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REVIEW PAPER

Effect of Schneiderian Membrane Thickening on the Maxillary Sinus Augmentation and Implantation Outcomes: A Systematic Review

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Abstract

Background Schneiderian membrane thickness may influence the final clinical outcome of sinus augmentation and dental implantation. Mucosal thickening has been regarded as a contributing factor for post-treatment complications. This study aimed to systematically review the available literature on the association between mucosal thickening and potential complications related to sinus augmentation and implant placement.

Methods An electronic search was carried out in MEDLINE, Embase, and Web of Science by two independent reviewers. It was complemented by manual search of the reference lists of all relevant studies. The studies reporting on sinus augmentation and dental implantation in cases with preoperative mucosal thickening were considered eligible for this study.

Results The initial search yielded 1032 articles. Five hundred and sixty-four records were screened by title and abstract, and 57 studies succeeded the inclusion criteria for full-text evaluation. Finally, 10 records remained for data extraction. The included studies assessed sinus augmentation and implantation procedures in 765 patients, 324 (42.3%) of them showed mucosal thickening. Increased membrane thickness did not significantly elevate the frequency of sinus augmentation complications. In addition, the overall implant survival rate was 99.03%.

Conclusions Within the limitations of the present study, the presence of mucosal thickening might not be a risk factor for sinus augmentation and implant survival rate.

Keywords Dental implant · Sinus floor elevation · Mucosal thickening · Survival rate

Introduction

Dental implants are commonly used to restore oral function and esthetics [1]. The presence of adequate bone volume is necessary for implant stability [2]. Inadequate vertical bone height in edentulous posterior maxilla is a common finding due to alveolar bone resorption and sinus pneumatization, which may jeopardize proper implant placement [3].

Several techniques have been introduced to counter this limitation including tilted implants [4], zygomatic implants [5], short implants [6], and sinus augmentation approaches. Maxillary sinus floor elevation with the use of bone substitutes to increase the vertical bone height was first published by Boyne and James [7]. In this technique, the Schneiderian membrane is elevated to provide adequate space for grafting material. This procedure could be carried out in conjunction with or prior to implant placement according to the residual alveolar bone height for primary implant stability [8].

Different methods and instruments have been developed over the years to increase the implant survival rate and minimize the postoperative problems following sinus augmentation [9]. However, some complications such as membrane perforation still occur and may affect the treatment outcome.

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As membrane integrity has been linked to the success of sinus augmentation [10], its meticulous management has been recommended. In addition, any pathology in the maxillary sinus may affect the procedure outcome and the success of implant placement [11]. The overall prevalence of pathologies in the maxillary sinus is reported to be 56.3% [12]. The most frequent abnormality in the sinus cavity is mucosal thickening (Fig. 1), with the prevalence ranging from 25.1 to 66% [13].

Schneiderian membrane thickening may increase the probability of the sinus membrane perforation. Membrane thickness more than 2 mm is considered pathologic [14] and is defined as a hyperplastic inflammatory reaction of the maxillary sinus membrane [15]. This finding could be a result of trauma, infection, chemical agents, foreign body reaction, neoplasm, or airway conditions such as allergies, rhinitis, or asthma [16]. Sinus membrane thickness could also be influenced by some factors including gingival biotype, periodontal diseases, smoking, or certain seasonal changes [17].

