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Prevalence, location and morphology of maxillary sinus septa: systematic review and meta-analysis

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Abstract

Aim: To gain further insights and resolve conflicting results in the literature regarding prevalence, predominant location and morphologic variability of maxillary sinus septa.

Material and Methods: Electronic and hand searching of English literature identified 33 investigations published from 1995 to 2011. Septa were defined as at least 2–4 mm in height.

Results: Septa were present in 28.4% of 8923 sinuses investigated (95% confidence interval: 24.3–32.5%). Prevalence was significantly higher in atrophic sinuses compared with dentate maxillae ($p < 0.001$). Septa were located in premolar, molar and retromolar regions in 24.4%, 54.6% and 21.0% respectively. Orientation of septa was transverse in 87.6%, sagittal in 11.1% and horizontal in 1.3% of cases. Septa height measured 7.5 mm on average. Complete septa (dividing the sinus into two separate cavities) were found in only 0.3%. Other rare conditions included multiple septa in one sinus (4.2%) and bilateral septa (17.2%). Septa diagnosis using panoramic radiographs yielded incorrect results in 29% of cases.

Conclusions: In view of their high overall prevalence and significant morphologic variability, 3D radiographic imaging prior to sinus floor augmentation may help to reduce complication rates in the presence of maxillary sinus septa.

Key words: dental implants; maxillary sinus floor elevation; radiographic diagnosis; sinus anatomy; sinus membrane perforation

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Maxillary sinus septa are barriers of cortical bone that divide the maxillary sinus floor into multiple compartments, known as recesses. Today's knowledge on paranasal sinus anatomy is largely based on the work of Austrian anatomist Emil Zuckerkandl in the late 1800s (Stammberger 1989); however, maxillary sinus septa were first analysed regarding their prevalence and characteristics by Arthur S. Underwood, an anatomist at King's College London, and are thus also referred to as Underwood's septa (Underwood 1910). Although sinus septa have been considered clinically insignificant variations for decades, they have gained practical relevance for periodontists, oral and maxillofacial surgeons as well as otolaryngologists (Rysz & Bakoń 2009). Septa have become increasingly important after the introduction of sinus floor augmentation surgery as their presence may complicate both creation and inversion of the access window in the lateral sinus wall, as well as elevation of the sinus membrane from

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the bony sinus floor (Betts & Miloro 1994).

Prevalence of maxillary sinus septa ranges between 10% and 58% in the literature (Yang et al. 2009, Maestre-Ferrín et al. 2011). Recent literature reviews on the topic identified conflicting study results regarding not only overall prevalence but also septa height, predominant septa location as well as prevalence in edentulism (Katranji et al. 2008, Maestre-Ferrín et al. 2010, Rossetti et al. 2010). Therefore, the aim of this investigation was to gain further insights into prevalence, location and morphology of maxillary sinus septa using a meta-analytic approach.

Material and Methods

Literature search and selection

A MEDLINE search of English literature (last search performed on 1 January 2012, key words: maxillary sinus septa, antral septa, maxillary sinus bone ridges, maxillary sinus bone walls, partitioned maxillary sinus and maxillary sinus crests) was supplemented by hand searching relevant journals including electronic publications ahead of print (*Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *Implant Dentistry*, *International Journal of Oral and Maxillofacial Implants*, *Journal of Clinical Periodontology*, *Journal of Oral Implantology*, *Journal of Oral and Maxillofacial Surgery* and *Journal of Periodontology*) and reference lists of retrieved papers as well as review articles. Studies were considered if they met the following inclusion criteria: (1) trials investigating maxillary sinus septa by 3D radiographic imaging or visual inspection in adults, and (2) presenting data on septa prevalence (primary outcome). Reporting on secondary outcome measures (septa location, septa height, septa integrity, septa orientation and accuracy of panoramic radiographs in septa diagnosis) was not considered a criterion for inclusion. After exclusion of 703 duplicates, 29,431 abstracts were screened. Full texts of 566 papers were obtained for further assessment against the stated criteria: 512 did not meet inclusion criterion 1 and 19 did not meet criterion 2 (Appendix S1).

Data collection and validity assessment

Thirty-five publications underwent data extraction and methodological appraisal. Authors of seven studies were contacted for clarification or missing data (listed in Acknowledgements section). The Newcastle-Ottawa scale (NOS) was used as quality assessment tool (Wells et al. 2001). Studies that received NOS ratings ≥ 7 stars (of nine possible stars) were judged as high quality (Chak et al. 2009) and included in the analysis, whereas two studies had to be excluded (NOS rating of six stars): one study (Shibli et al. 2007) was allotted no star in NOS category F (assessment of outcome) due to retrospective evaluation of 2D radiographs, another (Reiser et al. 2001) revealed shortcomings in NOS category A (representativeness of the exposed cohort) due to non-consecutive recruitment of human cadaver half-heads. The vast majority of included studies, by contrast, evaluated both sinuses of a subject (94%) whereas the remainder allowed data extraction for patient-based statistical analysis.

