What is the frequency of anatomical variations and pathological findings in maxillary sinuses among patients subjected to maxillofacial cone beam computed tomography? A systematic review

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Abstract
Background: When considering dental implant rehabilitation in atrophic posterior sectors, the maxillary sinuses must be evaluated in detail. Knowledge of the anatomical variations and of the potential lesions found in these structures conditions the outcome of sinus lift procedures and therefore of the dental implants. A systematic review is made to determine the frequency of anatomical variations and pathological findings in maxillary sinuses among patients subjected to cone beam computed tomography (CBCT).

Material and Methods: A PubMed (MEDLINE) literature search was made of articles published up until 20 December 2015. The systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA). The quality of the studies included in the review was assessed using the Methodological Index for Nonrandomized Studies (MINORS).

Results: The combinations of search terms resulted in a list of 3482 titles. Twenty-three studies finally met the inclusion criteria and were entered in the systematic review, comprising a total of 11,971 patients. The most common anatomical variations were pneumatization and sinus septa. The prevalence of maxillary sinus disease ranged from 7.5% to 66%. The most common pathological findings of the maxillary sinus were mucosal thickening, sinusitis and sinus opacification.

Conclusions: Although the main indication of CBCT of the maxillary sinus in dentistry is sinus floor elevation/treatment planning and evaluation prior to dental implant placement, this imaging modality is increasingly also used for endodontic and periodontal purposes. There is no consensus regarding the cutoff point beyond which mu-
cosal thickening of the maxillary sinus should be regarded as pathological, and the definition of maxillary sinusitis moreover varies greatly in the scientific literature. In this regard, international consensus is required in relation to these concepts, with a clear distinction between healthy and diseased maxillary sinuses.

**Key words: Maxillary sinus, cone beam computed tomography, dental implant, maxillary sinus floor augmentation, sinus membrane, sinus floor elevation.**

**Introduction**

Implant placement in the posterior maxilla may be a challenging surgical procedure because of the reduced vertical bone height resulting from expansion of the maxillary sinus. Sinus floor elevation procedures are often needed to treat such bone deficiencies, in order to allow correct placement of dental implants (1). Apart from differences in indications, transcrestal and lateral window sinus augmentation procedures are predictable, and implants placed in grafted sinuses have high survival rates (2-4). Nevertheless, complications still occur, associated mainly with membrane perforation that is often caused by inadequate surgical planning or maneuvers (5). In this regard, perforation or damage of the Schneiderian membrane reportedly occurs in an average of 19.5% of the cases (up to 58.3%) (2). The anatomical variability that may be found in the maxillary sinus has a strong impact upon the risk of sinus membrane perforation and subsequent implant failure. Computed tomography is considered the gold standard for sinus diagnosis, because of its ability to provide multiple sections through the sinus at different planes and allow visualization of bone and soft tissues (6). Barone et al. noted that membrane perforation might lead to graft migration and sinus infection. Thus, an intact Schneiderian membrane is desirable to ensure better vascularization, graft stability and environmental conditions for maturation of the inserted bone graft materials (7,8). When considering dental implant rehabilitation in atrophic posterior sectors, the maxillary sinuses must be evaluated in detail. Knowledge of the anatomical variations and of the potential lesions found in these structures conditions the outcome of sinus lift procedures and therefore of the dental implants. Since the maxillary sinus is an anatomical structure that can be visualized by maxillary CBCT, the professionals performing such explorations must not only record the radiological findings for which CBCT is requested (dental implants, endodontics, periodontics, etc.) but should also evaluate the rest of the structures seen during the exploration. In this regard, the aim of the present systematic review was to answer the question: What is the frequency of anatomical variations and pathological findings in maxillary sinuses among patients subjected to maxillocorial cone beam computed tomography (CBCT)?

**Material and Methods**

The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement was used in this study (9).

- **PICO question**

What is the frequency of anatomical variations and pathological findings in maxillary sinuses among patients subjected to maxillocorial cone beam computed tomography (CBCT)?

- **Search Strategy for the Identification of Studies**

The PubMed (MEDLINE) database of the United States National Library of Medicine was used for a literature search of articles published up until December 2015. The following search terms were used in different combinations: “cone beam computed tomography”, “mucosal thickness”, “sinus membrane” “maxillary sinus”, “CBCT”, “posterior maxilla”. Two examiners read the titles and abstracts of all studies, and no blinding was carried out regarding author names, journals or publication date. The search was completed with a review of the references of the selected articles in order to identify additional studies not found in the initial literature search. In addition, a manual search (likewise up until December 2015) was made of the following journals: Clinical Implant Dentistry and Related Research, Clinical Oral Investigations, Clinical Oral Implants Research, Implant Dentistry, The International Journal of Oral and Maxillofacial Implants, Journal of Clinical Periodontology, Journal of Oral Implantology, Journal of Periodontology and Medicina Oral, Patologia Oral y Cirugia Bucal.

