

Original paper

Pneumatization of the sphenoid sinus, dorsum sellae and posterior clinoid processes in computed tomography

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Abstract

Purpose: Assessment of sphenoid sinus (SS), posterior clinoid process (PCP), and dorsum sellae (DS) pneumatization is significant when planning surgical approaches both to intra- and extrasellar pathologies. The authors analysed pneumatization of the SS, with particular attention paid to pneumatization of the PCP and DS.

Material and methods: The study was based on 100 computed tomography angiography examinations. SS, PCP, and DS pneumatization grades were assessed using the classification system proposed by Hardy. The analyses were conducted in sagittal planes: midline plane (MP), sagittal posterior clinoid plane right (SPCP-R), and sagittal posterior clinoid plane left (SPCP-L). The occurrence of the highest pneumatization grade (IVB according to Hardy), which encompasses DS and PCP, prompted the authors to conduct a further analysis in the coronal plane. In this way, seven DS and PCP pneumatization symmetry types were identified.

Results: In the MP and SPCP-R, the most frequent pneumatization grade was grade III (41% and 38%, respectively). In the SPCP-L, grade IVA prevailed (41%). Grade IVB was found in 12% of the SPCP-R images, 10% of the SPCP-L images, and in 12% of the MP images. Consistent pneumatization grades in all analysed planes were found for 64% of cases. This was usually grade III noted in 28% of cases.

Conclusions: SS pneumatization is characterised by considerable individual variability. There are a number of SS pneumatization classification systems, but the system proposed by Hardy is the most useful for assessment of DS and PCP pneumatization. Grade III of SS pneumatization is the most common. Pneumatization encompassing DS and PCP was found in 10-12% of cases.

Key words: posterior clinoid process, dorsum sellae, sphenoid sinus, pneumatization, computed tomography.

Introduction

The sphenoid sinus (SS) is located within the body of the sphenoid bone, and its shape and size are characterised by considerable individual variability. The average SS volume is approximately 7.5 ml in an adult. In cases of considerable pneumatization, the SS can extend even to the fora-

men magnum. Owing to its natural connection with the nasal cavity, the SS is significant when planning surgical approaches to both intra- and extrasellar pathologies [1]. The posterior clinoid process (PCP) and dorsum sellae (DS) are located in the middle cranial fossa on the superior surface of the sphenoid bone and form slight bony eminences of variable shapes and pneumatization grades

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[2-4]. In 1920, Congdon was the first to present a division of SS pneumatization with reference to the sella turcica. He distinguished three types: I (conchal), II (presellar), and III (sellar) [5]. Later Hardy added types IVA and IVB to include more developed cases of pneumatization.

The subject of SS pneumatization is usually undertaken in the context of surgical approaches to intrasellar pathologies [6]. PCP and DS pneumatization, on the other hand, is mentioned together with surgical accesses to pathologies located within the clivus or interpeduncular cistern [7,8].

Moreover, DS and PCP can form an obstacle by concealing deeper anatomic structures, for instance the basilar artery apex. In such cases, surgical conditions can be improved by reducing these structures (usually the posterior clinoidectomy [PCP]) using a microdrill [9].

In the case of pneumatized DS or PCP removal (grade IVB according to Hardy), the risk of a dangerous complication in the form of cerebrospinal rhinorrhoea must be taken into account [10,11].

In the case of extensive pneumatization encompassing the DS and PCP, lesions in the clivus or intrapeduncular cistern can also be accessed through the trans-sphenoidal approach [9,12].

There are a number of SS pneumatization classification systems, but the system proposed by Hardy is the most useful for assessment of DS and PCP pneumatization [5,10].

The aim of this research was to develop reproducible and useful study methods to evaluate SS pneumatization, with particular emphasis on DS and PCP pneumatization grades.

Material and method

The retrospective analysis involved anonymised computed tomography angiography (CT angiography) images of 100 patients (54 women and 46 men) aged 18-88 years (mean age 52.49 years, standard deviation 18.64) diagnosed for headache. CT parameters were as follows:

16-row helical CT scanner GE BrightSpeed, collimation of 1 mm, slice thickness of 0.625 mm, pitch 1.0., voltage 120 kV. Non-ionic contrast material (Omnipaque 350) was injected into the one of the veins of the cubital region, i.e. the median cubital vein, at a rate of 3.5-4.5 ml/s to the total volume of 80-100 ml using a power injector.

