Evaluation of cone beam computed tomography imaging in placed dental implants: comparison between multiplanar reconstruction and parasagittal images

Avaliação de imagens de tomografia computadorizada de feixe cônico em implantes instalados: comparação entre reconstrução multiplanar e imagens parassagitais

DOI:10.34117/bjdv7n4-101

Recebimento dos originais: 07/03/2021
Aceitação para publicação: 01/04/2021

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ABSTRACT
This study aimed to compare multiplanar reconstruction (MPR) to parasagittal images of cone-beam computed tomography (CBCT) for localizing placed dental implants concerning adjacent anatomical structures (nasal fossa floor, maxillary sinus, inferior alveolar canal and nasopalatine canal).
The CBCT exams of 164 placed implants were analyzed. All tomographic images were imported to Imaging Studio software to create parasagittal image templates. The images were randomized and analyzed by two oral and maxillofacial radiologists who classified whether or not there was perforation of the anatomical structure in question.
According to Kappa coefficient of agreement, the results including, all anatomical structures for inter-observer assessment was 0.81 and for intra-observer assessment, 0.79 for observer one and 0.89 for observer two. For each anatomical structure, the agreement ranged from 'substantial' to 'almost perfect' (nasal fossa floor 0.72, nasopalatine canal 0.92, maxillary sinus 0.81, and inferior alveolar canal 0.81).
Based on our findings, there was substantial to almost perfect agreement when comparing MPR and parasagittal images of CBCT regarding of implant position relationship with anatomical structures. Since both modalities did not differ in implant position, and the

MPR represents the complete and original volume that enables analysis in three dimensions, they can be the first-choice imaging modality to analyze placed dental implants.

Keywords: Cone-beam computed tomography, Dental implants, Diagnostic imaging

RESUMO

O objetivo deste estudo foi comparar a reconstrução multiplanar (RMP) com imagens parassagitais de tomografia computadorizada de feixe cônico (TCFC) para localização de implantes dentários colocados, em relação às estruturas anatômicas adjacentes (soalho da cavidade nasal, seio maxilar, canal da mandíbula e canal nasopalatino).

Os exames de TCFC de 164 implantes colocados foram analisados. Todas as imagens tomográficas foram importadas para o software Imaging Studio, para criar modelos de imagens parassagitais. As imagens foram randomizadas e analisadas por dois radiologistas bucomaxilofaciais que classificaram se havia ou não perfuração da estrutura anatômica relacionada.

De acordo com o coeficiente de concordância Kappa, os resultados que incluem todas as estruturas anatômicas para avaliação interobservador foram 0,81 e para avaliação intraobservador, 0,79 para o observador um e 0,89 para o observador dois. Para cada estrutura anatômica, a concordância variou de 'substancial' a 'quase perfeita' (soalho da cavidade nasal 0,72, canal nasopalatino 0,92, seio maxilar 0,81 e canal da mandíbula 0,81).

Com base em nossos achados, houve concordância substancial a quase perfeita ao comparar as RMP com imagens parassagitais de TCFC em relação à relação da posição do implante com as estruturas anatômicas. Como as duas modalidades não diferiram na posição do implante e a RMP representa o volume completo e original que permite a análise em três dimensões, ela pode ser a modalidade de imagem de primeira escolha para analisar implantes dentários colocados.

Palavras-chave: Tomografia computadorizada de feixe cônico, Implantes dentários, Diagnóstico por imagem

1 INTRODUCTION

Dental implants are a clinical resource widely used in oral rehabilitation, aiming to restore patient's function and aesthetics.[1] Dental implant planning must include detailed information about bone volume and anatomical structures, such as nerves, vessels, nasal fossa floor and maxillary sinus cavities.

CBCT (cone-beam computed tomography) imaging allow the assessment of volumetric images of the maxillofacial area without anatomical structures overlapping, and is the imaging modality of choice for pre-operative planning in implant dentistry.[2–4]

The adequate image exam reduces the incorrect implant position causing less iatrogenic perforations like invasion of the nasal fossa floor, sinus cavities and mandibular canal, which may cause impairments at the trans or post-operative times. To generate tomographic images, a software reconstructs the acquired images and transforms them into axial, coronal and sagittal images (multiplanar reconstruction - MPR), allowing the visualization of anatomical structures three-dimensionally, thus improving diagnosis, treatment planning and evaluation. [5–7]

Orthogonal post-processing images, also called parasagittal slices, are perpendicular slices following the axial curvature of the mandible/maxilla. These images are generated from a manually drawn line over these structures. The AAOMR (American Academy of Oral and Maxillofacial Radiology) and other authors suggest the use of parasagittal slices for implant planning. [2,8] The use of MPR and parasagittal images for pre-surgical implant planning provides an alveolar ridge morphometry and proximity to anatomical structures. A postoperative exam is recommended to assess the correct positioning of the implant.[9] However, scientific literature is scarce when comparing implant position in MPRs vs. parasagittal images in terms of assessing adjacent anatomical structures.

