UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

FACULDADE DE ODONTOLOGIA

PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

PLANEJAMENTO DO TAMANHO DO IMPLANTE DENTÁRIO UTILIZANDO IMAGENS DE RADIOGRAFIA PANORÂMICA DIGITAL E TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO

LETICIA RUHLAND CORRÊA

Profª. Drª. HELOÍSA EMÍLIA DIAS DA SILVEIRA

Orientadora no País

Profª. Drª. ANN WENZEL

Orientadora no Exterior

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Linha de Pesquisa: Diagnóstico de Afecções Buco-Faciais

LETICIA RUHLAND CORRÊA

Orientadora no País: Profª. Drª. HELOÍSA EMÍLIA DIAS DA SILVEIRA

Orientadora no Exterior: Profª. Drª. ANN WENZEL

Tese apresentada ao Programa de Pós-Graduação em Odontologia, da Universidade Federal do Rio Grande do Sul, como pré-requisito final para a obtenção do título de Doutor em Clínica Odontológica/ Radiologia.

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"Se vi mais longe foi por estar de pé sobre ombros de gigantes."

Isaac Newton

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% – porcentagem

3i – Implantes Biomet 3i

AAOMR – *American Academy of Oral and Maxillofacial Radiology* / Academia Americana de Radiologia Bucomaxilofacial

CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

CBCT – *cone beam computed tomography* / tomografia computadorizada de feixe cônico

CBCT- *cross sectional images* - imagens transversais de tomografia computadorizada de feixe cônico

CBCT- *cross* - imagens transversais de tomografia computadorizada de feixe cônico

CBCT- *generated panoramic views* - reconstruções panorâmicas geradas a partir de tomografia computadorizada de feixe cônico

CBCT-pan – *CBCT panoramic view* / reconstruções panorâmicas geradas a partir de tomografia computadorizada de feixe cônico

CEP – Comitê de Ética em Pesquisa em Seres Humanos

cm – centímetro

CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico

CT – *computed tomography* / tomografia computadorizada

D-pan – *digital panoramic radiography* / radiografias panorâmicas digitais

Dr. Odont. - título de "professor livre docente" com validade na Escandinávia (Suécia, Noruega e Dinamarca)

et al. - *et alii* (masculino), *ou et aliae* (feminino), *et alia* (neutro) / e outros

FO-UFRGS – Faculdade de Odontologia da Universidade Federal do Rio Grande do Sul

FOV – *field of view* / campo de visão

i. e. – *id est / that is / in other words* / isto é

Inch – *inches* / polegadas

kVp – kilovolt pico

mA – miliampere

mm – milímetros

N – Implantes Nobel Biocare

Obs – obsevador

PDF - *Portable Document Format* / formato portátil de documento. Formato de arquivo, desenvolvido pela Adobe Systems, para representar documentos de maneira independente do aplicativo, do hardware e do sistema operacional usados para criá-los.

PhD – Grau acadêmico de doutor.

S – Implantes Straumann

T – Implantes Titamax TI Neodent

TCFC – tomografia computadorizada de feixe cônico

TCFC-pan – reconstruções panorâmicas geradas a partir de tomografia computadorizada de feixe cônico

TCFC-transversais – imagens transversais de tomografia computadorizada de feixe cônico