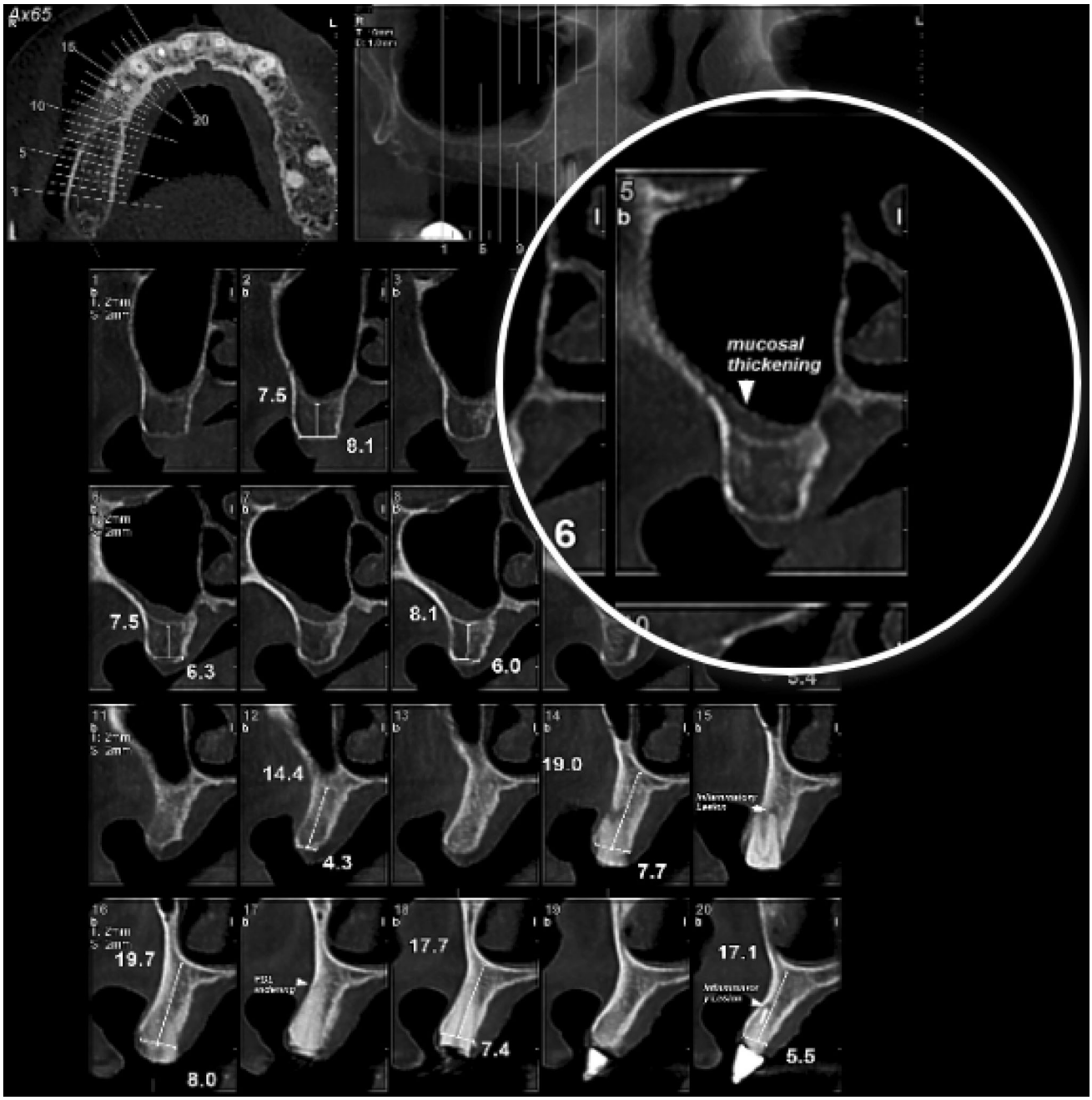

Fig. 1 Mucosal thickening is the most common sinus abnormality

Although mucosal thickening is the most common abnormality in the sinus cavity, the evidence regarding its effects on the outcomes of dental implant treatment is still limited. Therefore, this systematic review aimed to investigate the effect of sinus membrane thickness on the outcomes of sinus floor elevation and implant placement.

Methods

The present systematic review was performed in accordance with the "Preferred Reporting Items for Systematic Review and Meta-Analysis" protocol (PRISMA) [18].

PICO question (Participant, Intervention, Comparison, Outcome):

1. Participants (P): Partially or completely edentulous patients in need of the posterior maxillary implants.
2. Intervention (I): Sinus floor augmentation and dental implants in patients with mucosal thickening.
3. Comparison (C): Sinus floor augmentation and dental implants in patients without mucosal thickening.
4. Outcomes (O): Sinus floor elevation outcome and implant success and/or survival rates.