This study aimed to compare the MPR to parasagittal images of CBCT for localizing placed dental implants concerning adjacent anatomical structures (nasal fossa floor, maxillary sinus, inferior alveolar canal and nasopalatine canal).

2 MATERIALS AND METHODS

The study was approved by the Ethics Committee Research at FOUSP (University of São Paulo School of Dentistry), under the protocol number 3,565,445.

TOMOGRAPHIC IMAGES SELECTION

Fifty-five (55) CBCT exams were randomly selected from Labi3D (3D-Imaging Laboratory) FOUSP database. All volume data were acquired from iCAT scanner Next Generation (Imaging Sciences International, Hatfield, PA, USA), using the following protocol: The field of view (FOV) consisted of 8 x 8 cm (height x diameter) cylinder, with 0.25 mm voxel size, 40 seconds of scanning, 90 kV, and 7 mA.

The inclusion criteria were good quality images (no metallic or movement artifacts close to the implants), with the maxilla and/or mandible placed implants regardless of position and quantity; both genders (45.5% male and 54.5% female patients) were included from any group age (mean age: 63 years old). Images with zygomatic implants, metallic artifacts, foreign bodies, bone grafts or bone pathologies impairing the implant's analysis were excluded.

In total, 164 implants were analyzed. They were located around the following structures: nasal fossa floor (61), nasopalatine canal (13), maxillary sinus (54), inferior alveolar canal (36). One implant may have been analyzed in more than one category (e.g. maxillary sinus and nasal fossa floor).

IMAGE ANALYSIS

Tomographic files in DICOM (Digital Imaging Communication in Medicine) format were exported to Imaging Studio software version 3.401 (Copyright © 2016 Anne Solutions, São Paulo, Brazil) to generate multiplanar reconstructed images. Subsequently, using the same software, parasagittal images were obtained (1mm thick and 1mm of space between them). For observation purposes, MPR and parasagittal images were independently randomized through a website (www.random.org; Randomness and Integrity Services Ltd, Dublin Ireland).

The images were analyzed separately and independently by two oral and maxillofacial radiologists using the same software, in the same environment and computer (Dell Computer Corporation, Round Rock, TX, U.S.A.), Windows 10 (Microsoft Corporation, Washington, U.S.A). Both observers were allowed to use all software tools to assist the diagnosis, such as contrast, brightness adjustment and magnifying tools.

The analysis criteria were the implant location in the MPRs and parasagittal images, concerning the adjacent anatomical structures: nasal fossa floor, nasopalatine canal, maxillary sinus and mandibular canal (Figures 1-3).

Both MPR and parasagittal images were classified as 0 (zero) if there was no perforation of the neighboring anatomical structure and 1 (one) if there was. The data were inserted in an Excel® (Microsoft, Redmond, USA) spreadsheet.

STATISTICAL ANALYSIS

For statistical analysis, the Kappa test was employed to analyze inter-and intra-observer agreements using the IBM SPSS Statistics Subscription software (© Copyright IBM Corporation, New York - USA).

3 RESULTS

Table 1 shows the interobserver agreement (observers 1 and 2) for MPR and parasagittal images. The kappa (K) coefficient was 0.81 and was classified as almost perfect agreement according to the widely used Altman scale, adapted from Landis and

Koch [10], demonstrating that the observers were calibrated. It also shows the K coefficient for intraobserver agreement (observers 1 and 2), 0.79 and 0.89, respectively. Since the oral and maxillofacial radiologists only had information through radiographic images, there was no reference standard (clinical exam) to be used.

Table 2 shows the intraobserver agreement for each anatomical structure and its classification [10], identifying the nasopalatine canal with the highest coefficient and nasal fossa floor with the lowest.

Figure 3 (parasagittal image), represented in slice # 27 in the Figure 2b, demonstrates perforation of the cortical of nasal fossa floor. This perforation was not observed in MPR images (Figure 1).