- **Study Selection Criteria**

Before starting the study, a series of inclusion and exclusion criteria were established. Chosen full-text articles were assessed for the following inclusion criteria: randomized clinical trials, prospective cohort studies, controlled clinical trials and retrospective studies, with a sample size of ≥ 200 patients. We excluded studies involving patients with congenital diseases (e.g., harelip and cleft palate) or maxillocorial traumatisms that could affect the region of the maxillary sinus. *In vitro* studies, animal studies, systematic reviews and case reports were also excluded. Authors were contacted for clarification of missing information when necessary. No restrictions were placed on the year
or language of publication. All articles selected from the electronic and manual searches were independently assessed by the first and second authors of the present study, according to the established inclusion criteria. Any disagreements between the reviewing authors were resolved by consensus, or by consulting the last signing author of the study. The level of agreement between the two reviewing authors was assessed using the Cohen kappa statistic.

- Data Extraction and Assessment of Methodological Quality

Data were independently extracted from the included studies by two reviewers (JAA and JVDV). A third reviewer (JFMF) was consulted in the event of any disagreement. Two authors independently evaluated the quality of the studies included in the systematic review using the Methodological Index for Nonrandomized Studies (MINORS) (10). The MINORS scale includes the following points: (a) a clearly stated aim; (b) inclusion of consecutive patients; (c) prospective collection of data; (d) appropriate endpoints; (e) unbiased assessment; (f) a follow-up period; (g) losses to follow-up of < 5%; and (h) prospective calculation of the study size. The items on the MINORS scale are scored as 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). We defined study quality as poor (< 5), fair (6-10) or good (≥ 11). The level of agreement between the two reviewing authors was assessed using the Cohen kappa statistic.

Results

- Study selection

The combinations of search terms resulted in a list of 3482 titles. Of these, 1412 were found to be duplicated; as a result, 2070 references were reviewed. Subsequently, 2005 papers were excluded on the basis of the evaluation of the title and abstract, thus leaving 65 articles for eligibility assessment. Twenty-three publications finally met the inclusion criteria and were thus selected for inclusion in the systematic review (Fig. 1). The main indication of maxillary sinus CBCT was sinus floor elevation/treatment planning and evaluation prior to dental implant placement (50%), followed by exploration for endodontic and periodontal purposes. In only two articles was CBCT indicated for orthodontic evaluation. Inter-rater reliability based on the kappa statistic was 0.89.

- Assessment of study quality

Two reviewers independently and in duplicate evaluated the quality of the included studies (Table 1) as part of the data extraction process. Any disagreements were resolved by consensus or by consulting the last signing author of the present study. The mean score for the global studies was 10 (range 7-12). Of the 23 studies finally included, 11 (11,13,15,17,21-26,28) were of fair quality, with a score of 6-10 points, and 12 studies (1,12,14,16,18-20,27,29-32) were of good quality, with a score of ≥ 11 points. Agreement between the reviewers for risk of bias assessment as evidenced by the kappa statistic was 0.90.

- Description of the studies

One cross-sectional study and 22 retrospective studies were included in the systematic review. The demographic data (patient age and sex) and information referred to the maxillary sinus findings of the publications are summarized in table 2. In the present systematic review we included a total of 11,971 patients.

- Anatomical variations of the healthy maxillary sinus

Over 50% of the included studies (n=15; 65.2%) identified anatomical variations of the healthy sinus.

- Sinus septa

Five studies (1,12,9,22,24) offered information on the prevalence of maxillary sinus septa, which ranged from 33.2-58%. Most patients (12) with septa showed one septum in one sinus (24.6%); 13.7% showed one septum in each sinus. Other combinations (up to three septa per sinus) were found in 8.7% of the patients. The septa were commonly found in the region of the first and second molars (60.7%) (1).

- Relationship between the roots of maxillary teeth and the maxillary sinus floor

Several studies (26,30,31) offered data on the relationship between the roots of maxillary tooth and the maxillary sinus floor. In one publication (26) involving 5166 maxillary premolars and molars, the roots extended below the sinus floor mainly in relation to the first (92.4%) and second premolars (71.6%); the roots penetrated into the sinus floor in 34.2% of the cases, and contacted the sinus floor in 36.7% of the cases.