TCFL – tomografia computadorizada de feixe em leque

UFRGS – Universidade Federal do Rio Grande do Sul

μSv – micro Sievert – dose equivalente de radiação ionizante

O objetivo deste estudo foi comparar o tamanho do implante dentário (largura e comprimento) planejado utilizando-se radiografias panorâmicas digitais (D-pan), reconstruções panorâmicas geradas a partir de Tomografia Computadorizada de Feixe Cônico (TCFC-pan), e imagens transversais de Tomografia Computadorizada de Feixe Cônico (TCFC-transversais), em quatro sistemas de implantes. Para tal, foram avaliados 103 sítios de implantes unitários nas regiões de pré-molares superiores e molares inferiores em 71 pacientes. Em cada paciente foram realizadas uma radiografia panorâmica digital (D-pan) e uma Tomografia Computadorizada de Feixe Cônico (TCFC). Para a realização da D-pan, foi colocada uma esfera de metal de 5 mm de diâmetro na região edêntula para que fosse realizada a calibração linear da imagem. Os dados adquiridos nas TCFC foram reconstruídos em imagens panorâmicas de 10 mm de espessura (TCFC-pan) e em imagens transversais de 1 mm de espessura (TCFC-transversais). Foram realizadas medidas em todas as imagens. Todas as modalidades de imagem foram exibidas no mesmo monitor e avaliadas por três observadores que utilizando o programa PorDios, identificaram quatro pontos de referência no espaço disponível e delimitaram o sítio de implante. Os tamanhos (largura e comprimento) dos implantes foram comparados entre as três modalidades de imagem e as diferenças foram analisadas. Utilizando o software SPSS, foi selecionado o tamanho do implante mais próximo (igual ou menor) que serviria no espaço disponível, baseado nos tamanhos existentes nos quatro sistemas utilizados (Nobel Biocare, Straumann, 3i e Neodent). O tamanho do implante selecionado nas imagens TCFC transversais foi comparado com o tamanho do implante selecionado nas outras duas modalidades (D-pan e TCFC-pan), para cada um dos sistemas separadamente. Como resultado, na maioria das vezes, o tamanho do implante foi menor nas TCFC-transversais, do que quando comparado com D-pan e TCFC-pan. Houve diferença significativa na largura do implante nas regiões de pré-molares entre D-pan e TCFC-pan. O implante foi significantemente mais curto na TCFC-transversal do que na D-pan, nas regiões de molares. A maioria das mudanças ocorreu para um tamanho mais fino e mais curto, que resultou em um tamanho de implante significantemente menor nas TCFC-transversais. Os resultados permitem concluir que quando o implante é planejado utilizando-se imagens transversais de TCFC este é selecionado em um tamanho mais fino e mais curto do que quando idealizados em radiografias panorâmicas digitais.

DESCRITORES: Implantes Dentários, Radiografia Panorâmica, Tomografia Computadorizada de Feixe Cônico.

The objective of this study was to compare the implant size (width and length) planned with digital panoramic radiographs, CBCT-generated panoramic views, or CBCT cross-sectional images, in four implant systems. Seventy-one patients with a total of 103 single-unit implants in the upper premolar and/or lower molar regions were examined with digital panoramic radiography (D-PAN) and cone beam computed tomography (CBCT). A 5-mm in diameter metal ball was placed in the edentulous area for the D-PAN. CBCT data sets were reformatted to a 10-mm thick CBCT panoramic view (CBCT-pan) and 1-mm cross-sections (CBCT-cross). Measurements were performed in the images using dedicated software. All images were displayed on a monitor and assessed by three observers who outlined a dental implant by placing four reference points in the site of the implant-to-be. Differences in width and length of the implant-to-be from the three modalities were analyzed. An automated program selected the implant size, which was the closest (smaller or equal) size implant that would fit the measured size, based on the sizes available in four worldwide-used implant systems (Nobel Biocare, Straumann, 3i and Neodent). The implant size selected in the CBCT-cross images was then compared to that selected in the other two modalities (D-PAN and CBCT-pan) for each of the implant systems separately. The implant-to-be (average measurements among observers) was narrower when measured in CBCT-cross compared with both D-PAN and CBCT-Pan. For premolar sites, width also differed significantly between D-PAN and CBCT-pan modalities. The implant-to-be was also significantly shorter when recorded in CBCT-cross than in D-PAN. In premolar sites there were no significant differences in implant length among the three image modalities. It mattered very little for the change in implant step sizes whether CBCT-cross was compared to D-PAN or CBCT-pan images. Our results show that the selected implant size differs when planned on panoramic or cross-section CBCT images. In most cases implant size measured in cross-section images was narrower and shorter than implant size measured in a panoramic image or CBCT-based panoramic view.