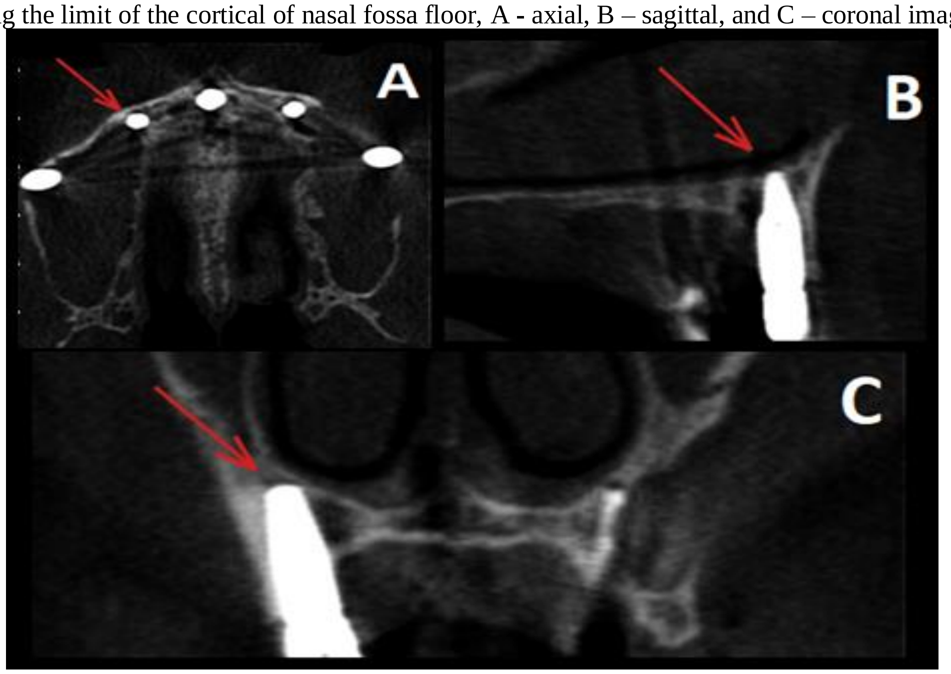
Table 1 - Kappa's coefficient. MPR x parasagittal inter- and intraobserver agreement

	Observer 1 x Observer 2	Observer 1 x Observer 1	Observer 2 x Observer 2
MPR x Parasagittal	0,81	0,79	0,89
Valid cases	328	164	164
Classification [10]	Almost perfect agreement	Substantial agreement	Almost perfect agreement

Table 2 - Anatomical structure intraobserver coefficient

Anatomical Structure	Kappa's coefficient (MPR x Parasagittal)	Kappa coefficient classification[10]
Nasal Fossa Floor	0,72	Substantial agreement
Nasopalatine Canal	0,92	Almost perfect agreement
Maxillary Sinus	0,81	Almost perfect agreement
Inferior alveolar canal	0,81	Almost perfect agreement

Figure 1. Multiplanar reconstructed images; the arrows point the same dental implant in different views, respecting the limit of the cortical of nasal fossa floor, A - axial, B – sagittal, and C – coronal images.



Font: Author

Figure 2a. Axial image used to obtain the parasagittal images, and the respective numbered slices.

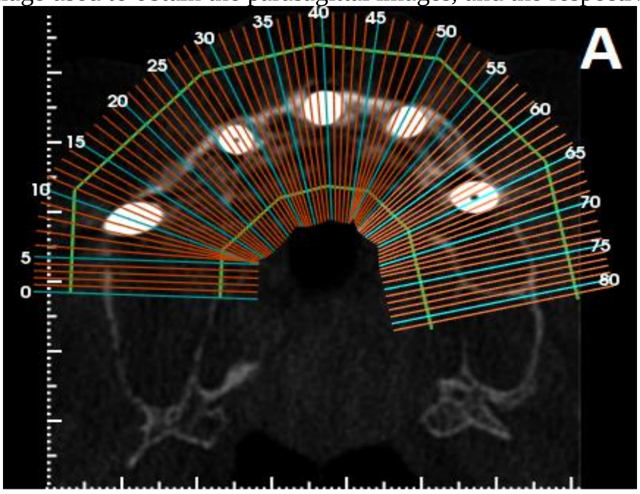


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Figure 2b. Parasagittal images. The arrow points the slice #27.

