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Maxillary sinus septa: prevalence, morphology, diagnostics and implantological implications. Systematic review

M. Malec, T. Smektała, G. Trybek, K. Sporniak-Tutak

Department of Dental Surgery, Pomeranian Medical University, Szczecin, Poland

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Background: *The purpose of this review is to indicate the prevalence of septa, illustrate the most adequate diagnostic method and further discuss pre-operative considerations and implantological implications.*

Materials and methods: *On June 30th, 2013, a comprehensive database search was executed using PubMed (Medline) and Google Scholar. No time frames were applied. Only publications in English, Polish and German in peer-reviewed journals were considered.*

Results: *The final number of articles was 55: 7 articles were found to describe the possible aetiology of sinus septa, 34 articles describing the prevalence, 21 including information on classification, 19 showed methods of diagnosis and 24 articles included practical information about the influence of the septa in pre- and implantation surgery. One article could be found in more than one category.*

Conclusions: *Septa can be found in 9% to 70% patients (mean prevalence: about 36%) in every age group — young dentate patients as primary septa and old edentate or edentulous patients as primary or secondary septa more frequent in edentate or edentulous patients. When planning any surgical procedures, septa incidence should be taken into consideration. Precise information about the septa can be obtained from computed tomography (CT) or cone-beam CT. With development of the knowledge and surgical technique, septa appearance has simply become another option for treatment as any form of disadvantage.*
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Key words: dental implants, sinus floor augmentation, maxillary sinus

INTRODUCTION

Sinus septa were first described in literature in 1909 by Underwood [47]. They are bony walls rising from the sinus floor and divide the cavity into compartments. Septa, if missed, may cause unexpected difficulties during surgery. With the increasingly importance of peri-implant surgery, the understanding of the presence of septa has vastly increased. They have become an obstacle and may significantly hinder sinus augmentation procedures. To overcome this problem, common surgical methods had to be modified. The purpose of this review is to indicate the prevalence of septa, illustrate the most adequate diagnostic method and further discuss pre-operative considerations and implantological implications.

Address for correspondence: Dr T. Smektała, Department of Dental Surgery, Pomeranian Medical University, ul. Powstańców Wielkopolskich 72, 70–111 Szczecin, Poland, tel: +48 91 466 17 36, fax: +48 91 466 17 66, e-mail: kzchstom@pum.edu.pl

Table 1. Inclusion and exclusion criteria for eligibility assessment process

Inclusion criteria	Exclusion criteria
Human studies	Animal studies
Literature from 1909	
Articles in Polish, English, German language	Articles in other languages
Notes about maxillary sinus septa	Notes about nasal septa and intra-alveolar septa
Anatomy, physiology, difference in anatomical structures including septa	Diseases, congenital and acquired malformations, tumours of maxillary sinuses
Diagnostic of maxillary sinus septa (panoramic radiographs, computed tomography; cone-beam computed tomography, transillumination, intraoperative and cadaver study)	
Surgery and implantology of maxillary sinuses concerned with septa	Peri-implant surgery without septa significance

MATERIALS AND METHODS

On June 30th, 2013, a comprehensive database search was executed using PubMed (Medline) and Google Scholar. No time frames were applied. Only publications in English, Polish and German in peer-reviewed journals were considered. A single search equation was used for the search process: ("Maxillary Sinus" [Mesh] OR maxillary sinus OR Sinus maxillaris OR sinus Highmori OR sinus Highmore) AND (septa OR septum).

The titles and abstracts obtained were screened and evaluated by 2 observers according to inclusion and exclusion criteria (Table 1). Studies not meeting the inclusion criteria were excluded from further evaluation. Finally, article bibliographies that passed the eligibility assessment were screened, with any discrepancies in the selection settled through discussion. Prisma flow diagrams presented the search and evaluation process (Fig 1).

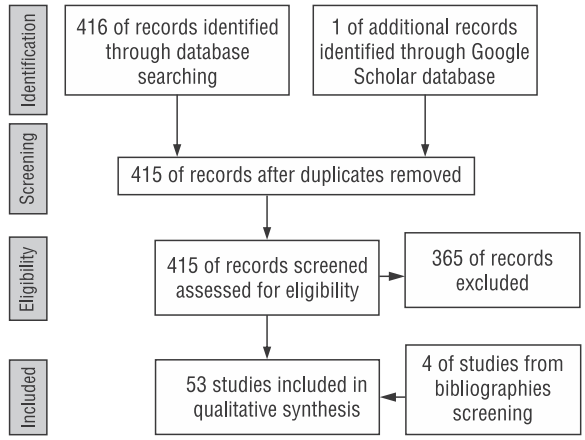

Figure 1. Prisma flow diagram presenting literature search and evaluation process.