KEYWORDS: Cone Beam Computed Tomography, Dental Implants, Panoramic Radiography.

O primeiro passo para a colocação de um implante dentário é o planejamento, sendo este a chave para o sucesso do tratamento. Nesta etapa o profissional deverá realizar um exame clínico detalhado e solicitar exames complementares, onde se inclui a investigação por imagem que permite a mensuração da quantidade de osso disponível nos possíveis sítios para a inserção do implante dentário.

Diferentes métodos de imagem são utilizados como exames pré-operatórios em implantodontia, cada um deles com a sua indicação específica. Algumas estruturas anatômicas como o canal da mandíbula, os assoalhos da fossa nasal e seios maxilares devem ter os seus limites respeitados para a instalação adequada do implante. Além disso, mesmo em regiões onde a disponibilidade óssea é suficiente, um mínimo de osso cortical deve estar presente para que no ato cirúrgico haja o travamento do implante (COSCARELI, OLIVA, CAVALCANTI, 2008).

Assim como a quantidade de osso alveolar remanescente, a avaliação pré-operatória da densidade óssea auxilia o profissional neste planejamento (SHAHLAIE *et al.*, 2003; ARANYARACHKUL *et al.*, 2005). O tipo e a arquitetura do osso são fatores importantes no sucesso do tratamento de implantes dentários, quanto menor a qualidade óssea, maior a chance de insucesso. As classificações ósseas têm sido questionadas por serem subjetivas e existem estudos que visam determinar as variações de densidade óssea em sítios onde seriam colocados implantes dentários, utilizando a tomografia computadorizada (TURKYILMAZ *et al.*, 2008).

Na decisão sobre o exame a ser realizado, a dose de radiação deve ser considerada e vários são os estudos que comparam as doses de exposição ao paciente provenientes de equipamentos com diferentes tecnologias e marcas. Em pesquisas realizadas com manequim, os resultados obtidos foram de aproximadamente 6,2 μSv a 13,3 μSv nas radiografias panorâmicas, de 45 μSv a 135 μSv nas tomografias computadorizadas de feixe cônico (TCFC) e 15.832,2 μSv na tomografia computadorizada *multislice* (LUDLOW *et al*., 2003; LUDLOW *et al*., 2006; WÖRTCHE *et al*., 2006; SILVA *et al*., 2008). A dose de radiação na TCFC é de 4 a 42 vezes maior do que na radiografia panorâmica e esta varia dependendo do equipamento, do *Field of View* (FOV) e dos parâmetros selecionados (LUDLOW *et al*., 2006). Um FOV menor deve ser usado para imagens dentais, enquanto um FOV maior deve ser restringido aos casos onde uma visualização mais ampla for necessária (HIRCH *et al*., 2008).

A exposição à radiação pode variar entre os equipamentos de TCFC, mesmo assim, é definitivamente menor que os níveis de dose de radiação da tomografia computadorizada de feixe em leque (TCFL) (SCHULZE *et al*., 2004; HAURET, HODEZ, 2009).

A TCFC é uma tecnologia que permite a obtenção de imagens com alta qualidade diagnóstica, baixo tempo de escaneamento e dose de radiação até 15 vezes menor que a TCFL, sem a perda de acurácia das medidas (ARANYARACHKUL *et al*., 2005; BAMGBOSE *et al*., 2008; SUOMALAINEN *et al*., 2008).

Em um estudo para avaliar a visibilidade do canal da mandíbula em imagens realizadas com tomografia computadorizada de feixe cônico (3D Accuitomo – J. Morita) em 30 pacientes, sete observadores avaliaram o canal da mandíbula e a crista óssea marginal para decidir se estas estruturas estavam claramente visíveis ou se eram difíceis de serem identificadas. Com as imagens obtidas, a concordância entre os observadores sobre a localização das estruturas foram altas, assim como, a visibilidade do canal da mandíbula e da crista óssea marginal (LOFTHAG-HANSEN; GRONDAHL; EKESTUBBE, 2008).

