CBCT images: an important tool in the analysis of anatomical variations of maxillary sinus related to Underwood septa features

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ABSTRACT
The lack of prior information on the presence of Underwood septa is the most common anatomical cause of Schneider’s membrane perforation during maxillary sinus floor elevation with lateral access. The objective of this study was to assess the incidence of Underwood septa, their location, type (primary or secondary) and height in Bulgarian patients. Cone beam computed tomography (CBCT) images of 200 patients were examined for the presence of Underwood septa. Presence of at least one septum was found in 144 patients. The non-parametric statistical Mann–Whitney U-test and Fisher’s exact test were used. No statistically significant differences were found between the two genders in terms of the presence of septa. In toothed patients, the location of the septa was behind the distal surface of the second molar in 57% of the cases. In patients with edentulous distal portions of the maxilla, location of the septa in the areas above the first premolar was seen in 54% of the cases. Depending on the presence of teeth, primary complete septa were found in toothed patients, and secondary partial septa were observed in edentulous patients. Prevalence of sagittal primary orientation was found in toothed patients (63%), while axial primary orientation of the septa was found in edentulous patients (58%). The obtained results suggest that precise determination of the septum orientation by CBCT would facilitate the correct choice of surgical approach to minimize the risk of Schneider’s membrane perforation.

Introduction
The development of implantology has enabled the placement of dental implants in the distal portions of the maxilla where the volume of the available bone is not always sufficient because of the presence of the maxillary sinus. This problem was solved by the use of a method for maxillary sinus floor elevation introduced by Tatum [1] in 1976 and described by Boyne and James in 1980 [2]. At present, this surgical procedure is considered to be routine in the planning and performing of implant treatment in the lateral, atrophic portions of the maxilla.

Performing this surgical procedure requires to take into consideration certain anatomical features that can result in difficulties and complications during the operation. The most common complications in this surgical procedure are perforation of Schneider’s membrane and cutting of the alveolar–antral vascular plexus [3,4], an inflammatory process involving the maxillary sinus (reportedly in 2%–5.6% of cases) [5], and others. The perforation of the sinus mucosa during the procedure of sinus floor elevation can be due to anatomical and iatrogenic factors. The most common anatomical cause for Schneider’s membrane perforation during this surgical procedure with lateral access is the lack of prior information on the presence of the so-called Underwood septa [6,7].

These antral septa were first described by Underwood in 1910 as inverted gothic arches dividing the sinus into two or more cavities. For many years, these septa were accepted as anatomical features without significant relevance to clinical practice. The development of medical science related to the use of advanced technologies in the treatment of the maxillary sinus (endoscopy) and the introduction of implantology and related diagnostic methods (cone beam computed tomography (CBCT)) resulted in the reassessment of these views. Surgical procedures for maxillary sinus floor elevation may be compromised in the presence of undiagnosed septa. When planning a window on the anterior wall of the maxillary sinus, the location of these septa should be taken into account in order to prevent perforation of Schneider’s membrane. The presence of fibrous tissue is the reason for the perforation of the sinus mucosa when lifted in a
region with Underwood septa. The incidence of these septa, according to a number of studies, varies in a wide range from 13% to 58% [8–10].

There are a number of classifications of maxillary sinus septa. According to Underwood, the maxillary sinus floor is divided into three zones: anterior (in the area above the premolars), middle (located above the first and the second molar) and posterior (a relatively small area above the third maxillary molar). Depending on the time of their occurrence, Krennmair et al. [11] differentiate the septa into primary (congenital) and secondary (occurring in the sinuses due to edentulism at the side of the corresponding sinus). According to some authors, combinations of primary and secondary septa [12] are also possible. Depending on the location, height and incidence of septa in the sinus, a reduction in the incidence of Schneider’s membrane perforation may be achieved in elective surgery such as maxillary sinus floor elevation.

The low reliability of panoramic radiographs in the diagnosis of maxillary sinus septa and in the overall assessment of the sinus floor and its anatomical variations before surgical procedures for sinus floor elevation [11] has determined the leading role of CBCT as a diagnostic tool.

The objective of this study was to assess the incidence of Underwood septa, their location, type (primary or secondary) and height in toothed or edentulous regions of the maxilla in Bulgarian patients, using CBCT, in order to facilitate the choice of surgical approach to minimize the risk of Schneider’s membrane perforation.

Subjects and methods

Subjects

A cohort of 298 patients were studied in the period 2014–2016. Impaired sinus aeration (inflammatory changes) was found in 98 patients and these patients were excluded from the study. In 56 cases, no septa were found. The remaining 144 patients had at least one sinus septum.