RESULTS

416 articles were initially found. After verification in terms of inclusion/exclusion criteria, 365 articles were excluded. Additional searching using the same search equation performed in Google Scholar resulted in 1 new article. The final number of articles was 50 from a database search plus 4 coming from bibliographies screening.

All selected articles were divided into 5 categories: aetiology, prevalence, classification, diagnosis and significance in pre- and implantation surgery. This division was created to clarify and optimise the presentation of results. Seven articles were found to describe the possible aetiology of sinus septa, 34 articles describing the prevalence, 21 including information on classification, 19 showed methods of diagnosis and 24 articles included practical information about the influence of the septa in pre- and implantation surgery. One article could be found in more than one category.

DISCUSSION

Aetiology

Our search revealed a number of hypotheses that were described in literature. Underwood suggested that bony septa are thin, shattered and sharp ended and are related to tooth development. They arise from the floor between the area of 2 adjacent teeth and divide the sinus into 3 compartments: anterior, middle and posterior [47, 48]. Naitoh et al. [32] suggested that septa may be a kind of reinforcement to hold the volume and shape of maxillary sinus and could be an effect of disharmony during the growth of bone surface sutures in the alveolar process and maxillary sinus. Van den Bergh et al. [49] stated that septa are carrying masticatory forces during the dentate phase

of life and after tooth loss they disappear. Neivert [33] proposed the idea that septa were derived from the "fingerlike projections" produced during embryological out-pouching of the ethmoid infundibulum in cases when the clinging wall did not resorb. Vinter et al. [52] stated that they are an effect of the irregularly process of sinus floor atrophy in different regions creating "bony crests", calling them secondary septa. Ulm et al. [46], was close to Vinter's hypothesis, and suggested biomechanically septa remains were the border of 2 post pneumatisation regression zones, allowing for the transfer of masticatory pressure.

Among the many presented hypothesis Krennmair's dichotomous division seems the most likely: 1) primary septa, formed during the development of bony head structures and the head's height, increase with the growing process of the head; 2) secondary septa are formed after tooth loss in the process of maxillary alveolar atrophy.

Classification

Krennmair et al. [21], as previously mentioned, divided septa into primary and secondary. Primary are connected with the development of head structures. They are higher than the secondary and may occur in dentate or edentulous patients. Secondary septa are an effect of alveolar process pneumatisation. In most cases they are lower and occur only in edentulous maxillas [6, 51, 52]. Results have shown a greater number of septa in partially edentulous and edentulous than in dentate patients [20, 21, 26, 36, 50, 51]. Park et al. [37] reported dissimilar results, finding more septa in dentate maxillas (Table 2).

Table 2. Maxillary sinus septa prevalence depends on patients' dentition

Authors	Dentate	Partially dentate	Edentulous
Krennmair et al. [21]	13.2%		26.8%
Lee et al. [26]	19.3%		27.7%
Koymen et al. [20]		39.2%	46.4%
Van Zyl and van Heerden [50]	66%		71%
Velásquez-Plata et al. [51]		66.7%	33%
Park et al. [37]	38.7%	37.8%	23.4%
Orhan et al. [36]	3.8%	37.8%	3.4%

Major studies present the occurrence of mostly 1 septum [13, 17, 19, 20, 26, 31, 32, 34, 37, 41, 43, 44, 46, 51], except van Zyl and van Heerden [50] who found 2 septa. The highest number of septa was 4 [20, 37, 43, 50, 51]. Septa may be complete or partial; complete septa divide the maxillary sinus into separate compartments. However more commonly, they are partial (Table 3).

