augmentations	Amount of Schneiderian membrane perforations (% of perforations)
Cricchio *et al.* (34)	96	11 (11.46%)
Dursun *et al.* (35)	16	3 (18.75%)
Thor *et al.* (36)	27	11 (40.74%)
Cricchio *et al.* (37)	10	0 (0%)
Cha *et al.* (20)	217	35 (16.28%)

Table 7. The rate of Schneiderian membrane perforations across all studies

Total amount of sinus augmentation procedures	366
Total amount of Schneiderian membrane perforations (% of total perforations; ±Standard deviation)	60 (16.39%; ±14.88)

Table 8. Publications, in which the bony window was used as a bone graft

Study	Amount of sinus augmentations	Amount of Schneiderian membrane perforations (% of perforations)
Caubet *et al.* (41)	14	2 (14.29%)
De Vicente *et al.* (39)	42	5 (11.90%)
Kim *et al.* (43)	36	8 (22.22%
Galindo-Moreno *et al.* (44)	82	0 (0%)
Martos-Diaz *et al.* (38)	10	1 (10%)

Table 9. The rate of Schneiderian membrane perforations across all studies

Total amount of sinus augmentation procedures	184
Total amount of Schneiderian membrane perforations (% of total perforations; ±Standard deviation)	16 (8,70%; ±8,02)

In total, 11 studies mentioned the use of this surgical technique. 5 of those studies fit the quantitative analysis selection criteria (Tables 8 and 9).

Statistical analysis

The mean perforation rate across all different bony window usage techniques was 6.6% (Table 10). Above average perforation rates occurred when:

- The bony window is elevated out of the surgical site and repositioned after placing the bone graft (16.4%).
- The bony window is used as a bone graft (8.7%).

Below average perforation rates occurred when:

- The bony window is elevated into the newly formed sinus cavity (4.3%).
- The bony window is elevated out of the surgical site and discarded (4.2%).

There was a statistically significant difference ($p<0.05$) in perforation rates between the group, in which the bony

window was repositioned after elevation (16.4%), and between the groups, in which the bony window was elevated and afterwards discarded (4.2%) and when the bony window was elevated into the sinus cavity (4.3%). There were no other statistically significant differences between different groups.

Difference between methods of bony window usage are a statistically significant factor in Schneiderian membrane perforations ($\chi 2$= 73.554; df=3; p<0.001).

DISCUSSION

The most common surgical complication of sinus augmentation is the perforation of Schneiderian membrane (2). During the systematic literature search we found 4 different methods to use the bony window. However, the rate of perforations varied a lot between the articles that used the same method of lateral bony window usage. The biggest variation in the number of perforations was discovered in the group that repositioned the bony window to its original position (0% to 40,47%) (36,37). Competence of a surgeon, individual anatomy of the sinus, instruments used during the surgery, sedation of the patient, factors directly affecting surgeons work (stress, shivering hands) could all affect the number of perforations during the procedure. Even more, sometimes surgeons may not notice small perforations (7). Giuliano Garlini *et al.* noticed that during the lateral sinus augmentation when bony window was elevated into newly formed sinus cavity it did cover some sinus perforations, that is why surgeon might not notice them (7). During the augmentation procedure sinus membrane can be perforated at 3 stages: while preparing bony window, elevating sinus membrane and putting graft material into the sinus cavity. Only one article mentioned which stage of the procedure caused the perforation and in all of their cases it was during the lifting of the sinus membrane (40). In another article A. Thor *et al.* discussed, that all of their perforations were most likely made during the elevation of sinus membrane (36). Instruments used during the surgery may also have some influence to the rate of membrane perforations. However, in this review publications were not grouped according to surgical instrument type. Current scientific literature is heterogeneous in regards to piezoelectric and rotary instrument type relationship with sinus membrane perforation rates. Some of the publications say that piezoelectric instruments improve tactile sense and decreases the number of complications. Despite that, A. Barone *et al.* noticed that more complications were made using piezoelectric instruments, but the difference was not statistically significant (13). Ricket *et al.* did not notice any difference between piezoelectric and rotary instruments (45). Other complications, such as post-operative bleeding, pain, were not included into our study due to the low number of publications mentioning them.

Conclusions

There was a statistically significant difference between different groups of bony window usage techniques in reference to sinus membrane perforation rate. The lowest rate of sinus membrane perforations occurred when bony window was elevated inside the sinus cavity or discarded. However, many

Table 10. Average Schneiderian membrane perforation rates across different bony window usage techniques

	Bony window usage technique				
	The bony window is elevated into the newly formed sinus cavity	**The bony window is elevated out of the surgical site and discarded**	**The bony window is elevated out of the surgical site and repositioned after placing the bone graft**	**The bony window is used as a bone graft**	**Total**
The amount of successful sinus lifts	1164a	459a	306b	168a, b	**2097**
Rate of successful sinus lifts	95.7%	95.8%	83.6%	91.3%	**93.4%**
The amount of Schneiderian membrane perforations	52a	20a	60b	16a, b	**148**
Rate of perforations	4.3%	4.2%	16.4%	8.7%	**6.6%**
Total amount of attempted sinus lifts	**1216**	**479**	**366**	**184**	**2245**

Each subscript letter (a,b) denotes a subset of bony window usage technique categories whose column proportions do not differ significantly from each other at the ,05 level.

other factors could influence this Schneiderian membrane perforation rate. Due to the lack of publications that investigate the effects of different bony window usage methods, clinical recommendations cannot be drawn from current data.

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