- Other anatomical variations

In one study (19) involving 500 patients, the most frequent anatomical variation detected was pneumatization (83.2%). This same study (19) described the presence of exostosis in 2.6% of the cases, with unilateral location in 84.6% of the cases. Three publications (15,19,21) offered information on the prevalence of maxillary sinus hypoplasia, which ranged from 0.2-4.8%.

- Maxillary sinus disease

- Thickening of the sinus membrane

The prevalence of mucosal thickening ranged between 35.1-66% (13,20,21,25,28,32). The cutoff point beyond which thickening is considered pathological is normally 1-3 mm. However, the prevalence of maxillary sinus mucosal thickening was 41.5% in patients without apical periodontitis, over 70% in patients with moderate apical periodontitis, and 100% in those with severe apical periodontitis (17).

- Sinusitis and mucosal cysts

The prevalence of maxillary sinusitis ranged from 7.5-50% (11,13,20). The prevalence of mucosal cysts in turn ranged from 3.5-16.4% (11,16,18,32).

- Opacification of the maxillary sinus
Partial or complete opacification showed a prevalence of 1.8-68.2% (14,16,19,21,28,32). In one study (16) involving 1026 maxillary sinuses, 68.2% presented opacification of less than one-third of the sinus.

- Antroliths and polyps
  The prevalence of antroliths ranged from 1% (32) to 3.2% (19, 21), while the frequency of polyps ranged from 2.3% (11) to 25% (32).

- Other lesions of the maxillary sinus
  One publication (21) on the frequency distribution of sinus abnormalities in images from 703 patients and 1406 sinuses documented malignant tumors in 1% of the cases, benign odontogenic tumors in 0.3%, fibrous dysplasia in 0.2%, and ossifying fibroma in 0.2%. Another study (19) reported a foreign body prevalence of 1.6%.

**Discussion**

The present systematic review has examined the scientific evidence with a view to determining the frequency of anatomical variations and pathological findings of the maxillary sinuses in patients subjected to maxillofacial CBCT. Twenty-three publications were included in our systematic review, comprising a total of 11,971 patients. The most common anatomical variations were pneumatization and sinus septa. The prevalence of sinus maxillary disease ranged from 7.5-66% - the most common disorders being mucosal thickening, sinusitis and opacification.

Maxillary sinus septa are barriers of cortical bone that divide the maxillary sinus floor into multiple compartments known as recesses (33). Septa have become in-
can be elevated without further procedures. The shapes of the sinus membrane from the bony sinus floor (34). Septum separation of the sinus cavity, requiring the preparation of the sinus membrane from the bony floor (34). Surgical treatment (12), because in routine cases the membrane with a low height (up to 2 mm) do not require further augmentation surgery, since their presence may free handling without creating uncontrolled pressure on the sinus floor,Arguably important after the introduction of sinus of the septa to release the sinus mucosa from the bony wall of the maxillary sinus. The sinonasal septa require resection, because the pathological area of the sinus septa cannot be reached by the instruments. High septal antrum lead to partial or complete separation of the sinus cavity, the orientation of the septa limits the mobility of the sinus instruments, resulting in the sinus membrane from the bony floor (34). Surgical treatment (12), because in routine cases the membrane with a low height (up to 2 mm) do not require further augmentation surgery, since their presence may free handling without creating uncontrolled pressure on the sinus floor.