Pesquisadores estudaram a eficiência da radiografia panorâmica convencional, tomografia convencional e TCFL para a localização do canal da mandíbula antes da colocação de implantes dentários na região posterior da mandíbula de seis crânios secos. As mensurações obtidas com as imagens foram comparadas com aquelas obtidas diretamente nas mandíbulas. Os autores concluíram que as medidas obtidas com TCFL foram mais consistentes com as medidas diretas que as medidas obtidas com a radiografia panorâmica e tomografia convencional (PEKER; ALKURT; MICHCIOGLU, 2008).

Por outro lado, um estudo comparou as doses de radiação para o planejamento de implantes utilizando um manequim com dosímetro que foi submetido à radiografia panorâmica, à tomografia convencional e à tomografia computadorizada. Os pesquisadores concluíram que a tomografia computadorizada forneceu imagens excelentes, mas ao custo do aumento da dose de radiação. Concluíram também que com a radiografia panorâmica aliada à tomografia convencional pode-se obter informações adequadas com uma grande redução da dose de radiação em comparação à TCFL (LECOMBER *et al*., 2001).

A radiografia panorâmica vem sendo substituída pela tomografia computadorizada de feixe cônico para planejamento de implantes dentários, mesmo nos casos de implantes unitários. Essa mudança no critério de seleção de imagem não leva em consideração a quantidade de possíveis sítios de implantes, assim como a dose de radiação a ser absorvida pelo paciente.

Tendo em vista as colocações acima, justifica-se a realização de um estudo que investigue se existe diferença entre o planejamento do tamanho do implante dentário unitário executado a partir de radiografias panorâmicas, com aqueles realizados utilizando tomografias computadorizadas de feixe cônico.

Geral

Comparar a escolha do tamanho do implante dentário realizada a partir de imagens de radiografia panorâmica digital e tomografia computadorizada de feixe cônico.

Específico

Comparar a escolha do tamanho do implante dentário unitário nas regiões de pré-molar superior e de de molar inferior realizadas a partir de imagens de radiografia panorâmica digital e tomografia computadorizada de feixe cônico.

Planning of dental implant size with digital panoramic radiographs, CBCT-generated panoramic images, and CBCT cross-sectional images

Leticia Ruhland Correa, PhD student[a]; Rubens Spin-Neto, PhD[b]; Andreas Stavropoulos, PhD, dr. odont.[c,d]; Lars Schropp, PhD[e], Heloísa Emília Dias da Silveira, PhD[a]; Ann Wenzel, PhD, dr. odont.[b]

[a]Department of Dentistry – Oral Radiology, Federal University of Rio Grande do Sul, Porto Alegre, Brazil.

[b]Department of Dentistry – Oral Radiology, Aarhus University, Aarhus, Denmark.

[c]Department of Dentistry – Periodontology, Aarhus University, Aarhus, Denmark.

[d]Center for Experimental and Preclinical Biomedical Research, (CEPBR), Athens, Greece.

[e]Department of Dentistry – Prosthetic Dentistry, ,Aarhus University, Aarhus, Denmark.

Running title: Planning of oral implant size with CBCT

Key-words: *implant planning, implant size, digital panoramic radiography, cone beam computed tomography.*

Corresponding author:
Leticia Ruhland Correa
Dept. of Dentistry - Oral Radiology, Fed. University of Rio Grande do Sul
Rua Ramiro Barcelos, 2492, Bairro Santana, Porto Alegre, Brazil.
leticiaruhland@gmail.com

Planning of dental implant size with digital panoramic radiographs, CBCT-generated panoramic images, and CBCT cross-sectional images

Abstract

Objectives: To compare the implant size (width and length) planned with digital panoramic radiographs, CBCT-generated panoramic views, or CBCT cross-sectional images, in four implant systems.