As Underwood [48] stated, the maxillary sinus can be divided into three compartments: anterior

Table 3. Number of maxillary septa occurring in 1 patient

Authors	Number of examined		1	2	3	> 3
	Subjects	Sinuses				
Neugebauer et al. [34]	1029		253	30	20	
Naitoh et al. [31]	15		10	1		
Koymen et al. [20]	205	410	69	28	8	4
Ulm et al. [46]		41	11	2		
Van Zyl and van Heerden [50]	200		49	51	27	11
Velásquez-Plata et al. [51]	156	312	64	4	1	4
Shen et al. [43]	423	846	65	49	9	1
Gosau et al. [13]	65		14	9	1	
Lee et al. [26]		204	50	8		
Park et al. [37]	74		47	19	6	2
Kasabah et al. [17]		68	22	2		
Rysz and Bakoń [41]		222	40	8	1	
Shibli et al. [44]	1024		135	86	1	
Kim et al. [19]	100	200	48	4	1	

Table 4. Average height of septa across the studies

Authors	Average height of septa [mm]
Neugebauer et al. [34]	Transversely: 7.3 ± 5 Sagittally: 11.7 ± 6
Naitoh et al. [31]	3.8
Ulm et al. [46]	7.9
Van Zyl and van Heerden [50]	6.2 ± 3.7
Krennmair et al. [21]	8.1 ± 2.5
Velásquez-Plata et al. [51]	Laterally: 3.5 ± 3 Medially: 5.9 ± 3
Gosau et al. [13]	5.4
Maestre-Ferrin et al. [29]	4.9
Orhan et al. [36]	Males: 4.86 ± 2,01 Females: 5.02 ± 2.14
Rosano et al. [39]	8.72

(between premolars), middle (between first molar and second molar) and posterior (above the third molar). Some authors have made small changes but generally this classification is still accepted [48]. Krennmair et al. [21] differs in 2 areas: the middle — first molar and posterior — second molar, Velásquez-Plata et al. [51], Kim et al. [19] and Lee et al. [26] — 3: anterior- second premolar, the middle — between the second premolar and second molar, posterior — behind second molar.

The septa can be oriented sagittally, transversally, horizontally or atypically. Naitoh et al. [32] marked the position of the septa in relation to the transverse palatal suture; Park et al. [37] found buccopalatal, sagittal and transversal type of septa. Sagittally and transversely orientated septa were found by Neugebauer et al. [34], Krennmair et al. [21], Underwood [48]. Van Zyl and Heerden [50], Shen et al. [43], Koymen et al. [20], Kasabah et al. [17], Ulm et al. [46], Orhan et al. [36] divided septa orientation into: buccopalatal/ /mediolateral orientated, Rosano et al. [39] — anterior-lateral, sagittal and transversal, finally Selcuk et al. [42] proposed vertical and horizontal position.

The height of the septa varies from up to 11.7 mm, anything lower than 2 mm was treated by most authors as exostoses. Van Zyl and Heerden [50], Naitoh et al. [32], Kim et al. [19] did not excluded septa at any height [51]; Lee et al. [26] classified septa as bony walls with a height of more than 2.5 mm, Naitoh et al. [31] over 2 mm and Rosano et al. [39] over 3 mm (Table 4).

The angles of septa orientation were also measured by: 1) Park et al. [37] (the angle between sagittal section and septa) with a mean of 76.29° on the right side and a mean of 83.94° on the left, 2) Naitoh et al. [31] from 40.6° to 86.8°, 3) Orhan et al. [36] 34.1° to 123.6° depending on the sinus region [31, 32, 36, 37].

Prevalence

Prevalence ranges from 9.5% to 69% and widely differs depending on the diagnostic method. Across studies, septa were examined with panoramic radiograph (OPG) [12, 17, 18, 22, 32, 44], computed tomography (CT) [12, 14, 15, 17–22, 26–28, 31, 32, 37, 41–43, 46, 50, 51], cone-beam computed tomography (CBCT) [15, 23, 34, 36, 38], in vitro cadaver studies [9, 13, 22, 31, 32, 39, 41, 46, 54] and intraoperative examination [45, 55]. The highest incidence was found by Maestre-Ferrín [28] — 70% (CT) and van Zyl and van Heerden [50] — 69% (CT), the lowest by Yang et al. [54] — 9% in cadaver studies (Table 5). Some authors examined the difference between gender/sex [19, 20, 26, 36, 37, 43, 50]. The incidence was higher in males, excluding Park et al. [37] who found more septa in females (Table 6). Our review also revealed that the septum was more often on left side than on right [19, 26, 36, 37, 43, 51] but the difference was relatively small. Only Koymen et al. [20] found more septa on right side (Table 7).

The highest prevalence was in the middle and anterior region. Lee et al. [26] and Gonzales-Santana et al. [12] stated that the greatest number was found in the middle region and Ulm et al. [46] in the anterior region (Table 8).