### Table 1. Quality assessment scores using the Methodological Index for Nonrandomized Studies (MINORS).

| Study                  | Clear aim (a) | Inclusion of consecutive patients (b) | Prospective collection of data (c) | Appropriate endpoints (d) | Unbiased assessment (e) | Follow-up period (f) | Losses to follow-up < 5% (g) | Prospective calculation of study size (h) | Total score (of 16) | Study quality |
|------------------------|--------------|--------------------------------------|-----------------------------------|---------------------------|------------------------|----------------------|-----------------------------|---------------------------------|-------------------|---------------|
| Cha et al. 2007 (11)   | 2            | 1                                    | 1                                 | 2                         | 0                      | 0                    | 0                           | 1                               | 8                 | Fair          |
| Neugebauer et al. 2010 (12) | 2            | 2                                    | 1                                 | 2                         | 0                      | 0                    | 2                           | 1                               | 11                | Good          |
| Smith et al. 2010 (13) | 2            | 1                                    | 1                                 | 1                         | 0                      | 0                    | 1                           | 1                               | 7                 | Fair          |
| Ritter et al. 2011 (14) | 2            | 2                                    | 1                                 | 2                         | 0                      | 0                    | 2                           | 1                               | 11                | Good          |
| Allareddy et al. 2012 (15) | 2            | 1                                    | 1                                 | 2                         | 0                      | 0                    | 1                           | 1                               | 8                 | Fair          |
| Genco et al. 2012 (16) | 2            | 2                                    | 2                                 | 2                         | 0                      | 2                    | 1                           | 1                               | 11                | Good          |
| Lu et al. 2012 (17)    | 2            | 2                                    | 2                                 | 1                         | 0                      | 1                    | 1                           | 1                               | 9                 | Fair          |
| Photikian et al. 2012 (18) | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 2                           | 1                               | 11                | Good          |
| Lams et al. 2012 (19)  | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 2                           | 1                               | 11                | Good          |
| Brullmann et al. 2012 (20) | 2            | 2                                    | 2                                 | 2                         | 0                      | 2                    | 2                           | 2                               | 12                | Good          |
| Rege et al. 2012 (21)  | 2            | 2                                    | 2                                 | 2                         | 0                      | 1                    | 1                           | 1                               | 10                | Fair          |
| Li et al. 2013 (22)    | 2            | 1                                    | 1                                 | 2                         | 0                      | 0                    | 1                           | 1                               | 8                 | Fair          |
| Shanbag et al. 2013 (23) | 2            | 1                                    | 1                                 | 2                         | 0                      | 0                    | 1                           | 1                               | 8                 | Fair          |
| Orhan et al. 2013 (24) | 2            | 1                                    | 2                                 | 2                         | 0                      | 0                    | 1                           | 1                               | 9                 | Fair          |
| Block et al. 2014 (25) | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 1                           | 1                               | 10                | Fair          |
| Ok et al. 2014 (26)    | 2            | 1                                    | 2                                 | 2                         | 0                      | 0                    | 1                           | 2                               | 10                | Fair          |
| Chan et al. 2014 (27)  | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 2                           | 2                               | 12                | Good          |
| Raghav et al. 2014 (28) | 2            | 1                                    | 1                                 | 2                         | 0                      | 0                    | 1                           | 1                               | 8                 | Fair          |
| Ren et al. 2015 (29)   | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 1                           | 2                               | 11                | Good          |
| Goller-Bulut et al. 2015 (30) | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 1                           | 2                               | 11                | Good          |
| Tian et al. 2015 (31)  | 2            | 2                                    | 2                                 | 1                         | 0                      | 0                    | 2                           | 2                               | 11                | Good          |
| Borstein et al. 2015 (31) | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 2                           | 2                               | 12                | Good          |
| Nunes et al. 2016 (32) | 2            | 2                                    | 2                                 | 2                         | 0                      | 0                    | 2                           | 2                               | 12                | Good          |
Table 2. Demographic data and information referred to the findings of the maxillary sinus.