CBCT imaging

The study was conducted by analysing 200 CBCT images of patients aged 18–70 years of age: 100 images in patients with edentulous distal portions of the maxilla, and 100 ones in patients with preserved dentition (101 female and 99 male patients). The images were taken for the purpose of searching for abnormalities in jaw bones. The study excluded patients with impaired pneumatization of maxillary sinuses, as well as paediatric patients. Septa with a height of more than 2 mm were studied.

GALILEOS comfort (Dentsply Sirona Germany) was used to perform CBCT. The images were obtained after standard positioning of the subjects according to the manufacturer’s recommendations. The voltage and current were determined depending on the patient’s age, constitution and the purpose of the study. They were in the range of 90–120 kV and 21–42 mA, respectively. The effective dose also varied between 29 and 54 Sv, with 21 and 42 mA, respectively. The exposure time was 14 s. The scanning volume was 15 cm × 15 cm × 15 cm, with an isotropic voxel of 0.15 mm. All patients were scanned after giving informed consent.

The location and orientation of the septa were determined in the three projection planes: axial, coronal and sagittal. With the help of the cursor, we focused on the studied septum, and the septum was automatically visualised in the three planes (Figure 1). In toothed patients, we divided each maxillary sinus into three parts on the sagittal planes: anterior (from the medial surface of the first premolar to the distal surface the second premolar), middle (from the distal surface of the second premolar to the distal surface of the second molar) and posterior (behind the distal surface of the second molar). In edentulous patients, we used the axial slices for this purpose, by separating the paranasal cavities into three parts: anterior, middle and posterior.

We measured the septum length in millimetres both on axial and sagittal slices (Figure 2). The primary orientation of the septa was determined, depending on whether their height was greater in the sagittal or axial plane. The orientation of the septa was found by comparing the slices of the three projection planes and registering the direction of each septa. Then the heights of the septa in each slice were compared, the orientation in the slice with the greatest height was determined as
primary and the orientation in the slice with the second greatest height of the septum was determined as secondary.

**Statistical analysis**

Numerical variables were tested for normality with the Shapiro–Wilk test. Data are presented as mean values with standard deviation (± SD) (for normal distribution) or as the interval between the 25th percentile and the 75th percentile (for non-normal distribution). Mann–Whitney U-test was applied to compare the septa height between the two groups of patients. Boxplot diagrams were used for graphical visualisation of the septa height (outliers were distinguished according the criteria 1.5 of the interquartile range). Fisher’s exact test was used for comparison of categorical variables. The significance level was set at 5% (P < 0.05). Calculations were made with MS Excel 2016.

**Results and discussion**

The awareness of the presence of Underwood septa makes it possible to reduce the risk of possible complications when lifting the maxillary sinus floor [4,13]. The analysis of the results obtained in our study showed that there was no relationship between the presence of Underwood septa and the gender of the patients. Our observations support the studies of other authors about the absence of correlation between the patient’s gender and the presence of maxillary sinus septa [8,14]. The mean age (with standard deviation) of the patients included in this study was 52 ± 16 years (Table 1). The age profile of our patients coincides with that in other similar studies [8,15], which could be explained by the greater need for dental implants in this age group.

In total, 246 septa were found in 144 patients. Overall, at least one septum was present in 72% of the cases, which is different from the results of other authors, who found at least one septum in the range from 21.58% to 50.1% [8,16,17]. In our opinion, the low incidence of septa in the study by Shibli et al. can be explained by the fact that only edentulous patients were studied. In the studies by Sakhdari and Souto, the reported incidence of septa is 44.8% and 50.1%, respectively, but these results are significantly lower than our data. With regard to the number of septa, 34.5% of the cases studied by us had one septum; 27.5%, two septa; 8%, three septa; 0.5%, four septa; and 1.5%, five septa. Our results are in accordance with a similar report that 71% of the edentulous patients, as well as 66% of the toothed patients, had at least one septum [18].

Besides the number of septa, our study examined the type of septa and their location and orientation. According to the Underwood classification, the location of the septa in the patients with teeth in the distal part of the maxilla was predominantly in the posterior area (57%), whereas in edentulous patients, the highest incidence of septa was seen in the area of the premolars (54%) (Figure 3). These results are in dissonance with the studies of other authors, who have reported the incidence to be 64% in patients with toothed molar regions [13] and 26.8% in patients with edentulous molar regions, respectively [19].

CBCT is a method which has a greater informative value, as it provides accurate images with sub-millimetre resolution in formats allowing three-dimensional (3D) visualisation of the complex maxillofacial structures [20].