Diagnostics

During diagnostic process of sinus septa, a number of different methods were applied: OPG, CT, CBCT, direct examination, percussion, endoscopy, palpation and transillumination (Table 5) [2, 3, 37]. In OPG, septa cannot be decisively excluded or detected because they cannot be clearly differentiated from other anatomic structures [9, 46]. Some authors found that OPG gives a false diagnosis in the range of 11.8–52.68% [17, 20, 21, 28, 38, 49] compared to CT. CT caused a kind of revolution in the radiological diagnostic of hard tissue. It is very helpful in the accurate diagnosis of maxilla structures and for the planning of surgical procedures. CT also allows a practitioner to determine the thickness of the Schneiderian membrane [4, 26, 28, 37]. With highly advanced diagnostic methods and an image-guided procedure, septa can be viewed in detail [5, 10, 40]. In the use of 3 dimensional (3D) images some errors

Table 5. Numerical and percentage rate of the maxillary sinus septa occurrence across the literature

Authors	Diagnostic method	Number of examined subjects		Number of subjects with septa	
		Sinuses	Persons	Persons	Sinuses
Kasabah et al. [17]	OPG/CT	68	34		24 (35.9%)
Gonzales-Santana et al. [12]	OPG/CT	60	30	7 (25%)	
Shibli et al. [44]	OPG		1024	221 (21.6%)	
Lee et al. [26]	CT	236	204	55 (27%)	58 (24.6%)
Ulm et al. [21]	Cadaver		41		13 (31.7%)
Krennmair et al. [21, 22]	OPG/CT	265	165		32 (16%)
		194			
		61		17 (27.8%)	
		41		13 (31.7%)	
		42		12 (28.5%)	
Underwood [48]	Cadaver	90	45		30 (33%)
Velásquez-Plata et al. [51]	CT	312	156	51 (32.7%)	75 (24%)
Rysz and Bakoń [41]	CT	222			49 (26%)
Neugebauer et al. [34]	CBCT	2058	1029	484 (47%)	683 (33.2%)
Naitoh et al. [31, 32]	CBCT	30	15	7 (47%)	11 (37%)
	Cadaver	88	44		(41.7%)
Koymen et al. [20]	CT	410	205		145 (35.4%)
Van Zyl and van Heerden [50]	CT	400	200	138 (69%)	222 (56%)
Shen et al. [43]	CT	846	423	124 (29.3%)	173 (20,45%)
Kfir et al. [18]	OPG/CT		57	26 (45.6%)	
Gosau et al. [13]	Cadaver	130	65	24 (27%)	
Maestre-Ferrín et al. [28]	OPG/CT	60			32 (53.3%)
					42 (70%)
Park et al. [37]	CT	400	200	74 (37%)	111 (27.7%)
Ella et al. [9]	Cadaver	150		29 (39%)	
Kim et al. [19]	CT	200	100	38 (38%)	53 (26.5%)
Lugmayr et al. [27]	CT	200	100		26 (13%)
Nunes et al. [35]	CBCT	252			67 (26.59%)
Lana et al. [23]	CBCT		500	222 (44%)	
Güncü et al. [14]	CT	242			39 (16.1%)
Orhan et al. [36]	CBCT	544	272		316 (58%)
Kang et al. [15]	CT		150		(44%)
Rosano et al. [39]	Cadaver	60	30	12 (40%)	20 (33.3%)
Toscano et al. [45]	Intra-op		50		(30%)
Yang et al. [54]	Cadaver		74	7 (9.5%)	
Zijderveld et al. [55]	Intra-op		100	(48%)	
Selcuk et al. [42]	CT	330			151 (22.8%)

Cadaver — cadaver study; CBCT — cone-beam computed tomography; CT — computed tomography; Intra-op — intraoperative sinus examination; OPG — panoramic radiograph

may occur, due to differences that take place during the transformation from 2D slices to a 3D reconstruction. Though reconstructions present a smaller number of artefacts but are less accurate [36, 37]. CBCT can show results as precisely as in vitro/in vivo examinations [34].