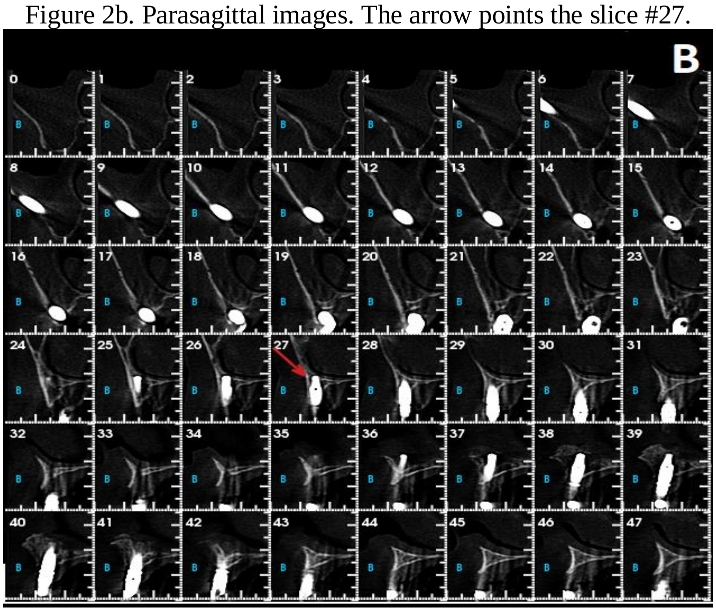

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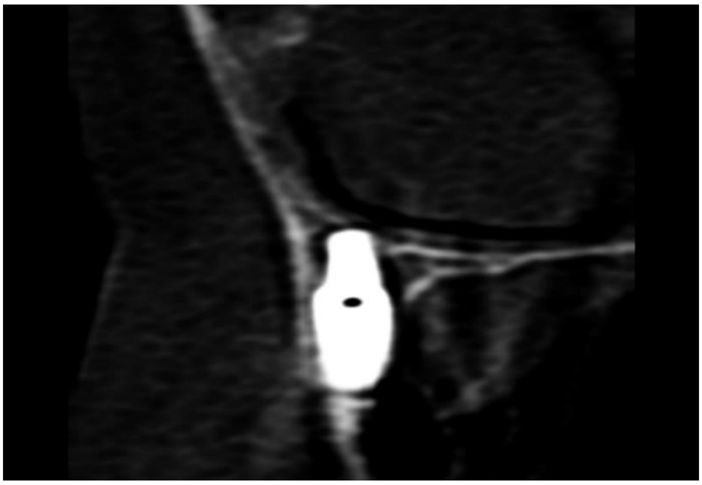
Figure 3. Parasagittal image (slice # 27 in the figure 2b) depicting perforation of the cortical of nasal fossa floor.



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4 DISCUSSION

CBCT is the recommended imaging exam in dental implant planning because it reduces the risk of incorrect implant placement. [2,3] Hartmann et al. [11] suggested that approximately 2.5 mm of distance should be maintained from any nerve canal. In the case of nerve rupture (neurotmesis), the prognosis for recovery is poor, *id est*; in terms of neurosensorial damage, prevention is the critical factor. In implant dentistry, prevention and dental implant long-term success include the election of a CBCT imaging exam.[7]

According to the statistical results of this study, the agreement values ranged from 'substantial agreement' (0.61-0.80) to 'almost perfect agreement' (0.81-1.00), suggesting that the observers were calibrated (Table 1). These results would also indicate that both MPR and parasagittal images can be used for observing implant positioning. CBCT basic principles were published by the AAOMR[8] some years after these devices were introduced in dentistry as imaging diagnostic tool. After that, a European guideline by SEDENTEXCT (Safety and Effectiveness of a New and Emerging Dental X-ray Modality)[12] was created aiming to establish evidence-based guidelines on the use of CBCT in dentistry. Although this study’s results did not show a significant variation when comparing MPR and parasagittal images, the SEDENTEXCT guideline emphasizes the importance of analyzing the complete tomographic volume (MPR), not just the area of interest (parasagittal images). This routine practice may avoid that critical image variation in parasagittal images vs MPRs may lead to misinterpretations. The results corroborate with studies that demonstrate that CBCT is essential to analyze the maxilla anterior region, mainly to locate the boundaries of the nasopalatine canal and nasal fossa floor in the pre-operative dental implant planning.[13,14] Bahsi et al[15] mentioned the vast array of anatomical variations in the nasopalatine canal, while Yilmaz et al.[16] demonstrate how inaccurate implant placement is responsible for many of sensorial damage.