| Author            | Type of study / sample | Cone beam computed tomography (CBCT) findings of the maxillary sinus |
|-------------------|------------------------|---------------------------------------------------------------------|
| Cha et al. 2007 (11) | Retrospective Patients: 252; 100 M, 152 F. Mean age: 18.6 years | Sinusitis 7.5%, retention cysts 3.5%, polyps 2.3%, deviation of the nasal septum 0.4%, large turbinates 0.4% |
| Smith et al. 2010 (13) | Retrospective Patients: 883; 386 M, 497 F. Mean age: 44.2 years | A total of 50.0% of the patients had evidence of maxillary sinusitis. There was a statistically significant higher prevalence of maxillary sinusitis in males (61.8%) compared to females (41.8%; p < 0.0001). 12.1% had right maxillary sinusitis, 15.6% had left-side involvement, and 21.0% had bilateral sinus disease. |
| Neugebauer et al. 2010 (12) | Retrospective Patients: 1029; 536 M, 493 F. Mean age: 40.9 years | Of the 1029 patients investigated, 545 (53%) showed no septum and 484 (47%) showed at least one septum in one sinus. In terms of position, 257 septa were close to the first molar, 225 were near the second molar, 144 were close to the third molar, and 139 were near the second premolar. Forty-four septa were associated with the first premolar. In the area of the canines, only 5 septa were detected. |
| Ritter et al. 2011 (14) | Retrospective Patients: 1609; 536 M and 493 F Mean age: 44.1 years | Pathological findings in either one or both sinuses were recorded in 579 patients (56.3%). 280 (27.2%) showed pathological signs in both sinuses, and 299 patients (29.1%) in either one of their sinuses. Patients < 60 years old in this study showed the most pathological signs, and there was a statistically significant difference between the investigated age groups (p < 0.02). Maxillary sinusitis 38.1%; total opacification 7%; partial opacification with liquid accumulation 12%; polyposidal mucosal thickening 6.5%. |
| Allareddy et al. 2012 (15) | Retrospective Patients: 1000; 382 M, 618 F. Age: 5-87 years | Mucitis / sinusitis / mucus retention pseudocysts (grouped as a single category) were the most common findings (55.1%). Hypoplastic sinuses had a prevalence of 2.1% and osteoma 0.4%. |
| Gracco et al. 2012 (16) | Retrospective Patients: 513; 382 M, 618 F. Age: 12-60 years | A total of 50.3% of the patients and 30.9% of the sinuses had pathological alterations, with 38.8% and 11.5% of the subjects showing bilateral and unilateral incidental findings, respectively. Mucosal thickening (> 1 mm) was observed in 40.1% of the patients and 25.1% of the sinuses. Pseudocysts were detected in 10.1% of the patients and 5.75% of the sinuses; 68.2% of the sinuses presented less than one-third opacification. |
| Lu et al. 2012 (17) | Retrospective Patients: 372; 178 M, 194 F. Mean age: 35.8 years | Among the patients with maxillary posterior teeth apical periodontitis, more than 80% had maxillary sinus mucosal thickening, and the prevalence of maxillary sinus mucosal thickening increased with the size of the lesion. The prevalence of maxillary sinus mucosal thickening was 41.5% in patients without apical periodontitis, > 70% in patients with mild and moderate apical periodontitis, and 100% in those with severe apical periodontitis. |
| Photiakhan et al. 2012 (18) | Retrospective Patients: 250; 110 M, 140 F Mean age: 46.1 years | The average mucosal thickness in sinuses with mucosal thickening was 5.0 – 3.9 mm (range: 1.6-20.3 mm). Distribution of mucosal thickness of sinuses with mucosal thickening: 65.8%; 1-1.5 mm; 5-10 mm; 4.8%; 10.1-15 mm; 4.1% > 15 mm. Cysts: 16.4% of the patients and 10% of the sinuses. Mean height: 14.4 ± 6.4 mm. Sinuses with severe periodontal bone loss were three times more likely to present mucosal thickening, whereas periapical lesions and root canal fillings showed no such association. |
| Lana et al. 2012 (19) | Cross-sectional Patients: 500; 238 M, 262 F Mean age: 52 years | The anatomical variations detected comprised pneumatization (83.2%), antral septa (44.4%), hypoplasia (4.8%) and exostosis (2.6%). The identified lesions were mucosal thickening (> 3 mm in 54.8% and > 3 mm in 62.6%), polyposidal lesions (6.6%), discontinuity of the sinus floor (17.4%), air-fluid level (4.8%), bone thickening of the maxillary sinus wall (3.3%) and antroliths (3.2%). Discontinuity of the sinus lateral wall was identified in 2.6% of the patients. Sinus opacification and foreign body were respectively found in only 1.8% and 1.6% of the patients. Pneumatisation sites were multiple in 46%. In 54% of the cases, pneumatisation was located only at a single site (alveolar). |
| Brüllmann et al. 2012 (20) | Retrospective Patients: 204; 83 M, 121 F Mean age: 47.5 years | A total of 74% of the patients showed mucosal findings. Thirty-three percent of the patients showed findings of apical transparency, 12% had perforations of the vestibular wall, 11% had perforations of the maxillary sinus floor, and 0.5% had a perforation of the palatal wall. Overall, 56% of the patients showed maxillary mucosal thickening (> 3 mm). Undiagnosed hyperplasia of the sinus mucosa may contribute to the clinical symptoms, leading to a diagnosis of atypical odontalgia or temporomandibular pain. |
| Rege et al. 2012 (21) | Retrospective Patients: 1113; 435 M, 678 F. Mean age: 49 years | Inflammatory lesions: membrane thickness > 3 mm: 66%; retention cysts: 10.1%; opacification: 7.8%; polyps: 5.6%; antroliths: 3.2%. Rest of sinus lesions: erosional communication: 2.2%; fractures: 1.4%; malignancy: 1%; inflammatory cyst: 0.4%; odontogenic cyst: 0.3%; benign odontogenic tumors: 0.3%; sinus hypoplasia: 0.2%; fibrous dysplasia: 0.2%; ossifying fibroma: 0.2%. |
| Shanbag et al. 2013 (23) | Retrospective Patients: 243; 131 M 112 F Mean age: 50.9 years | On analyzing the maxillary sinuses: sinus mucosal thickness < 2 mm: 55.4%; 2.5 mm: 24.7%; 5-10 mm: 10.8% > 10 mm: 9.1%. A total of 2.5% sinuses showed signs of acute sinusitis. Teeth with periapical lesions were most frequently first and second molars. Mucosal thickening ≥ 2 mm was more frequently observed in relation to teeth with periapical lesions and periodontal disease (p < 0.001) and was mostly ≤ 5 mm (p < 0.001). Sinus mucosal thickening was highly prevalent (60%) in this sample of dental patients and twice as more frequent in males than in females. Teeth with periapical lesions were 9.75 times more likely to be associated to mucosal... |
Table 2 continue. Demographic data and information referred to the findings of the maxillary sinus.