Material and methods: Seventy-one patients with a total of 103 single-unit implants in the upper premolar and/or lower molar regions were examined with digital panoramic radiography (D-PAN) and cone beam computed tomography (CBCT). A 5-mm in diameter metal ball was placed in the edentulous area for the D-PAN. CBCT data sets were reformatted to a 10-mm thick CBCT panoramic view (CBCT-pan) and 1-mm cross-sections (CBCT-cross). Measurements were performed in the images using dedicated software. All images were displayed on a monitor and assessed by three observers who outlined a dental implant by placing four reference points in the site of the implant-to-be. Differences in width and length of the implant-to-be from the three modalities were analyzed. An automated program selected the implant size, which was the closest (smaller or equal) size implant that would fit the measured size, based on the sizes available in four worldwide-used implant systems (Nobel Biocare, Straumann, 3i and Neodent). The implant size selected in the CBCT-cross images was then compared to that selected in the other two modalities (D-PAN and CBCT-pan) for each of the implant systems separately.

Results: The implant-to-be (average measurements among observers) was narrower when measured in CBCT-cross compared with both D-PAN and CBCT-Pan. For premolar sites, width also differed significantly between D-PAN and CBCT-pan modalities. The implant-to-be was also significantly shorter when recorded in CBCT-cross than in D-PAN. In premolar sites there were no significant differences in implant length among the three image modalities. It mattered very little for the change in implant step sizes whether CBCT-cross was compared to D-PAN or CBCT-pan images.

Conclusion: Our results show that the selected implant size differs when planned on panoramic or cross-section CBCT images. In most cases implant size measured in cross-section images was narrower and shorter than implant size measured in a panoramic image or CBCT-based panoramic view.

Introduction

Radiographic methods for the assessment of bone quantity and quality are traditionally used in the treatment planning for dental implant placement. Panoramic images provide an overview of the jaws and are usually considered adequate in the initial evaluation of the implant site. However, panoramic images do not display the bucco-lingual aspect of the alveolar bone. Knowledge of anatomic features like the location of the mandibular canal, the maxillary sinuses and the nasal cavity, as well as of the angulation and bone volume of the alveolar crest is a prerequisite for appropriate implant treatment planning (Lofthag-Hansen et al., 2008). The bucco-lingual aspect of the alveolar bone can only be obtained with conventional cross-sectional tomography, computed tomography (CT), or cone beam computed tomography (CBCT). CBCT provides high diagnostic quality images, short scanning time, and lower radiation dose compared to CT examination (Bamgbose et al., 2008; Suomalainen et al., 2008).

Generally, the clinical examination provides sufficient information for selecting implant width, and the panoramic radiograph offers sufficient information for selecting implant length. A cross-sectional image seems thus not necessary for the evaluation of the available bone volume in standard implant cases (Frei et al., 2004). On the other hand, The American Academy of Oral and Maxillofacial Radiology (AAOMR) recommends that the evaluation of a potential implant site should include cross-sectional imaging, orthogonal to the site of interest (Tyndall and Brooks, 2000). The increasing use of implants for oral reconstruction may thus be associated with a rise in requests for radiographic examinations with CBCT that in turn would increase the radiation burden to the population (Chau and Fung, 2009). Nevertheless, when CBCT data are available, CBCT-generated panoramic views can be considered as an alternative to conventional panoramic imaging (Mischkowski et al., 2007). Comparing these two modalities, Mischkowski et al. (2007) found that subjective image quality was ranked higher in panoramic radiographs than in CBCT panoramic views due to noise, poor contrast, and artifacts caused mainly by metallic dental restorations in the CBCT images. No significant difference between the two types of images was found regarding the detection of pathology, though. Furthermore, CBCT panoramic views were superior to panoramic radiographs for identification of the mandibular canal (Angelopoulos et al., 2008).