Study characteristics and quantitative data synthesis

Thirty-three investigations constituted the final selection (Table 1) reporting on 8923 sinuses: 7768 were investigated on computed tomographic images, 729 in patients undergoing sinus surgery and 426 in human cadavers. Twelve investigations regarded only septa higher than 2–4 mm to exclude irregularities and uneven patches of the sinus floor from the analysis, eight of them used the threshold definition of ≥ 2.5 mm proposed by Ulm et al. (1995). Septa prevalence is given as overall percentages with 95% confidence intervals (CIs). Weighted means of septa height and 95% CIs were computed. Comparison of subgroups was performed using Fisher's exact and independent two-sample *t*-tests, for prevalence and height data respectively. Sensitivity (A/(A + C)) and specificity (D/(B + D)) of panoramic radiographs (PR) using computed tomography (CT) as a reference standard were calculated using absolute frequencies (A: septa visible in both CT and PR, B: septa visible in PR but not in CT, C: septa visible in CT, but not in PR, D: septa not visible in both CT and PR). All analyses were performed using R 2.4.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Prevalence of maxillary sinus septa

Septa were present in 28.4% of 8923 maxillary sinuses investigated in 33 studies (Table 1). One quarter of patients featured septa in one sinus only, whereas 17.2% showed them bilaterally ($n = 3731$). Two septa within the same sinus were observed in 3.7% [95% CI: 2.2–5.2], whereas only 0.5% [95% CI: 0.4–0.6] of sinuses had three or more septa ($n = 5323$). Equal numbers of septa were reported in right (50.7%) and left (49.3%) sinuses ($n = 1986$). Septa prevalence was significantly lower in the Asian population (22.9%, $n = 1936$, $p < 0.001$), whereas no gender difference could be observed ($n = 1103$, $p = 0.207$).

Location and height of maxillary sinus septa

The majority of septa (54.6% [95% CI: 47.1–62.2]) were found in first or second maxillary molar regions, whereas 24.4% [95% CI: 14.8–33.9] and 21.0% [95% CI: 14.8–27.2] were located in anterior (premolar) and posterior (retromolar) sinus regions respectively (Appendix S2). Septa prevalence was significantly higher in edentulous ridges compared with dentate ridges ($n = 1167$, $p < 0.001$). Septa distribution to anterior, middle and posterior regions showed significant differences between dentate (27.1%, 58.6%, 14.3%) and edentulous ridges (12.6%, 69.5%, 17.9%) indicating increased prevalence in molar regions following sinus pneumatization ($n = 339$, $p = 0.007$). Mean septa height measured 7.5 mm ($CI^{95\%}$ 6.7–8.4) ($n = 1686$) without differences between dentate and edentulous ridges ($n = 339$, $p = 0.902$).

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Table 1. Prevalence of maxillary sinus septa per sinus in the 33 included studies as well as patient-based frequencies of uni- and bilateral sinus septa: overall prevalence and 95% CIs (n.d. = no data)

References	No. sinuses	Sinuses with septa (%)	Patients with unilateral septa (%)	Patients with bilateral septa (%)
Becker et al. 2008	198	7.1	n.d.	n.d.
Cabbar et al. 2011	20	35.0	n.d.	n.d.
Çakur et al. 2011	144	25.7	n.d.	n.d.
Ella et al. 2008	150	33.3	10.7	28.0
González-Santana et al. 2007	60	25.0	23.3	13.3
Gosau et al. 2009	130	25.4	23.1	13.8
Güncü et al. 2011	242	16.1	n.d.	n.d.
Kasabah et al. 2002	68	35.3	70.6	0.0
Kasabah et al. 2003	146	13.0	n.d.	n.d.
Kfir et al. 2009	57	45.6	n.d.	n.d.
Kang et al. 2011	150	29.3	n.d.	n.d.
Kim et al. 2006	200	26.5	23.0	15.0
Koymen et al. 2009	410	35.4	35.6	17.6
Krennmair et al. 1997	200	16.0	10.0	11.0
Krennmair et al. 1999	102	29.4	n.d.	n.d.
Lee et al. 2010	236	24.6	25.5	1.5
Maestre-Ferrín et al. 2011	60	58.3	43.3	36.7
Naitoh et al. 2009	30	36.7	20.0	26.7
Neugebauer et al. 2010	2058	33.2	27.7	19.3
Park et al. 2011	400	24.3	25.5	11.5
Pelinsari Lana et al. 2011	1000	32.3	24.2	20.2
Rosano et al. 2010	60	33.3	13.3	26.7
Rysz & Bakoń 2009	222	22.1	n.d.	n.d.
Sbordone et al. 2010	10	40.0	0.0	40.0
Schwartz-Arad et al. 2004	81	28.4	n.d.	n.d.
Selcuk et al. 2008	660	22.9	19.1	13.3
Shen et al. 2011	846	20.4	17.7	11.6
Toscano et al. 2010	56	30.4	n.d.	n.d.
Ulm et al. 1995	41	31.7	n.d.	n.d.
van Zyl & van Heerden 2009	400	55.5	27.0	42.0
Velásquez-Plata et al. 2002	312	22.1	21.2	11.5
Yang et al. 2009	74	9.5	n.d.	n.d.
Zijderveld et al. 2008	100	48.0	n.d.	n.d.
Total	**8923**	**28.4 [24.3–32.5]**	**24.5 [18.1–30.9]**	**17.2 [12.1–22.4]**

