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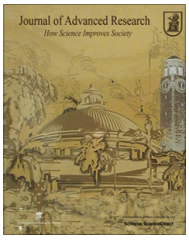

ORIGINAL ARTICLE

Three-dimensional linear and volumetric analysis of maxillary sinus pneumatization

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ABSTRACT

Considering the anatomical variability related to the maxillary sinus, its intimate relation to the maxillary posterior teeth and because of all the implications that pneumatization may possess, three-dimensional assessment of maxillary sinus pneumatization is of most usefulness. The aim of this study is to analyze the maxillary sinus dimensions both linearly and volumetrically using cone beam computed tomography (CBCT) to assess the maxillary sinus pneumatization. Retrospective analysis of 30 maxillary sinuses belonging to 15 patients' CBCT scans was performed. Linear and volumetric measurements were conducted and statistically analyzed. The maximum craniocaudal extension of the maxillary sinus was located around the 2nd molar in 93% of the sinuses, while the maximum mediolateral and antroposterior extensions of the maxillary sinus were located at the level of root of zygomatic complex in 90% of sinuses. There was a high correlation between the linear measurements of the right and left sides, where the antroposterior extension of the sinus at level of the nasal floor had the largest correlation (0.89). There was also a high correlation between the Simplant and geometric derived maxillary sinus volumes for both right and left sides (0.98 and 0.96, respectively). The relations of the sinus floor can be accurately assessed on the different orthogonal images obtained through 3D CBCT scan. The geometric method offered a much cheaper, easier, and less sophisticated substitute; therefore, with the availability of software, 3D volumetric measurements are more facilitated.

Introduction

Maxillary sinus pneumatization can pose a surgical hazard in terms of oro-antral communications following extraction [1,2] and endodontic surgery of the antral related teeth [3]. It also increases the risk of introducing foreign bodies, root tips, or teeth displacement into the sinus cavity [4], and it is well known to influence orthodontic teeth movement [5–7]. Oro-antral communications facilitate microbial contamination of the maxillary sinus. If the communication remains open or if the infection persists, chronic inflammation of the sinus' membrane may result with subsequent permanent epithelization of the oro-antral fistula – a situation that further increases the risk of sinusitis [2].

Lastly and needless to say that implant-supported rehabilitation of posterior maxilla is jeopardized by the natural tendency of the maxillary sinus to pneumatize bone during life and the inherent bone remodeling, which pursue teeth loss

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causing rapid alveolar bone resorption. Implant insertion within inadequate bone quantity carry risk of oro-antral communication and in such circumstance, maxillary sinus floor elevation is predictable and the possibility of using graft material is not even far. Both procedures require extra preoperative planning [8–12]. The sound knowledge and preoperative vision of this region will assist the surgeon to be more confident and be familiar with the common anatomic variants and to avoid such serious complications.

Periapical, panoramic, and conventional CT [13] have been recommended for the preoperative planning. In many clinical situations, the use of three-dimensional imaging proved to be beneficial as compared to two-dimensional imaging and overcomes its limitations [14,15]. CT scan was developed to overcome the lack of cross-sectional information, superimposition, distortion, and magnification noted in the conventional radiography [6,16–18].

Exploring the normal radiographic anatomy of the maxillofacial region has reached areas that were hidden in the past. This is true concerning the maxillary sinus pneumatization especially with the increased reliability of 3D imaging. Three-dimensional CT technologies have greatly improved the ability to explore the interior of the cranium and to estimate the volumes of different anatomical compartments such as the maxillary sinus and the nasal cavity. It also facilitated the correlation between these anatomical compartments and the different ethnic groups relative to climate variations. However, the large dose of ionizing radiation delivered by medical CT is crucial and debatable [19–21].

Outstandingly, the CBCT technology has achieved considerable reduction of absorbed radiation doses compared to medical CT imaging and a bit similar to dental panoramic radiography [22–24]. Field of view limitations have further reduced the effective dose. Standard dental protocol scans using traditional CT delivers 1.5–12.3 times greater radiation than comparable medium field of view dental CBCT scans [24]. Till that moment, the image quality of CBCT was adjudged to be equivalent to that of traditional CT for visualizing the maxillofacial structures. Moreover, beam-hardening artifacts due to dental-filling materials and implants are far weaker at CBCT than CT [25–28].