The study involved imaging scans encompassing all anatomic structures relevant for this investigation, without motion artefacts or foreign bodies, e.g. vascular clamps.

The study excluded patients:

- after craniocerebral trauma,
- after a neurosurgical procedure within the head,
- with a diagnosed intracranial tumour,
- with a pathology (tumour, inflammation etc.) within the SS.

SS pneumatization in relation to the sella turcica, DS, and PCP was analysed in the sagittal plane using the classification system proposed by Hardy (Figure 1).

The analyses were carried out in the planes shown in Figure 2.

The occurrence of the highest pneumatization grade, encompassing the DS and PCP (IVB according to Hardy), prompted the authors to conduct a further analysis in the coronal plane. In this way, seven pneumatization symmetry types were identified within the DS and PCP (Figure 3 and 4).

This study complies with the current laws of Poland and it was approved by the Ethics Committee of the Medical University of Silesia in Katowice, Clinical Research Ref.: KNW/0022/KB/74/I/17.

Statistical analysis

Statistical calculations were performed in the PQStat version 1.6.2.901.

The relationship of sex and age with a pneumatization grade was analysed using the χ^2 test and Fisher's exact test.

The tested probability was deemed significant at $p < 0.05$, and highly significant at $p < 0.01$.

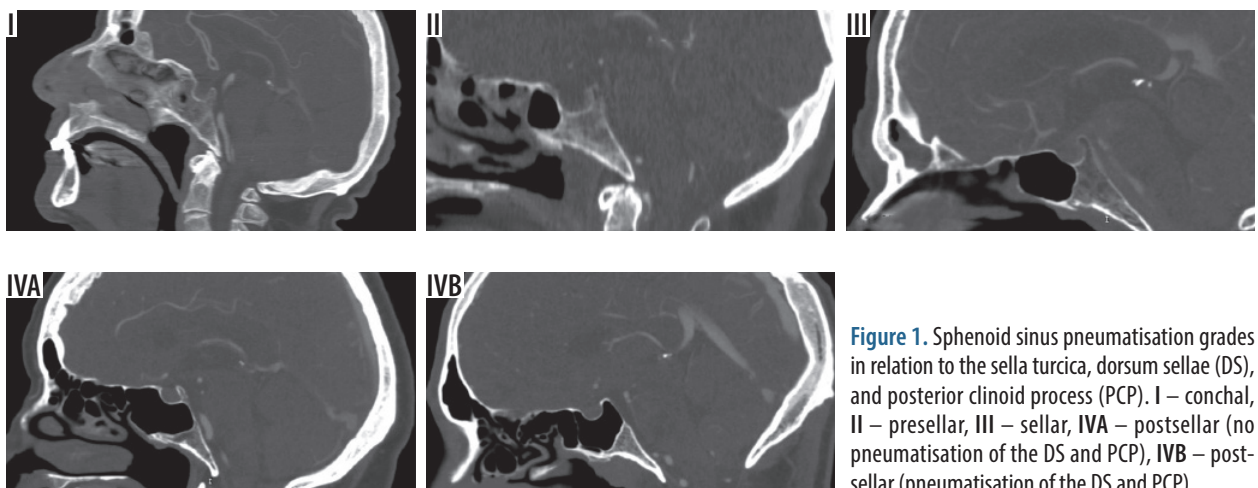


Figure 1. Sphenoid sinus pneumatization grades in relation to the sella turcica, dorsum sellae (DS), and posterior clinoid process (PCP). I – conchal, II – presellar, III – sellar, IVA – postsellar (no pneumatization of the DS and PCP), IVB – post-sellar (pneumatization of the DS and PCP)