Search Strategy

An exhaustive search of the literature was carried out by two reviewers (R. A, A. M) in MEDLINE, Embase, and Web of Science up to April 2020. Search terms included the following keywords, which were modified appropriately for each database:

1. (implant) AND (sinus augmentation OR sinus lift OR sinus elevation OR sinus floor augmentation OR sinus floor elevation) AND (mucosal thickening OR mucosal thickness OR membrane thickness OR schneiderian membrane OR mucosal thickening pathology).
2. (edentulous jaw OR edentulous mouth OR partially edentulous jaw) AND (alveolar resorption OR alveolar bone atrophy OR alveolar bone loss) AND (sinus augmentation therapy OR maxillary sinus floor augmentation) AND (Schneiderian membrane OR sinus membrane).
3. (sinus lift OR sinus floor elevation OR bone augmentation) AND sinus AND mucosal thickening AND dental implant.

We did not limit our search strategy regarding the study design, as doing so could have excluded some pertinent publications [19]. No publication status, language or time restrictions were applied. The electronic search was complemented by manual search of the reference lists of all relevant articles. Any disagreements during the process were resolved by discussion with a third reviewer (M. K).

Inclusion Criteria

Titles and abstracts of the retrieved articles were screened independently by two independent authors (A. M, M, N) based on the predetermined inclusion criteria.

The inclusion criteria were as follows:

1. Prospective or retrospective human studies with $\geq$ 10 participants
2. Full text availability
3. Reporting on preoperative sinus membrane thickness
4. Reporting on implant survival and/or success rates
5. Sinus floor elevation outcomes

The exclusion criteria were as follows:

1. Without proper follow-up information.
2. Review, case reports, expert opinions, in vitro studies, and animal studies
3. The procedure success could not be clearly derived from the presented data

Data extraction was performed by two independent authors (A. M, M, N) using a predefined data extraction table. Any disagreements was resolved by a third author (M. K).

Qualitative Assessment

Two reviewers (R. A, M, K) independently assessed the quality of the identified studies and resolved any disagreements through discussion.

For non-randomized clinical trials, qualitative assessment was performed using Newcastle–Ottawa Quality Assessment Scale (NOS) [20]. Quality assessment for one randomized controlled clinical trial was assessed based on The Cochrane risk of bias tool for randomized trials [21].

Statistical Analysis

To carry out the present systematic review the Microsoft Excel was used for calculations. Furthermore, Comprehensive Meta-Analysis 2.2.064 was used for meta-analysis and the corresponding forest plot.

Results

A total of 1032 articles were retrieved through all three search strategies. After exclusion of 468 duplicate entries, 564 records were remained for further screening. Excluding articles based on titles and abstracts, 57 studies were remained for full text assessment. One article was added by

manual search of the reference lists of all relevant articles. Finally, 10 records [22–30] were included for the final evaluation (Fig. 2).

The qualitative assessment for non-randomized studies is presented in Supplementary Table. The only randomized clinical trial [14] was evaluated as "moderate potential risk' of bias based on the Cochrane risk of bias tool for randomized trials.

In order to evaluate the effects of mucosal thickening on the outcomes of sinus grafting and implant placement success, increased mucosal thickness of more than 2 mm was considered pathologic (regardless of the reason for the thickening), in accordance with some previous studies [31–33].

The included studies assessed sinus augmentation procedures in 765 patients aged between 18 and 94 years (351 females, 414 males), with the mean follow-up duration of 39.3 months. They received 865 implants, considering 4 studies did not report their implant numbers [22, 23, 27, 30] (Table 1). The mean smoking rate was 25.7%, while three studies did not report on smoking status of their participants [23, 24, 27].

The most common method used for evaluation of the mucosal thickness was cone-beam computed tomography (CBCT) (61.5%) (Table 2). Two studies [14, 30] used computed tomography (CT) scans to measure mucosal thickness, while one study [24] used CT only for cases with sinusitis. The reported cases of mucosal thickening reached