Considering the anatomical variability related to the maxillary sinus, its intimate relation to the maxillary posterior teeth, and because of all the implications that pneumatization may possess, three-dimensional assessment of maxillary sinus pneumatization is of most usefulness. This is especially the case whenever surgical endodontic apicectomy, periodontal flaps, surgical extraction, implant installation, orthognathic surgeries, or surgical intervention for space occupying lesions involving the maxillary sinus and/or the maxilla are intended.

The literature on this direction using CBCT is rather scarce [6,26,29]. Therefore, the aim of this study was to analyze the maxillary sinus dimensions both linearly and volumetrically to assess the maxillary sinus pneumatization.

Patients and methods

The present study was performed as a retrospective analysis of data stored in a private radiology center. Out of respect for doctor patient confidentiality, all personal information concerning the patients as well as the diagnostic cause of the CBCT scan was hidden. The inclusion criteria of patients to the study were based solely on the radiologists' interpretation about lack of mucosal thickening in either maxillary sinuses as well as any bone deformities. Fully edentulous patients were excluded. Fifteen patients were selected and informed consent was taken from them. Both sinuses in 15 patients' scans were measured giving rise to data from 30 sinuses.

Images were acquired using the i-CAT Imaging system (Next Generation, Imaging Sciences International, Hatfield, USA). The patients were exposed in the sitting position and immobilized using a head band to adjust the head against the head rest and chin cup. The mid-sagittal plane was aligned to be perpendicular to the horizontal plane using vertical and horizontal alignment beams as recommended by the manufacturer. The i-CAT is equipped with an amorphous Silicon Flat Panel, and a single 360 degrees scan collects the projection data for reconstruction. The X-ray field size applied was 16 cm diameter × 13 cm height, and scanning time was 8.9 s (fast enough to avoid patient movement, image blurring, and haziness). Operating parameters were 120 kVp and 5 mA with slice thickness of 0.3 mm (the standard resolution for scanning at i-CAT machine). The i-CAT's Vision software (Imaging Sciences International) was used which allows the recording of linear measurements of images. The measurements were performed by observer (N A.-W.), who has a 15 years experience in oral and maxillofacial radiology. This study was approved by the Research Ethics Committee, Faculty of Oral and Dental Medicine, Cairo University.

Sinus linear measurements

The linear measurements were performed according to a protocol that was tested elsewhere for inter- and intraobserver agreement and showed statistically non-significant differences between the observers [30]. Since there were no radiopaque markers used in this study, the selection of the cuts for measuring sinus dimensions was based on the presence of certain anatomical landmarks. According to the anatomical fact that the maxillary sinus is pyramidal in shape with an almost square base oriented medially [31], the measurements of the sinus dimensions were conducted as follows:

1. Linear measurements of the maxillary sinus length (craniocaudal extension; CC): On the i-CAT Vision software, MPR was chosen for interfacing; adjusting the orientation axis for the axial cut parallel to the occlusal plane at the alveolar crest level; adjusting the orientation axis of the sagittal cut to be midway between buccal and palatal cortices; adjusting the coronal cut at area of intended measurement by rotation of the axial image till the orientation axis for the coronal cut becomes perpendicular on buccal cortex. This was repeated at interdental areas between upper first and second premolars, upper second premolar and upper first molar, upper first and second molars, upper second and third molars; giving rise to 4 craniocaudal measurements: CC 1st and 2nd premolars, CC 2nd premolar and 1st molar, CC 1st and 2nd molars and CC 2nd and 3rd molars, respectively, for each side (Fig. 1). The coronal cut oriented exactly interdental was used (its axis of orientation in the axial cut was positioned interdentally). The measurements were taken from the lowest point of the cortical boundary of orbital floor to the lowest border of the cortical boundary of the sinus floor. To standardize the