| Author et al. | Year | Study Type | Patients | Mean Age | Findings |
|---------------|------|------------|----------|----------|----------|
| Orhan et al. 2013 | (24) | Retrospective | Patients: 272; 120 M and 152 F | Mean age: 6-83 years | The prevalence of maxillary sinus segments with septa was 58%. Maxillary sinus septa were more frequent in males than in females (p < 0.05). The anatomical location of the septa within the sinus revealed that 12.2% of the patients had bilateral septa. Most frequent location: central zone of the sinus (59.9%). Mean septal height: 5.5-5.9 mm. Mean septal length: 7.8-8.1 mm. |
| Li et al. 2013 | (22) | Retrospective | Patients: 424 | | Patients with septa: 44.81%; sinususes with septa: 32.67%. A total of 21.2% of the patients had multiple septa; 20.5% of the patients had bilateral septa. Most frequent location: central zone of the sinus (59.9%). |
| Block et al. 2014 | (25) | Retrospective | Patients: 831 | Mean age: 52.2 years | A total of 1662 sinuses were evaluated, with thickening of at least one sinus membrane in 46.7% and 30.1% of all sinuses evaluated. The prevalence of patients with sinuses and sinus membrane thickening was 36.8% of the patients and 24.3% of the sinuses (2-5 mm), 6.0% of the patients and 3.7% of the sinuses (> 5 mm to the level of the ostium), and 3.6% of the patients and 2.2% of the sinuses (sinus with soft tissue material beyond the ostium). Unilateral sinus disease was more common than bilateral disease. After tooth removal, sinus membrane thickening decreased, but did not completely resolve proportional to the severity of sinus obliteration before tooth removal. |
| Ok et al. 2014 | (26) | Retrospective | Patients: 849;428 M and 421 F | Mean age: 14.8 years | Roots extending below the sinus floor was most frequently seen in the first (92.4%) and second premolars (71.6%). In addition, it occurred most frequently in the mesiobuccal (39.9%) and distobuccal (39.7%) roots of the first molar teeth. Roots penetrating into the sinus floor: 34.2% (most frequently palatine roots of the first molar teeth). Roots contacting the sinus floor: 36.7% (most frequently in the mesiobuccal roots of the second molar teeth). The relationship between the posterior teeth and the sinus floor differed according to the age decade interval (p < 0.05). The second decade and males were most susceptible to undesirable results. |
| Chan et al. 2014 | (27) | Retrospective | Patients: 720; 135 M, 185 F | Mean age: 50.1 years | The mean sinus width at the usual lower boundary of lateral window osteotomy (average 2.3 mm from the floor of sinus) was 9.0 (2.8) mm, with the thirty-third and sixty-seventh percentile sinus width values being 7.6 and 9.9 mm, respectively. The mean sinus width at the usual upper boundary of lateral window osteotomy (15 mm from crest) was 16.0 (4.4) mm, with the thirty-third and sixty-seventh percentile sinus width values being 14.0 and 17.3 mm, respectively. |
| Raghav et al. 2014 | (28) | Retrospective | Patients: 201; 110 M 91 F | Mean age: 32 years | The prevalence for the sum of incidental findings was 59.7%. Maxillary sinus scans showed mucosal thickening in 35.1%, opacification in 16.6%, polyoidal-mucosal thickening in 7.2%, others in 0.7%, and no findings in 40.2%. Of 110 male patients, 79% had at least one pathology in either of the sinuses, whereas 72.5% of the 91 investigated scans of female patients showed pathological signs in either sinus. |
| Ren et al. 2015 | (29) | Retrospective | Patients: 221; 113 M and 108 F | Mean age: 30.1 years | The prevalence of mucosal thickening paralleled the degree of alveolar bone loss, with 87.9% of patients displaying mucosal thickening when alveolar bone loss of the maxillary posterior teeth was severe. Similarly, the periodontal status of patients was worse with mucosal thickening than with normal mucosa. Furcation lesions and vertical infraorbital pockets were more likely to be associated to mucosal thickening. |
| Goller-Bulut et al. 2015 | (30) | Retrospective | Patients: 205; 101 M, 104 F | Mean age: 38.8 years | There was a significant correlation between mucosal thickening of maxillary sinus and both periodontal bone loss and age. The frequency of mucosal thickening increased as the severity of the apical lesion increased. A positive correlation was found between mucosal thickening and the degree of periodontal bone loss and periapical lesions. Teeth with inadequate root canal therapy and extensive caries were associated with mucosal thickening: pulp-periapical alterations were significantly related to mucosal thickening. |
| Tian et al. 2015 | (31) | Retrospective | Patients: 488; 302 M 546 F | Mean age: 34 years | The first premolar was always farther and the second molar mesiobuccal root was closer to the border of the maxillary sinus floor. The root protruding into the sinus was rare in the first premolar and dominated in the first molar palatine root. The root was closer to the border of the maxillary sinus floor before the age of 20 and farther after the age of 60. Age significantly influenced the mean distances and the frequency of the root above the maxillary sinus floor. |
| Bornstein et al. 2016 | (1) | Retrospective | Patients: 212; 86 M, 126 F | Mean age: 53.8 years | In most cases, septa were observed in the first or second molar region on the floor of the maxillary sinus. Of the septa identified, 33.1% were located in the roof of the sinus, whereas 24.3% were related to the infraorbital canal. The most common orientation of the septa was coronal (61.8%), followed by axial (7.6%) and sagittal (3.6%). There was no evidence that the frequency of maxillary sinus septa was associated to age, sex, or dentition status of the patients. |
| Nunes et al. 2016 | (32) | Retrospective | Patients: 200; 85 M and 125 F | Mean age: 41.2 years | Most sinus abnormalities were associated to at least one maxillary posterior tooth with a periapical lesion (p > 0.05). The most frequent sinus abnormality in the presence of a periapical lesion was mucosal thickening. The highest frequency of abnormalities was found when the radiolucency area was subjacent to the sinus floor. Mucosal thickening 38%, sinus polyp 25%, antrostomy pseudocyst 5.4%, nonspecific opacification 1.08%, periostitis 5.4%, antrostome 1%, mucosal thickening and periostitis 13%, mucosal thickening and antrostome 2.1%, mucosal thickening, periostitis, and antrostome 1%, sinus polyp and antrostomy pseudocyst 1%, sinus polyp and periostitis 4.3%, antrostomy pseudocyst and periostitis 1%, periostitis and antrostome 1%. |