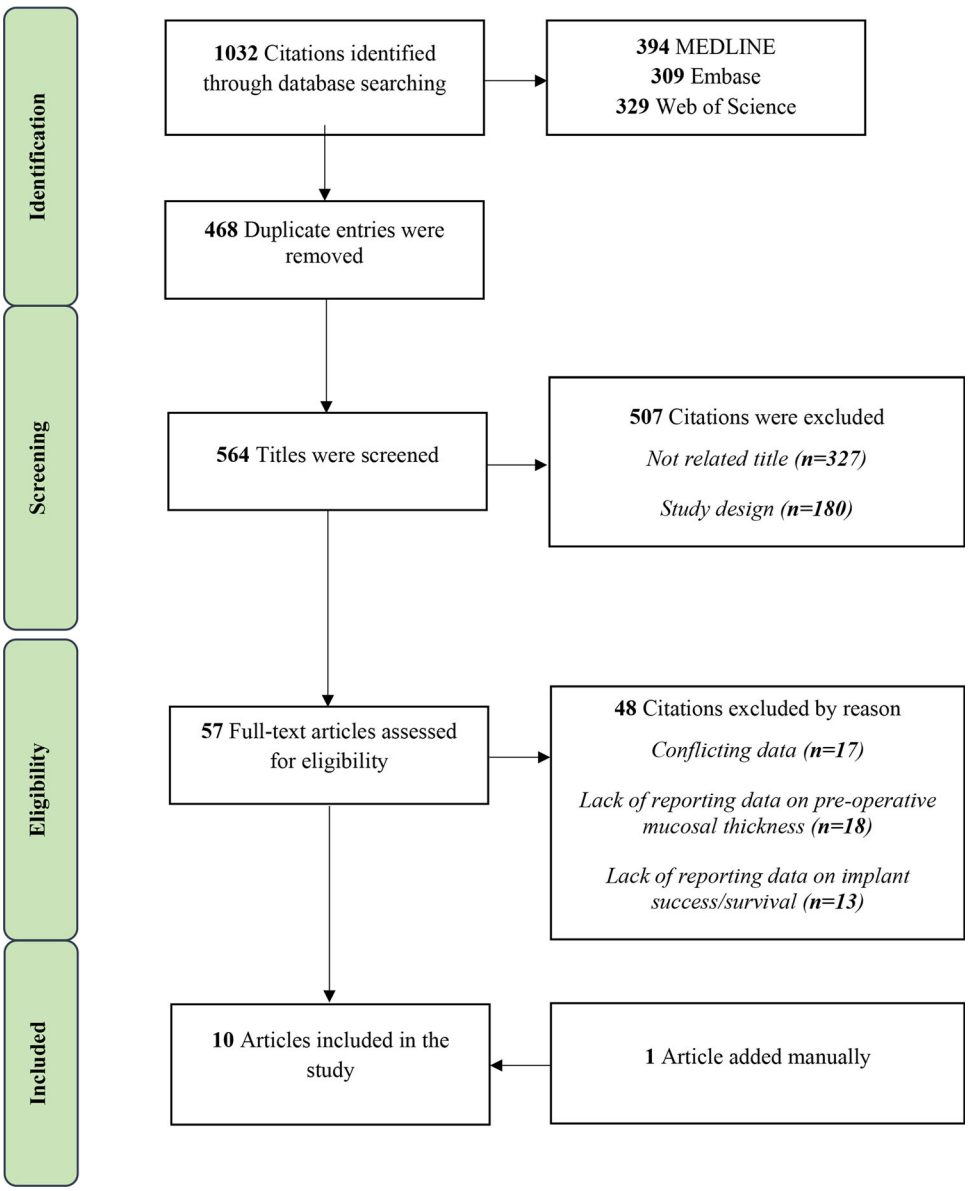

Fig. 2 Flowchart of the screening process

Table 1 Characteristic of the participants in the included studies

Author/year	Study design	Participants (*n*)		Age (Y)	Gender	Smoking
		Overall	MT			
Ritter et al./2020 [30]	Retrospective	145 sinuses	55 MT (> 2 mm) 19 Cyst/Polyp 5 Sinus opacification 10 Ostium obstruction	18–94	82 F 63 M	31 (21%)
Küçükkurt/2019 [26]	Retrospective	88 115 sinuses (27 bilateral, 61 unilateral)	43 27 MT (≥ 3 mm) 35 sinuses\ 16 Peseudocyst (17 sinuses)	30–73	34 F 54 M	47 (53.4%)
Gong et al./2019 [23]	Retrospective	92	19 MT (> 2 mm)	44–48	38 F 54 M	NR
Najm et al./2018 [28]	Retrospective	13 14 sinuses	2 MT (> 2 mm) 1 in a smoker	38–69	13 F	2 (15%)
Chen et al./2017 [22]	Prospective	84	19 Solitary polyps or cysts 17 MT 6 Fluid accumulation 1 Near-total opacification 2 Calcification spots	Average: 48.8	29 F 55 M	16 (19%)
Qin et al./2017 [29]	Prospective	100	28 13 Flat thickening 15 Pseudocyst	20–80	47 F 53 M	19 (19%)
Maska et al./2017 [27]	Retrospective	29	6.9% Minimal thickening (> 1 mm but ≤ 2 mm) 20.7% Moderate thickening (> 2 mm but ≤ 5 mm) 65.5% Severe thickening (> 5 mm)	NR	11 F 18 M	NR
Kfir et al./2014 [25]	Retrospective	16	16	26–64	7 F 9 M	4 (25%)
Kayabasoglu et al./2014 [24]	Retrospective	94 145 sinuses (51 bilateral, 43 unilateral)	94	29–71	32 F 62 M	NR
Garcia et al./2013 [14]	RCT	104 (135 sinuses)	58 (> 2 mm) 3 mucosal cyst	39–81	58 F 46 M	30 (27.8%)

MT Mucosal thickening, *F* Female, *M* Male, *Y* Years, *NR* Not reported

324 patients (excluding pseudocysts, polyps, and opacification), and its prevalence among articles that had not excluded cases with normal mucosa was 30.6% [14, 22, 23, 26–30, 34, 35]. Five studies used lateral window approach for sinus floor augmentation [14, 24, 26, 28, 30], four studies applied transcrestal technique [23, 25, 29, 30] (two studies with bone substitute [23, 29]), and two studies did not report on their surgical approach [22, 27]. Ritter et al. [30] applied both approaches (79% Lateral window and 21% transcrestal sinus grafting).