Only few studies have assessed the impact of radiographic information on the bucco-lingual bone dimension on the planning of dental implant size. One study concluded that conventional tomography had little impact on determining implant dimensions while decision on bone grafting or other pre-implant procedures was facilitated by the use of conventional spiral tomography in cases with severely resorbed bone ridge or alveolar extension of the maxillary sinus (Diniz et al., 2008). According to Schropp et al. (2011), however, the additional information from conventional cross-sectional radiography resulted in a considerable change in implant size selected solely on the basis of conventional panoramic radiography. Until now, there are no studies evaluating the impact of additional information on the bucco-lingual dimension through CBCT on the implant size chosen on the basis of panoramic radiography. Similarly, no studies have evaluated the possibility to use CBCT-generated panoramic views for the selection of implant size instead of conventional panoramic tomography.

The purpose of this study was to compare the implant size (width and length) planned with digital panoramic radiographs, CBCT-generated panoramic views, or CBCT cross-sectional images, in four implant systems.

Material and methods

Study sample

Seventy-one patients (50 women and 21 men, mean age 43.8 years, ranging from 24 to 71 years) requiring one or more single-unit implant(s) in the upper premolar and/or lower molar regions, were included in the study. A total of 103 implant sites were evaluated (Table 1). For each patient, digital panoramic radiographs (D-PAN) and CBCTs were recorded.

Radiographic modalities and image generation

D-PANs were recorded in a digital panoramic unit (CCD Sensor Cranex® D, Soredex Oy, Tuusula, Finland). Before image recording, a 5-mm diameter metal ball was fixed by a piece of wax at the intended implant site(s). After acquisition, images were saved as original bitmap format (BMP).

CBCT was performed with the ICat New Generation (Imaging Sciences, Hatfield, USA). The unit was set to 120 kV, 5 mA, using a 16x6 cm FOV, with an acquisition time of 26.0 seconds and a 0.2 mm voxel size. The CBCT data sets were initially handled in the ICat dedicated software (Xoran Tecnologies® Inc., Ann Arbor, MI, US). Starting from the reference axial view, a curve was drawn resulting in one sagittal and fifteen cross-section images from each implant site saved as PDF file. In this PDF file, a ruler underneath the sagittally reconstructed image indicated the location of all cross-sectional images belonging to the set.

The DICOM datasets were thereafter imported to OnDemand 3DApp software (Cybermed Inc, Seoul, Korea). The reconstructed volume was set parallel with the horizontal axis of the alveolar process. Windowing (contrast control) was set at band width (W) 3086 and center level (L) 667 defining which shades of grey were shown to the user (Spin-Neto et al., 2011). The images were displayed in three planes perpendicular to each other. A curve was drawn in the axial view of the implant site resulting in 1-mm thick cross-sectional images. The cross-section through the middle of the implant site was chosen (CBCT-cross) and saved in bitmap format (BMP).

A pilot study was performed in order to select the CBCT section thickness providing the best quality panoramic view, resembling a true panoramic radiograph. In 15 randomly selected implant sites, a curve was drawn using the axial view resulting in three panoramic views with different thickness (5, 10, 20 mm). Contrast/windowing was set as width (W) 2829 level (L) 803. Three observers independently assessed the images and individually decided which one presented best the bone and anatomical structures in the implant site. All observers agreed that the 10-mm section thickness possessed the best image quality. The 5-mm sections showed more artifacts from metal restorations, and the 20-mm sections had poorer contrast and seemed more blurred. The remaining CBCT data sets were then reformatted to a 10-mm thick CBCT panoramic view (CBCT-pan).

Planning implant size

D-PAN, CBCT-cross and CBCT-pan images (Fig. 1) were imported to dedicated software designed for performing distance measurements in digital images (PorDios®; Gotfredsen et al. 1999). With the intent to select the appropriate implant size, the D-PAN, CBCT-pan and CBCT-cross images of the 103 implant sites were assessed by three observers: one periodontist (obs1), one radiologist (obs2), and one prosthodontist (obs3), all familiar with implant planning in radiographs. The images were displayed to the observers on a Lenovo® Thinkvision® 21-inch monitor (Lenovo, Morrisville, USA) with a resolution of 1680x1050 pixels.