\(F = \text{females}; M = \text{males}\)
the membrane (35). In our systematic review, the prevalence of maxillary sinus septa ranged from 33.2-58%. There is no consensus regarding the cutoff point beyond which mucosal thickening of the maxillary sinus is considered pathological. In this regard, different authors define pathological thickening as ≥ 1 mm (16), ≥ 2 mm (17) or ≥ 3 mm (19,21). In a study involving 831 patients, the prevalence of sinus membrane thickening was 36.8% (2-5 mm) of the patients and 24.3% of the sinuses; 6.0% of the patients and 3.7% of the sinuses presented more than 5 mm to the level of the ostium, and 3.6% of the patients and 2.2% of the sinuses presented soft tissue material beyond the ostium (25). A study (18) of CBCT images of 500 maxillary sinuses found the average mucosal thickness in sinuses with mucosal thickening to be 5.0-3.9 mm (range 1.6-20.3 mm). The majority of sinuses with mucosal thickening had a mucosal thickness of < 5 mm. Severe periodontal bone loss was significantly associated to mucosal thickening of the maxillary sinus. Sinuses with severe periodontal bone loss were three times more likely to have mucosal thickening (18), while Brüllman et al. recorded an odds ratio (OR) of 10.2 for the association of periodontitis to visibly thickened mucosa (20).