Eight studies installed implants simultaneously with sinus augmentation [14, 23–26, 28–30], three studies used a delayed implant installation protocol [14, 22, 30], and one study [27] did not report the implant placement approach (two studies [14, 30] applied both protocols). The overall implant survival rate was 99.03%, which was not significantly different in sinuses with and without mucosal thickening. One study even reported separate survival rates in cases with and without mucosal thickening (98.7% vs. 94.1%) [26]. In addition, the survival rate showed no relationship with the implant placement protocol (simultaneous/delayed or one stage/two stage) ($p > 0.05$). Three studies [22, 23, 30] reported distinct sinus membrane perforation rates in cases with and without mucosal

Table 2 Membrane thickness, residual bone height, and surgical approach in the included studies

Author/year	Method of evaluation	Preoperative membrane thickness (mm)	Average residual bone height (mm)	Surgical approach	Implant (n)	Implant placement
Ritter et al./ 2020[30]	CT	8.9 ± 4.6 mm	NR	79% Lateral window 21% Transcrestal	NR	97 Simultaneous (67%) 48 Delayed (33%)
Küçükkurt/ 2019 [26]	CBCT	7.97 ± 2.82 mm 12,6 ± 4.47 mm Pseudocyst	3.1 ± 1.40 mm Control group 4.5 ± 1.70 mm MT group	Lateral window	168	Simultaneous
Gong et al./ 2019 [23]	CBCT	> 2 mm	5.36 ± 1.28 mm Control group 5.15 ± 1.34 mm MT group	Transcrestal Bone substitute	NR	Simultaneous
Najm et al./ 2018 [28]	CBCT	> 2 mm	5.6 ± 1.9 mm	Lateral window	21	Simultaneous
Chen et al./ 2017 [22]	CBCT	> 2 mm	NR	NR	NR	Delayed
Qin et al./ 2017 [29]	CBCT	> 2 mm	7.21 ± 1.12 mm	Transcrestal Bone substitute	100	Simultaneous (non-submerged)
Maska et al./ 2017 [27]	CBCT	> 2 mm	NR	NR	NR	NR
Kfir et al./ 2014 [25]	CT	15 ± 4.8 mm	NR	Transcrestal with balloon elevation	30	Simultaneous
Kayabasoglu et al./2014 [24]	OPG CT in patients with sinusitis	≥ 5	NR	Lateral window	268	Simultaneous
Garcia et al./ 2013 [14]	CT	> 2	NR	Lateral window	278	61 Simultaneous 74 Delayed

MT Mucosal thickening, *CBCT* Cone-beam computed tomography, *CT* Computed tomography, *OPG* Orthopantomograph, *NR* Not reported

thickening, which shows that this finding was less frequent in sinuses with increased membrane thickness (Fig. 3).