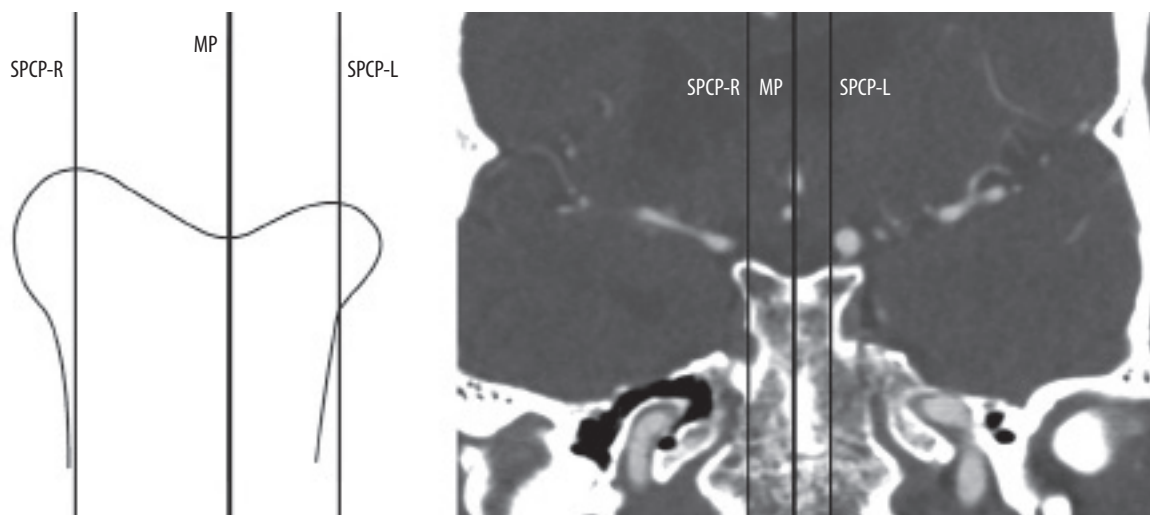


Figure 2. Planes for assessment of sphenoid sinus, dorsum sellae, and posterior clinoid process pneumatisation grades. MP – midline plane, SPCP-R – sagittal posterior clinoid plane right, SPCP-L – sagittal posterior clinoid plane left