The most common causes of odontogenic sinusitis are dental abscesses and periodontal disease perforating the Schneiderian membrane. It is estimated that 10-12% of all cases of maxillary sinusitis have a dental origin (18). Sinusitis is the leading cause of mucosal thickening in symptomatic individuals (18). The relationship between dental infections and maxillary sinusitis is well established (36). The cause of mucosal thickening among asymptomatic individuals, however, remains unclear. In a study (37) of 190 patients treated for unilateral paranasal sinusitis, odontogenic infection was implicated in approximately 70% of the cases of unilateral paranasal sinusitis. Odontogenic maxillary sinusitis can be difficult to diagnose, and imaging exploration under various conditions is recommended. The definition of maxillary sinusitis varies greatly in the scientific literature. This is reflected by the findings of our systematic review, where the prevalence of maxillary sinusitis ranged widely from 7.5-50% (11,13,20). According to some authors such as Smith et al. (13), sinusitis is defined as any evident thickening of the mucosa in the maxillary sinus, with a prevalence of 50.0% in a series of 883 patients. Intragenic perforation of the maxillary sinus membrane during membrane elevation increases the chance of postoperative sinusitis, owing to bacterial graft contamination or graft migration into the sinus cavity (38). With appropriate treatment, intraoperative sinus membrane perforations did not represent an elevated risk for implant loss, infectious complications or displacement of graft material (39). In a study comprising 407 sinus grafts in 300 patients (39), the prevalence of Schneiderian membrane perforation was 8.6%, and was significantly correlated to the presence of sinus septa (OR = 4.8), smoking (OR = 4.8) and decreased residual bone height (OR = 0.01). The frequency of postoperative sinusitis was significantly greater for sinus membrane perforation (OR = 10.5) and in smokers (OR = 12.3).

Panoramic radiography has been used as a routine screening tool for evaluation of the maxillomandibular complex (40). However, panoramic radiography has limitations in diagnosing sinus disorders, and computed tomography remains the most effective diagnostic technique (41). Martínez-González et al. (41) compared panoramic radiography and computed tomography in evaluating 84 maxillary sinuses, and found panoramic radiography to have limitations in diagnosing changes in the maxillary sinus, whereas computed tomography seemed to be a better imaging tool. In a study published by Wolff et al. (42) in a total of 253 patients subjected to both panoramic radiographic and CBCT analysis, CBCT imaging provided significantly more surgically relevant information in cases of implant dentistry and maxillary sinus diagnosis. Visualization quality of the maxillary sinus and bony structures in CBCT appears to be similar to that afforded by computed tomography. However, CBCT generates high-resolution isotropic volume data and therefore could offer benefits in evaluating the bony aspects of the maxillary sinus thanks to the use of a lower radiation dose (14).

- Limitations

The results of our systematic review cannot be extrapolated to the general population, since the great majority of the patients in the included studies corresponded to CBCT explorations performed in the context of dental implant planning, i.e., the patients were typically elderly individuals with missing teeth in the upper maxilla. The main limitation of our systematic review is the fact that the results were not integrated in a quantitative analysis, thereby precluding the conduction of a meta-analysis. This was mainly due to significant heterogeneity between publications referred to disease definitions (with multiple definitions regarding mucosal thickening and sinusitis of the maxillary sinus), measured outcomes and other aspects. Another aspect that also must be taken into account on interpreting the results is the fact that 12 studies were of good quality, while 11 were of fair quality - the mean MINORS score being 10 out of 16 (range 7-12). We were not able to take the "comparator" component C of the PICO question into account. In some cases the PICO question cannot be applied in its entirety, particularly in the case of anatomical studies. Huang et al. (43) reported that in some cases it is difficult to encode certain question classes without modifying the existing PICO structure or introducing counterintuitive elements. The PICO representation is unable to capture anatomical relations that may be relevant in
a clinical question. There is no slot in the PICO framework capable of capturing “body parts”.

Conclusions
Although the main indication of maxillary sinus CBCT is sinus floor elevation/treatment planning and evaluation prior to dental implant placement, this imaging modality is increasingly also used for endodontic and periodontal purposes. There is no consensus regarding the cutoff point beyond which mucosal thickening of the maxillary sinus should be regarded as pathological, and the definition of maxillary sinusitis moreover varies greatly in the scientific literature. In this regard, international consensus is required in relation to these concepts, with a clear distinction between healthy and diseased maxillary sinuses in order to facilitate comparisons between studies.

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