Discussion

Previous studies have reported that the mucosal thickness is ≥ 2 mm in 23–55% [36] and ≥ 3 mm in 10–12% [36, 37] of population. It has also been reported that 56.3% of the maxillary sinuses have pathologies [12], the most common of which is mucosal thickening, with prevalence ranging from 25.1 to 56.5% [13]. The studies included in this review reported mucosal thickening in 324 (42%) cases. The prevalence of mucosal thickening in articles that had not excluded cases with normal mucosa was 30.6%.

Most of the included studies reported the thickness of > 2 mm as mucosal thickening, which is consistent with other studies reporting the normal sinus membrane thickness ranging from 0.8 to 1.99 mm [27, 38], and the thickness of > 2 mm as pathologic mucosal thickening (regardless of the underlying etiology) [31–33]. However, some investigations [26, 27] considered other criteria as abnormal membrane thickness. This could be explained by the authors' definition of mucosal thickening and its

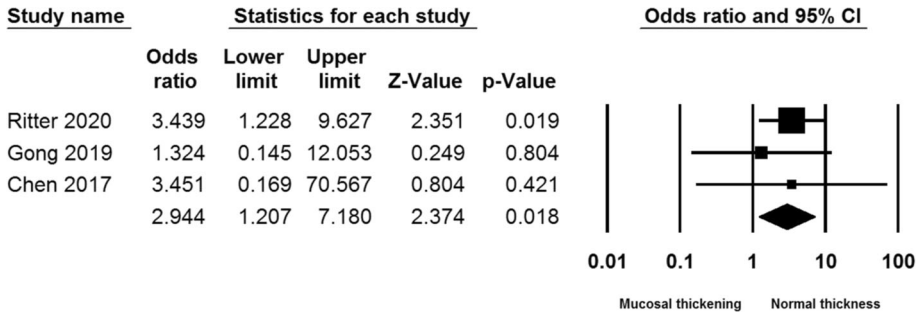

Fig. 3 Cumulative odds ratio of sinus membrane perforation in sinuses with and without mucosal thickening

Table 3 Follow up duration, implant outcome, and complications in the included studies

Author/year	Follow-up (months)	Survival rate/success rate (%)	Perforation rate (%)	Complication
Ritter et al./2020[30]	6–107	98.5% success rate	11% of cases with increased thickness 29% of cases with normal thickness	32 Mucosal perforation 10 Local infection 4 Postoperative bleeding 3 Flap dehiscence 2 Oroantral fistula
Küçükkurt/2019 [26]	25.1 ± 10 Control group 27.8 ± 9.5 MT group	96.4% 94.1% Survival rate (control group) 98.7% Survival rate (Pathology group)	NR	NR
Gong et al./2019 [23]	4–6	100% Survival rate	6.5% Normal thickness 5% MT	6 Mucosal perforation
Najm et al./2018 [28]	120	100% Survival rate	21.40%	3 Mucosal perforations
Chen et al./2017 [22]	3	100 Survival rate	7.1% Normal thickness No perforation in cases with thickening	1 Perforation
Qin et al./2017 [29]	7.82 ± 2.02	100% Survival rate	2.33%	3 Mucosal perforations
Maska et al./2017 [27]	12–94	100% Survival rate 100% Success rate	NR	NR
Kfir et al./2014 [25]	6–50	100% Success rate	None	None
Kayabasoglu et al./2014 [24]	5–47	99.6% Survival rate	8.5% (none of them developed sinusitis)	4 Postoperative sinusitis
Garcia et al./ 2013 [14]	12	95.3% Survival rate	7.50%	3 Postoperative pain 8 Perforations

MT Mucosal thickening, *NR* Not reported

consequences on the postoperative complications such as ostium obstruction [31, 32].

Higher prevalence of mucosal thickening was reported in patients with a history of periodontitis [27], which might be due to pro-inflammatory reactions involved in such circumstances. No association was found in terms of age [26], gender [26, 27], systemic factors, alveolar ridge height, endodontic treatment or other dental history issues [27]. However, previous systematic reviews concluded that periodontitis, smoking [39], male gender, and apical pathology [33] may result in the thickening of the sinus membrane. Such heterogeneous results could be rooted in differences in populations, sample sizes, and diagnostic thresholds for sinus membrane thickening (Table 3).