The atrophic maxillary alveolar ridge may represent a limitation to place dental implants, especially with the pneumatization of the maxillary sinuses. CBCT images provide an accurate 3D visualization of the maxillary sinus anatomy. The presence of maxillary sinus septa is associated with an increased risk of perforation of the Schneiderian membrane and an increased risk of sinus infection.[17]

In our study, some images showed variation of the placed implants, when comparing the two observers scores, especially regarding the nasal fossa. The variations may be explained by the imaging acquisition protocol, patient positioning, facial profile and metallic artifacts.[18,19] High density objects (metals) within the CBCT FOV will generate image artifacts. This phenomenon is called beam-hardening and occurs because of the distinct absorption of low energy X-ray photons by materials with high densities (e.g. titanium implants), thus generating images with localized hypodensities or dark voids, close to titanium implants or other high-density structures.[2,20]

A study by Vasconcelos et al.[21] demonstrated through simplified simulations using zirconia and titanium implants that the formation of metallic artifacts changes according to the chosen acquisition parameter and metallic artifact reduction tool, influencing in the image quality. High kVp leads to less absorption of energy by the photons, consequently reducing the artifact production. Pauwels et al [22] reported that for a specific type of tomography scan (3D Accuitomo 170; J Morita), the change in kV and mA could result in impaired image quality, generating more imaging noise. Both studies explain the possible variation in the assessment of dental implant positioning.

The exported DICOM (Digital Imaging and Communications in Medicine) format files correspond to the original images (raw data), processed through an algorithm software named 'reconstruction', hence creating a volumetric data set. Subsequent orthogonal images are generated secondarily from the volumetric data. [2,20] MPR volumetric set information allows the generation of parasagittal images, which are bidimensional images acquired through a software manual operation in the axial slice. It is only possible to generate these orthogonal images through the volumetric data (axial, coronal and sagittal). Although this reformatting is affected by some factors, studies guarantee the accuracy of post-processing linear measurements images.[23]

The ease of analyzing the MPRs and manipulate these images through the software aids the dentist's daily clinical practice. The fidelity of the bone structures and the images precision in MPRs compared to parasagittal slices observed in this study reinforces the use of CBCT in pre and post-operative dental implant planning.

In oral implantology, despite the high rates of success and predictability of dental implants, the peri-implantitis disease may result in loss of osseointegration. [1,24] The MPR images are very useful in the evaluation of these cases. The analyses of axial, coronal, and sagittal slices, simultaneously, make it possible to achieve the buccal-lingual dimension of bone defects, leading to an accurate diagnosis and treatment and improving the prognosis.[25] The use of MPRs supports the decision-making process of diagnosis/treatment in several areas of dentistry, as in peri-implant bone defects as well. [2,3,25] Tyndall et al[8] mentioned that the selection of any diagnostic imaging method must also be based on the dentist's judgment, who must gather scientific evidence, clinical experience, anatomical complexities involved, complications, risks and aesthetic results.

In CBCT imaging, the collected data/images are in digital form and hence are easily transferable between care providers. This is significantly impacted by the additional 3D information so crucial in implant dentistry. The full potential of this modality is further exploited by imaging software applications with optimized algorithms for enhanced interaction with the volumetric data acquired[26] . Our study emphasized the usefulness of the volume data using the raw data MPR from DICOM images. This allowed any manipulation, post-processing tools in order to assess of 3D surface alveolar ridge topography, characterization of vital anatomic structures relevant to the implant site, and the recognition of incidental pathology. Furthermore, we achieve similar results regarding the localization of implants when MPR was compared to parasagittal images, which is considered technically more appropriated to qualitative analysis for implant placement. However, parasagittal images express only the partial volume and did not depict a three-dimensionally in a full volumetric data.

It is important to emphasize that practitioners ordering CBCT scans are responsible for interpreting the entire image volume for potentially significant incidental findings that may require other intervention.[27] Be aware of this, CBCT using MPR images offers several benefits to implant dentistry and allows the dentist enhance clinical outcomes.

5 CONCLUSION

Based on our findings, there was substantial to almost perfect agreement when comparing MPR and parasagittal images regarding implant position relationship with anatomical structures. Since both modalities did not differ in implant position, and the MPR represents the complete and original volume that enables analysis in three dimensions, it can be the first-choice imaging modality to analyze placed dental implants.

ACKNOWLEDGEMENTS

MSc fellowship (Mariana Chagas Murai) from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Brasília, Brazil). We thank Dr. Solange Kobayashi Velasco for English grammar revision.

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