**Table 1. Distribution of patients by gender and age.**

| Age of patients | Mean | Median | Std. dev. | Minimum | Maximum |
|-----------------|------|--------|-----------|---------|---------|
| Men             | 51   | 51     | 17        | 19      | 83      |
| Women           | 52   | 57     | 16        | 23      | 86      |
| All patients    | 52   | 54     | 16        | 19      | 86      |

**Figure 2.** Sagittal slice of a maxillary sinus demonstrating the orientation of a septum.

**Figure 3.** Effect of the dentition on the primary location.
The images in the three planes (axial, coronal and sagittal) show the spatial position of the maxillary sinus septa with great precision. The possibility of determining the orientation of the septa in the three planes is of great importance. This makes it possible to determine the place for the surgical exposure and the height of lifting of the maxillary sinus floor, taking into consideration the irregular shape and height of the septa. [21]. Many authors determine the orientation of the septa depending on the slice in which the septum is registered. Park et al. [22] differentiate between buccopalatal, sagittal and transverse septa. The orientation of the septa in the studies of other authors is differentiated in the same way, and the orientation of the septa is registered in coronal and sagittal slices [15].

Further, we explored the hypothesis whether the primary orientation of the septa could be affected by the presence or absence of dentition. Fisher’s exact test showed a statistically significant difference ($p = 0.002$) between the prevalent primary orientation of the Underwood septa in toothed and edentulous regions of the maxilla. In toothed patients, the prevalent orientation was sagittal (63%), i.e. septa registered in the sagittal slice, whereas, in edentulous jaws, the prevalent orientation (58%) was axial (Figure 4). These results suggest that the presence of dentition could be considered a factor that significantly affects the primary orientation of the sinus septa. These data are in contrast with other reports where the frontal orientation prevails, but the presence of dentition is not considered by the authors a factor influencing the orientation of the septa [14,21]. Our results are in agreement with the studies of Souto et al. [17], in which the authors reported higher incidence of axial orientation, but further distinguished between partially and completely edentulous patients. In our opinion, such discrepancies could potentially be attributed to early loss of teeth in the distal portions of the maxilla.

The analysis of the effect of the presence or absence of teeth on the septum type (complete or partial) showed that complete septa prevailed in toothed patients (57%), while in edentulous patients, partial septa prevailed (62%). This difference was found to be statistically significant according to Fisher’s exact test ($p = 0.007$). Overall, the complete septa were observed to prevail (64.6%) over partial septa (35.4%). These data are in contrast with those in other studies, which have reported prevalence of partial septa [14]. In our opinion, the differences in the type of septa can again be explained by the early loss of teeth, as well as by the characteristics of the cohort studied (if CBCT was performed for a scheduled implant therapy only, it would be logical to find higher incidence of partial secondary septa).

The height of the septa is also important for the surgical procedures related to maxillary sinus floor elevation. According to some authors, the mean height of primary septa is 5.5 mm, and that of secondary septa is $-3.4$ mm [23].

High rate of errors was found when using panoramic radiographs for diagnosis of Underwood septa, ranging from 11.8% to 44.1% [11]. According to our results, the dentition could be considered to significantly affect ($p < 0.001$) the height of the primary septa (Figure 5). In toothed patients, the height was within the range of 6.7–11.9 mm (25th–75th percentile). In patients with edentulous distal portions, the height of the primary septa was within the range of 5.4–9.1 mm.

When comparing the results, there is a statistically significant difference between the secondary orientation of the septa ($p < 0.001$) in toothed and edentulous patients (Figure 6). It was found that in toothed patients, the
septum height was in the range of 4.1–7.9 mm. In edentulous patients, the height of the septa by secondary orientation was in the range of 2.9–5.8 mm. These results are in contrast to the results of other similar studies. Rancitelli et al. reported the height of the primary septa to be 5.5 mm, but they used axial slices only [23], while Malec et al. found mean height of the studied septa of 5.5 mm, but primarily in coronal slices [14]. In our opinion, Underwood septa should be studied in all the three projection planes, rather than limiting to a particular slice, in order to determine correctly the orientation of these anatomical structures.

The primary orientation of the septa allowed us to differentiate the location on the basis of the slice used, sagittal, axial or coronal. To the best of our knowledge, this is the first reported attempt to determine the orientation of the septum based on its height in different slices. The existing classification of the orientation of the septa [21] does not take into account the fact that the septa have irregular shapes and directions and it is very difficult to define the septum class by using 3D reconstructions. Knowledge of septum orientation is a prerequisite for good planning of the surgical procedure, i.e. in determining to what extent the sinus floor can be lifted without perforation of Schneider’s membrane due to change in the direction and the height of the septum.

Conclusions

The data obtained in this study demonstrated a huge variety in the maxillary sinus anatomy, due to different location, orientation and height of the Underwood septa. To the best of our knowledge, this is the first reported attempt to determine the orientation of the septum based on its height in different slices. Before performing maxillary sinus floor elevation, detailed information on the location and orientation of the septa is required with view of prevention of Schneider’s membrane perforation. Using the detailed classification of the septa orientation (primary and secondary) determined by CBCT facilitates the correct choice of surgical approach by providing information about the height, type and orientation of the septum.

Disclosure statement

The authors declare no conflict of interest.

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