The overall 3-year survival rate of implants installed in conjunction or after sinus augmentation was reported to be 90.1% in a previous systematic review [40]. The present review concluded an overall sinus floor elevation success rate of 97.1%. The survival rate associated with implants placed in the sinus augmentation regions with preoperative mucosal thickening (324 cases) was 99.3%. It could be concluded that the presence of mucosal thickening might not have any association with the sinus augmentation and implant survival rate. This finding is in accordance with another study [41] showing that sinus pathologies including sinus membrane thickening does not have any association with sinus augmentation and implant success rate [27, 42].

Physiologic mucosal thickening does not seem to contribute to implant failure [27]. However, no clear conclusions can be made on the association between mucosal thickening as a result of sinusitis and implant survival. Hence, it could be suggested that if sinusitis is suspected, clinicians should consult the appropriate medical specialists prior to implant placement. It has also been concluded that only patients with complete sinus opacification need to be referred to an otolaryngologist prior to surgery [30]. These are in agreement with other studies reporting that mucosal thickening might be a concern if it is associated or

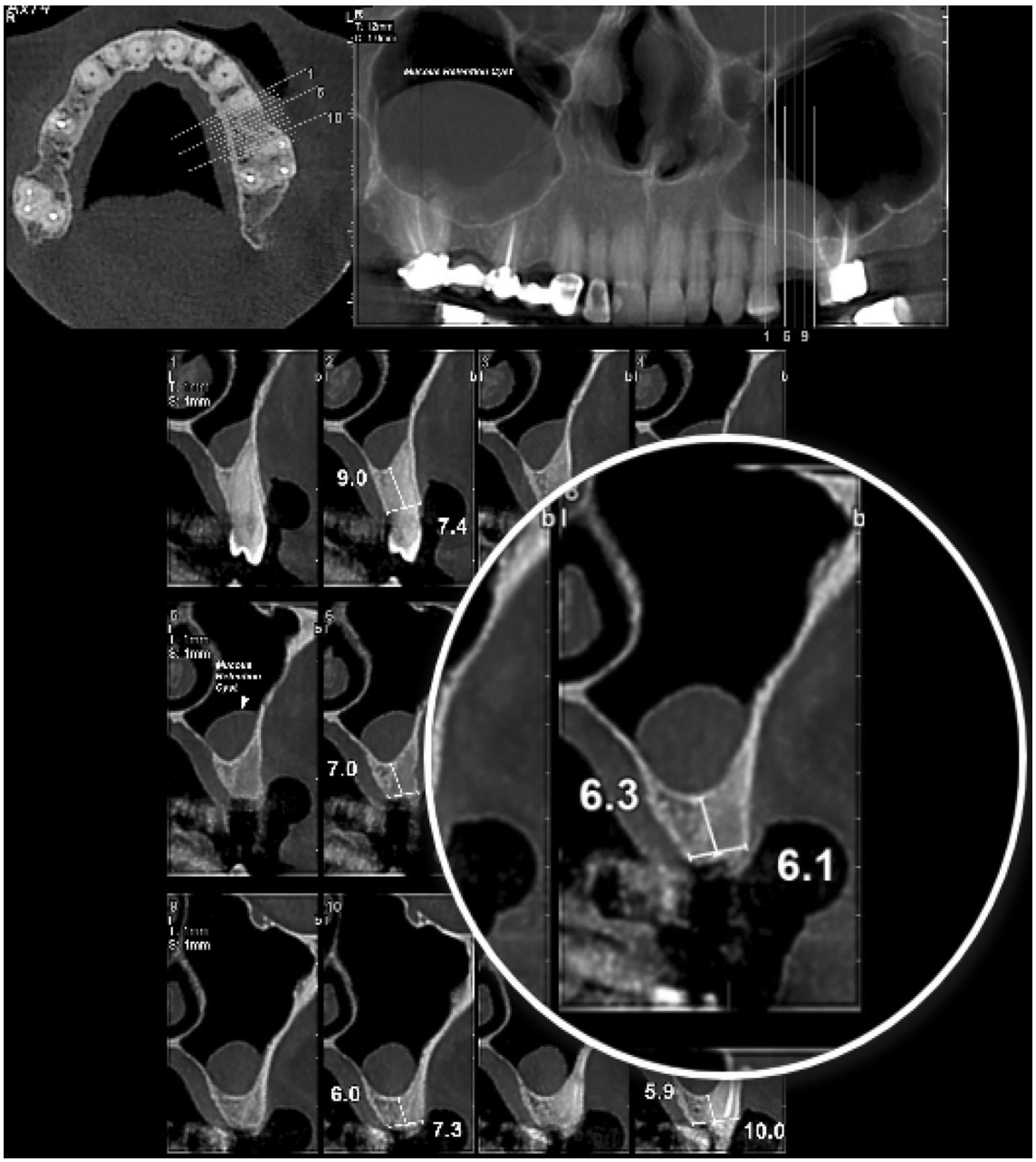

Fig. 4 Large cysts are suggested to be referred to an otolaryngologist before sinus augmentation

accompanied by other pathologies including large cysts, polyps and sinus opacifications (Fig. 4); such subjects have been suggested to be referred before sinus floor augmentation [22].

A noteworthy complication, which should be considered while evaluating the presence of mucosal thickening in sinus augmentation, is postoperative ostium obstruction. It seems that sinus augmentation for healthy sinuses has no risk of ostium obstruction, but mucosal thickening could be an obstacle during sinus elevation and may lead to failure or complications. It can also lead to ostium blockage when the sinus membrane is elevated and the graft material is placed under it, which in turn could lead to drainage disturbances and sinusitis [31]. Although this complication might not affect the implant survival rate, it should be considered preoperatively. Preoperative ostium obstruction was only reported in 10 cases in one study in this review [30], but it was not correlated to more frequent complications in asymptomatic patients.

Sinus membrane perforation is considered the most common complication during sinus augmentation procedure and the sinus membrane thickness has been studied as