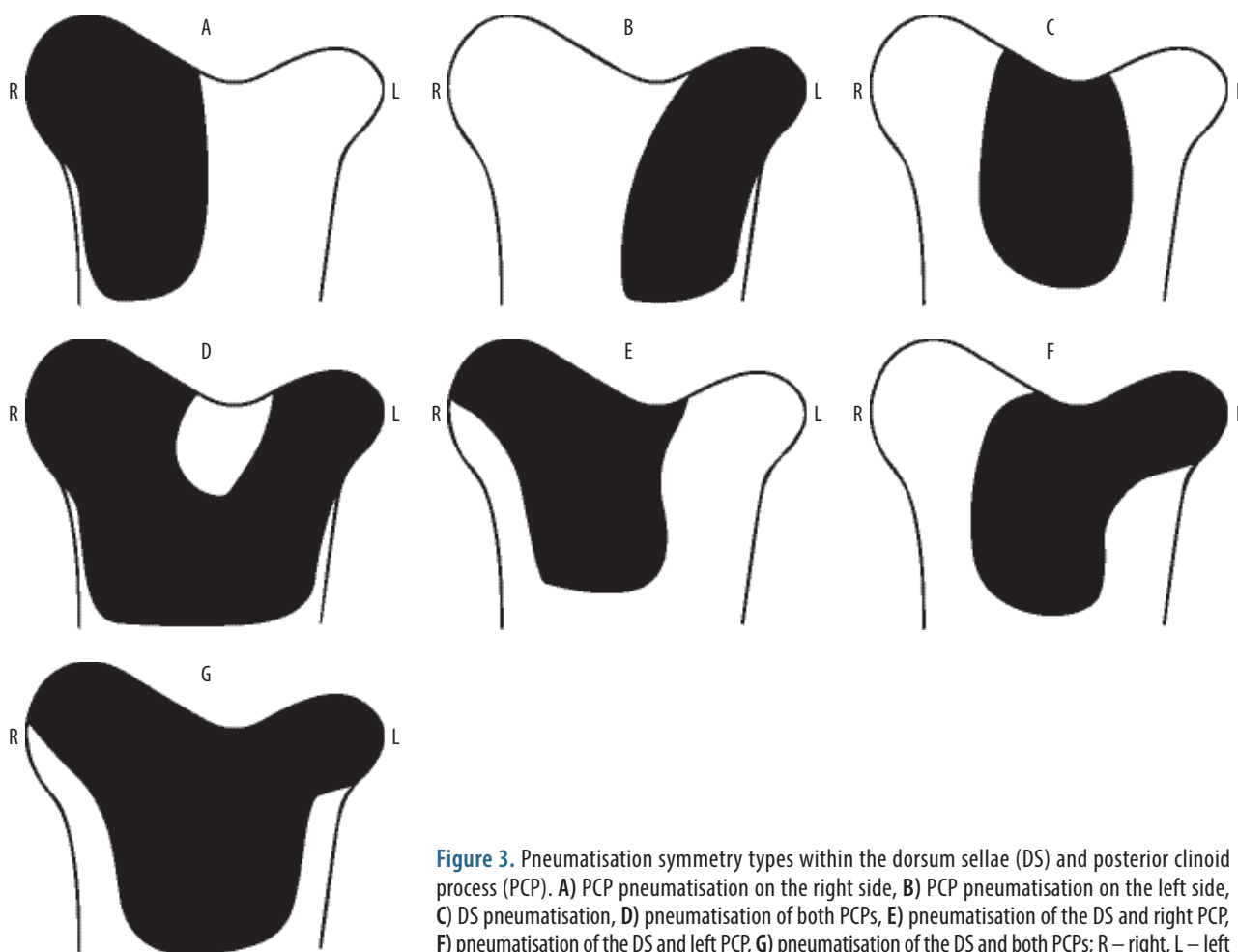


Figure 3. Pneumatisation symmetry types within the dorsum sellae (DS) and posterior clinoid process (PCP). A) PCP pneumatisation on the right side, B) PCP pneumatisation on the left side, C) DS pneumatisation, D) pneumatisation of both PCPs, E) pneumatisation of the DS and right PCP, F) pneumatisation of the DS and left PCP, G) pneumatisation of the DS and both PCPs; R – right, L – left

Results

In the analysed material ($n = 100$), scans in the MP plane showed grade III pneumatisation in 41% of cases, which together with grade IVA, identified in 38% of cases, accounted for 79%. In the SPCP-R plane, grade III was the most frequent (38%) while in the SPCP-L, grade IVA

prevailed (41%). Grade I was the rarest in MP, SPCP-R, and SPCP-L planes.

The highest pneumatisation grade, i.e. grade IVB, was found in 12% of the SPCP-R scans, 10% of the SPCP-L scans, and 12% of the MP scans (Table 1).

In women ($n = 54$), the most common pneumatisation grade in all planes was grade III.

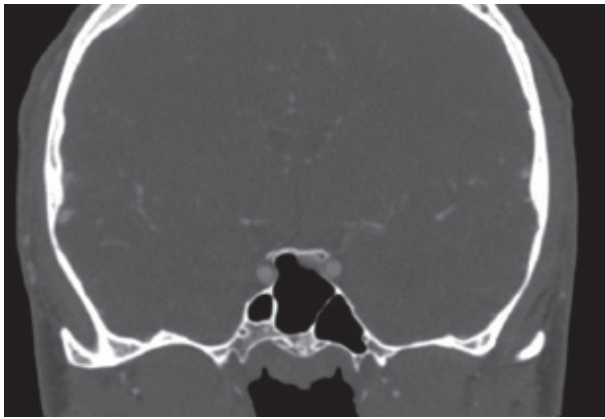


Figure 4. Pneumatization symmetry type E within the dorsum sellae (DS) and posterior clinoid process (PCP)

Table 2. Pneumatization grades in women

Pneumatization	Plane		
	MP (n = 54)	SPCP-R (n = 54)	SPCP-L (n = 54)
I	3 (6%)	2 (4%)	2 (4%)
II	2 (4%)	5 (9%)	6 (11%)
III	23 (42%)	24 (44%)	22 (40%)
IVA	23 (42%)	19 (35%)	21 (39%)
IVB	3 (6%)	4 (8%)	3 (6%)

I – conchal, II – presellar, III – sellar, IVA – postsellar – no pneumatization of the dorsum sellae (DS) and posterior clinoid process (PCP), IVB – postsellar – pneumatization of the DS and PCP, MP – midline plane, SPCP-R – sagittal posterior clinoid plane right, SPCP-L – sagittal posterior clinoid plane left