Significance in pre- and implantation surgery

Sinus septa may cause some disadvantages in surgical treatment and may show relative contraindication for sinus lifting. Some authors have stated that there is a negative correlation between the septum and the thickness of the Schneiderian membrane

Table 6. Occurrence according to gender

Authors	Male	Female
Park et al. [37]	35%	39%
Lee et al. [26]	30%	23%
Van Zyl and van Heerden [50]	44%	27%
Shen et al. [43]	34.8%	24.1%
Koymen et al. [20]	55.2%	48.7%
Kim et al. [19]	32.3%	18.3%
Orhan et al. [36]	50%	44.8%

Table 7. Septa prevalence according to patient side

Author	Left side	Right side	Both sides
Park et al. [37]	36.5%	32.4%	31.1%
Lee et al. [26]	25.4%	23.6%	
Shen et al. [43]	20.6%	20.3%	
Koymen et al. [20]	44.7%	55.3%	29.1%
Kim et al. [19]	52.5%	47.5%	
Velasquez-Plata et al. [51]	52%	48%	
Orhan et al. [36]	55%	44.9%	59.8%

that is tightly attached to the septa and may lead to the membrane tearing especially in situations where the septa are sharp edged [4–7, 30, 37, 55]. Alternatively, Ella et al. [9] and Kasabah et al. [16] have stated that there is no connection between the membrane tearing and the presence of the septa, where sinus lift takes place subperiosteally and the elevation of the mucosa is possible without tearing. Another problem during the sinus augmentation procedure is the preparation of an opening window, which is challenging due to the thicker bony walls. Inserting graft material may also cause complications [1, 37]. Therefore the height of the septa may have an influence on augmentation [34]. The difficulty in dividing Septa can be put into 3 categories: (E) easy, (M) moderate and (D) difficult based on location, height and number [53]. When the septa are lower than 2 mm or situated in a position which will not disturb the procedure, other treatments are not required. However a medium sized, high, sagittally or horizontally and multiple situated Septa can limit access to the maxillary sinus and required more advanced procedures by modifying the shape of the opening window [24, 49] in the following methods:

— "W" shaped access [6, 49];
— double or triple the window size and then remove the septa [6, 24, 45, 49];
— outline the window [55];
— prepare a trap door only on medial sinus lob (mesially to septa) or scalloped trap door [8];
— outfracture a trap door end re-adaption [25];
— inverted hinge door to create an area for grafting material [21];
— 2 trapezoidal bony windows on the other side of the septum, infracture the bony window and remove sharp edge [2].

Table 8. Number and percentage of maxillary sinus septa depends on alveolar process region

Author	Anterior region	Middle region	Posterior region
Gonzales-Santana et al. [12]	6	7	2
Naitoh et al. [31]	7	5	
Koymen et al. [20]	30	110	25
Ulm et al. [46]	11 (73.3%)	3 (19.9%)	1 (6.6%)
Van Zyl and van Heerden [50]	26%	49%	24%
Kim et al. [19]	15 (24.5%)	30 (50.8%)	14 (23.7%)
Velásquez-Plata et al. [51]	18 (24%)	31 (41%)	26 (35%)
Gosau et al. [13]	42.9%	28.6%	28.6%
Lee et al. [26]	18 (27%)	33 (50%)	15 (22.7%)
Maestre-Ferrín et al. [28]	17.5%	60%	22.5%
Park et al. [37]	25 (22.5%)	51 (45.9%)	35 (31.5%)
Shen et al. [43]	31 (15.98%)	105 (54.12%)	53 (27.32%)
Neugebauer et al. [34]	139	257	225
Orhan et al. [36]	45 (12.2%)	254 (69.1%)	70 (18.6%)
Selcuk et al. [42]	134 (20.3%)		17 (2.5%)

Due to complications connected with the traditional sinus lift procedure some other augmentation methods can be used to prevent this trauma:1) minimally invasive antral membrane balloon [18];

— supplementary or simultaneous LeFort osteotomy [21];
— horseshoe osteotomy [21];
— nasal floor elevation [21];
— antrostomy [8].

Completely different was Fortin's [11] technique in case of septa occur; the technique was based on placing the implant directly into the septa without any augmentation procedure.

CONCLUSIONS

1. The prevalence of maxillary sinus septa ranges from 9% to 70%, with a mean of 36%.
2. Septa can be found in every age group — young dentate patients as primary septa and old edentate or edentulous patients as primary or secondary septa with a greater amount in edentate or edentulous.
3. The most common case is one septum on the left side.
4. When planning any surgical procedures, septa incidence should be taken into consideration. Precise information about the septa can be obtained from CT or CBCT.
5. With development of the knowledge and surgical technique, septa appearance has simply become another option for treatment as any form of disadvantage.

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