a risk factor for perforation [31]. If perforations have any effects on the implant survival rate, and membrane thickness has an effect on the rate of perforations, then it could be expected that sinus membrane thickness should have an effect on the implant survival rate. The association between sinus membrane thickness and membrane perforation has been studied with some conflicting results. A significant correlation has been identified between membrane thickness and perforation rate in transcrestal approach [43], and the perforation rate was lowest when the thickness was 1.5–2 mm, which increased two to threefold in both thinner or thicker Schneiderian membranes. The studies included in this review reported the overall perforation rate of 8.62%, which was less common in sinuses with increased mucosal thickness (4.9% vs. 11.2%). It may postulated that a thin membrane might be perforated due to the lack of sufficient mechanical support to resist elevation force or bone graft insertion. In addition, some novel instruments have recently been introduced to prevent membrane perforation using transcrestal approach; these methods are, however, technique sensitive and inadvertent execution may lead to a higher rate of membrane perforation. Thicker membranes could resist stronger forces, allowing more compaction of the bone substitute material and consequently better osseointegration and higher implant survival rate [44].

The studies conducted on the association between sinus membrane perforation and implant survival rate have conflicting results, as well. A meta-analysis conducted in 2018 showed that an intraoperative sinus membrane perforation could increase the risk of implant failure after the sinus floor elevation [45]. This association may be explained by spreading of the grafting material in large perforations and consequent inflammation, which may lead to the failure of immediate bone grafting and implant loss. However, some other studies have concluded that sinus membrane perforation has no detrimental effect upon the implant survival rate [46], which is in agreement with the results of our included studies.

One of the main limitations of this review is that histologic studies have shown that 3-D imaging might overestimate mucosal thickness and lead to measurement inaccuracies. In addition, most of the included investigations did not follow a consistent and standardized method to measure membrane thickness, as it has shown that sinus membrane thickness is not homogeneous throughout the sinus cavity [47]. These limitations should be considered as a source of bias and be kept in mind during interpretation.

Conclusion

Within the limitations of the present study, it seems that the presence of physiologic mucosal thickening does not contribute to implant failure and sinus augmentation complications. However, more prospective studies are needed to conclude regarding the effect of pathologic increased mucosal thickness on implant survival.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12663-021-01551-y.

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Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethics approval Not applicable.

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