Table 4. Consistent pneumatization grades

Consistent pneumatization grades in the MP/SPCP-R/SPCP-L	Women (n = 54)	Men (n = 46)	Total (n = 100)
I	1 (2%)	0 (0%)	1 (1%)
II	2 (4%)	2 (5%)	4 (4%)
III	19 (35%)	9 (19%)	28 (28%)
IVA	15 (28%)	11 (24%)	26 (26%)
IVB	0 (0%)	5 (11%)	5 (5%)

I – conchal, II – presellar, III – sellar, IVA – postsellar – no pneumatization of the dorsum sellae (DS) and posterior clinoid process (PCP), IVB – postsellar – pneumatization of the DS and PCP, MP – midline plane, SPCP-R – sagittal posterior clinoid plane right, SPCP-L – sagittal posterior clinoid plane left

The frequency of grade IVB pneumatization in women in the SPCP-R plane was 8%, in the SPCP-L plane 6%, and in the MP plane 6% (Table 2).

In men (n = 46), the SPCP-R and SPCP-L images most frequently presented pneumatization grade IVA: 37% and 43%, respectively. In the MP plane, grade III prevailed: 39%.

The frequency of grade IVB pneumatization in men in the SPCP-R plane was 17%, in the SPCP-L plane 15%, and in the MP plane 19%.

There were no cases of grade I pneumatization in men (Table 3).

Table 1. Pneumatization grades in all analysed planes

Pneumatization	Plane		
	MP (n = 100)	SPCP-R (n = 100)	SPCP-L (n = 100)
I	3 (3%)	2 (2%)	2 (2%)
II	6 (6%)	12 (12%)	11 (11%)
III	41 (41%)	38 (38%)	36 (36%)
IVA	38 (38%)	36 (36%)	41 (41%)
IVB	12 (12%)	12 (12%)	10 (10%)

I – conchal, II – presellar, III – sellar, IVA – postsellar – no pneumatization of the dorsum sellae (DS) and posterior clinoid process (PCP), IVB – postsellar – pneumatization of the DS and PCP, MP – midline plane, SPCP-R – sagittal posterior clinoid plane right, SPCP-L – sagittal posterior clinoid plane left

Table 3. Pneumatization grades in men

Pneumatization	Plane		
	MP (n = 46)	SPCP-R (n = 46)	SPCP-L (n = 46)
I	0 (0%)	0 (0%)	0 (0%)
II	4 (9%)	7 (15%)	5 (11%)
III	18 (39%)	14 (31%)	14 (31%)
IVA	15 (33%)	17 (37%)	20 (43%)
IVB	9 (19%)	8 (17%)	7 (15%)

I – conchal, II – presellar, III – sellar, IVA – postsellar – no pneumatization of the dorsum sellae (DS) and posterior clinoid process (PCP), IVB – postsellar – pneumatization of the DS and PCP, MP – midline plane, SPCP-R – sagittal posterior clinoid plane right, SPCP-L – sagittal posterior clinoid plane left

Table 5. Type of pneumatization symmetry within the dorsum sellae (DS) and posterior clinoid process (PCP)

Type of pneumatization symmetry within the DS and PCP	Women (n = 54)	Men (n = 46)	Total (n = 100)
A	0 (0%)	3 (7%)	3 (3%)
B	3 (6%)	0 (0%)	3 (3%)
C	0 (0%)	1 (2%)	1 (1%)
D	0 (0%)	0 (0%)	0 (0%)
E	3 (6%)	1 (2%)	4 (4%)
F	0 (0%)	2 (4%)	2 (2%)
G	0 (0%)	5 (11%)	5 (5%)

There were no significant ($p > 0.05$) correlations between pneumatization grades and sex or age of the patients.

In this material (n = 100), consistent pneumatization grades for all planes (MP, SPCP-R, SPCP-L) were found for 64% of cases. Grade III was the most common: in 28% of cases (19 women and nine men), while grade I was the rarest: in 1% (only one female patient) (Table 4).

In this material (n = 100), pneumatization symmetry type A within the DS and PCP was found in men only (3% of cases), whereas type B was present only in women (3% of cases).