Septa morphology and visualization on panoramic radiographs

The vast majority of sinus septa (99.7% [95% CI: 99.1–100]) were incomplete, whereas only 0.3% [95% CI: 0.0–0.9] completely divided the sinus into two separate cavities ($n = 1825$). Orientation of septa was transverse (buccopalatal) in 87.6% [95% CI: 78.4–96.7], sagittal (mesiodistal) in 11.1% [95% CI: 2.1–20.2] and horizontal (parallel to the sinus floor) in 1.3% [95% CI: 0.0–3.6] ($n = 2038$). Transverse septa demonstrated significantly greater height at their medial (palatal) insertion compared with their lateral (buccal) aspect (6.9 mm *versus* 4.1 mm, $n = 299$, $p = 0.047$). Diagnosis of sinus septa using panoramic radiographs yielded incorrect results in 29.3% [95% CI: 11.9–46.7] ($n = 249$). Using CT scans as the reference standard, panoramic radiographs show a test sensitivity (true positive rate) of 53.8% [95% CI: 37.3–70.4] and a test specificity (true negative rate) of 80.4% [95% CI: 64.5–96.3].

Discussion

The overall prevalence of maxillary sinus septa (28.4%) proved to be only slightly lower than the frequency of 33.3% reported one century ago (Underwood 1910). The present meta-analysis, however, gained further insights into rare characteristics, such as complete septa (0.3%), saggital (11.1%) or horizontal (1.3%) septa orientation, multiple septa per sinus (4.2%) and patients showing bilateral septa (17.2%). Conflicting results in contemporary literature could be resolved: septa prevalence was found to range between 24% and 33% (four studies) in one review article (Katranji et al. 2008) and from 13% to 35% (11 studies) in a systematic review that also considered investigations using panoramic radiographs (Maestre-Ferrín et al. 2010). While 80% of included studies reported more septa in partially edentulous patients, a third review article concluded that septa were more frequent in edentulous jaws (Rossetti et al. 2010). In the present meta-analysis, a significantly higher prevalence in atrophic sinuses could be revealed. Moreover, controversies in study results regarding predominant septa location (55% in first or second molar regions) and mean septa height (7.5 mm) could be settled.

Potential limitations may arise from divergent criteria of septa definition throughout the included studies. However, no significant difference in septa prevalence could be found between threshold definitions of <2.5 mm *versus* ≥ 2.5 mm (27.9% *versus* 27.1%, $p = 0.786$) as well as

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between studies with *versus* without threshold definition (27.3% *versus* 29.2%, $p = 0.277$). Moreover, statistical comparison of mean septa height reported in studies with *versus* without threshold definition yielded no significant difference (6.6 mm *versus* 7.7 mm, $p = 0.301$). Another methodological issue that needs to be considered is the risk of measurement bias introduced by differences in outcome assessment: septa evaluation using 3D radiographic imaging (7768 sinuses = 87%) *versus* direct clinical observation (1155 sinuses = 15%), however, yielded no significant different results ($p = 0.102$). As radiographic investigations are frequently carried out in selected patient groups like those referred for implant treatment, recruitment bias may be assumed (Selcuk et al. 2008). This seems inevitable as radiation exposure calls for medico-ethical justification.

Compared with 3D computed tomography, diagnosis of sinus septa using 2D panoramic radiographs yield incorrect results in 29% of cases. Sinus septa showing a sagittal orientation may not be diagnosable at all using panoramic radiographs and may thus lead to the false assumption of narrow internal sinus anatomy and subsequent non-augmentation of the medial portion of the sinus cavity. The necessity of pre-operative radiographic imaging should be judged on its therapeutic consequences, in case of sinus floor augmentation ranging from modification in the surgical access strategy (or window design) to change in implant positions or total avoidance of bone graft surgery. In view of the high overall prevalence and significant morphologic variability in sinus septa seen in this investigation, 3D radiography prior to sinus floor augmentation surgery may help to reduce complication rates in the presence of maxillary sinus septa.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Flow chart for literature search and selection.
Appendix S2. Distribution of septa to anterior, middle and posterior sinus regions in 14 studies (overall distribution [95% confidence interval]).

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Clinical Relevance

Scientific rationale for the study: The presence of maxillary sinus septa may be associated with a higher risk of iatrogenic sinus membrane perforation during sinus floor augmentation surgery that may lead to post-operative sinusitis and graft infection.
Principal findings: Septa are predominantly found in first and second molar regions. Most are incomplete and show transverse (buccopalatal) orientation.
Practical implications: Therapeutic consequences of sinus septa range from modification in the surgical access strategy (or window design) to change in implant positions or total avoidance of bone graft surgery.

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