Type G was the most common (5% of cases) and occurred only in men. There were no cases of type D (Table 5).

Discussion

The SS is a pneumatic space located within the body of the sphenoid bone. Its size and shape are variable, and it is lined with mucous membrane and divided with one or several vertical septa [1].

It is formed in the fourth month of the foetal development from the nasal capsule of the embryonic nose [1].

At birth, the SS is not fully developed, shows no signs of pneumatisation, and its diameter reaches approximately 2 mm [13].

SS pneumatisation progresses with age. It reaches the sella turcica at approximately seven years of age and ends during puberty [1,13,14].

SS agenesis is seen in rare cases (1-1.5%), and no progress of the SS pneumatisation process up to the age of 10 years may indicate a pathology within the SS [1,15].

SS pneumatisation is an interesting subject for numerous fields of medicine (neurosurgery, laryngology, maxillo-facial surgery). Owing to the anatomic connection between the SS and the nasal cavity, the SS constitutes a route for an endoscope to reach different intra- and extrasellar pathologies [16].

According to Teatini *et al.*, the SS is the most variable space in the human body [17]. That is why thorough analysis of the anatomy in this region prior to a surgery is very important. Due to its location in close proximity to various vital structures, such as the pituitary gland, the cavernous sinus, the optic nerve, or the internal carotid artery, extensive SS pneumatisation that encompasses the DS or PCP might lead to the thinning of its walls and secondary inclusion of these structures into the sinus. This entails the risk of their damage during a surgical procedure [17].

The initial division of SS pneumatisation proposed by Congdon was created mainly for the purposes of trans-sphenoidal access to intrasellar pathologies [5,18].

Subsequently, as endoscopy developed and the trans-sphenoidal access was broadened to regions neighbouring the sella turcica, such as the clivus or suprasellar region, other classification systems that included the DS and PCP were developed, including the one proposed by Hardy.

Güldner *et al.* analysed CT scans of the paranasal sinuses in 580 patients (313 women and 267 men). They found conchal pneumatisation in two patients (0.3%), presellar pneumatisation in 38 patients (6.6%), sellar pneuma-

tisation in 332 patients (57.2%), as well as postsellar IVA pneumatisation in 104 (17.9%) and postsellar IVB pneumatisation also in 104 (17.9%) patients [19].

Based on high-resolution computed tomography (HRCT) of the paranasal sinuses, Tomovic *et al.* analysed SS pneumatisation in 170 patients (96 women and 74 men). They found grade I pneumatisation in 1.8% (three patients), grade II in 7.3% (12 patients), grade III in 47.6% (78 patients), and grade IV in 43% (71 patients) [20].

Idowu *et al.* conducted head CT scans in 60 patients (23 women and 37 men) and found that sellar pneumatisation was the most common (50 patients, 83%). The authors found no cases of conchal pneumatisation [21].

The outcomes of the present study are similar to those reported by other authors. In 100 patients, MP images showed conchal grade I pneumatisation in three patients (3%), presellar type II in six patients (6%), sellar type III in 41 patients (41%), and postsellar type IV in 50 patients (50%): IVA in 38 and IVB in 12 patients.

For the most accurate assessment, the authors analysed SS pneumatisation in three sagittal planes (MP, SPCP-R, and SPCP-L). When classifying a case to the IVB group in the MP plane, the DS was considered completely pneumatised. When classifying a case to the IVB group in the SPCP-R or SPCP-L planes, the authors assumed that the right and left PCPs, respectively, were pneumatised completely. In this way, the frequency of right PCP pneumatisation was 12%, left PCP pneumatisation 10%, and DS pneumatisation 12%.

Güldner *et al.* found no significant differences between the frequency of given SS pneumatisation types depending on gender [19]. Tomovic *et al.*, on the other hand, showed no correlations between SS pneumatisation and age [20].

In the material analysed in the present study ($n = 100$) there were no statistically significant ($p > 0.05$) correlations between pneumatisation grades and sex or age of the patients.

Conclusions

SS pneumatisation is characterised by considerable individual variability. Pneumatisation encompassing the DS and PCP, i.e. Hardy IVB, was found in 10-12% of cases. Type IVB by Hardy includes seven types of pneumatisation.

Conflict of interest

The authors declare that they have no conflict of interest.

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