Using the computer mouse, the observers outlined for each site in each image modality an implant with subjectively judged proper width and length by manually placing four reference points corresponding to the mesial, distal, coronal (i.e. platform level), and apical boundary of the implant-to-be. Implant dimensions were restricted by anatomical structures such as the mandibular canal, maxillary sinus and neighboring teeth. In regions where the alveolar ridge was very thin in CBCT-cross, the first choice during planning was to avoid additional therapy (i.e. guided bone regeneration), by placing the implant platform level more apically or slightly inclined so that a standard diameter implant could fit (i.e. available bone width bucco-lingually / bucco-palatally was approximately 4 mm). However, this was always performed taking into account the inclination of the neighboring teeth to avoid extreme implant positioning and restorative concerns. For this reason, the PDF set of all cross-sections of the implant site, including the neighboring teeth, was displayed on a second Lenovo® Thinkvision® 21-inch monitor (Lenovo, Morrisville, U.S.A.) with a resolution of 1680x1050 pixels situated beside the first monitor. The full data set of the implant site was thus available to the observers in case they needed to view the position and inclination of the neighboring teeth while recording the implant-to-be.

In D-PANs the platform level was set at the top of the alveolar bone crest. Additionally, four reference points were placed on the most coronal, apical, mesial and distal point of the metal ball in order to enable correction for image magnification. For the CBCT-pan and CBCT-cross images, two reference points were placed on a 10-mm ruler, one in each end, within the image.

In 10% of the images, the recordings of the metal ball and the ruler for calibration purposes were performed twice in order to assess manual dexterity of the observers.

Data treatment

From the images evaluated twice, the discrepancy between the first and second recording was assessed by calculating the distance in absolute number of pixels between the corresponding points placed on the metal ball (in D-PAN), and likewise on the ruler (in CBCT-cross and CBCT-pan). The variation in absolute pixel number is seen in Table 2. The largest variation was observed for the metal ball in D-PANs. The CBCT-cross and CBCT-pan images had an almost similar pixel variation. Obs1 obtained the lowest reproducibility, but overall the observer variation was only a few pixels. The calculation of implant size in millimeters was performed for each observer's recordings by calibrating to this observer's own recordings of the metal ball or the ruler in the image in question.

Width and length of the recorded implant-to-be were calculated separately for each observer and each site after correcting for the magnification factor in each image. For the D-PANs, the horizontal (width) and the vertical (length) planes were separately adjusted using the recordings on the metal ball. Based on mean values of implant width and length for the three observers, an "average" observer was calculated. Differences in width and length of the implant-to-be were analyzed by two-way-analysis of variance with the factors *observer* and *radiographic modality*, both for all sites and for premolar and molar sites separately. The pair-wise comparisons between the modalities were made by *post hoc t-tests*. The level of statistical significance was $P < 0.05$.

To estimate the impact on a change in width and length from the recordings on D-PAN/CBCT-pan to the recordings on CBCT-cross images in commercially available implant systems, four worldwide used implant systems were selected: Nobel Brånemark System® MkIII (N) (Nobel Biocare, Goteborg, Sweden), Straumann® Standard implants (S) (Straumann® AG, Basel, Switzerland), 3i Hybrid Osseotite® (3i) (BIOMET 3i, Palm Beach, FL, USA) and Titamax Ti Implant (T) (Neodent, Curitiba, Brazil). In February 2012, the following information on implant sizes available in each of these implant brands was available: N implant system had four widths and seven lengths constituting 25 sizes; S had three widths and six lengths constituting 16 sizes; 3i had five widths and eight lengths constituting 30 sizes, and T had four widths and six lengths constituting 17 sizes.

Implant sizes of each system separately were listed from the narrower to the wider and from the shorter to the longer in increasing size order. When comparing two methods, a one-size change in width (to a narrower or wider implant), length (to a shorter or longer implant), or both was defined as a one "step" change.

Based on the width and length of the implant recorded by the observers in each image from the three image modalities, and based on the available implant sizes in each implant system, an automated program generated the implant size, which was the closest (smaller or equal) size implant that would fit the measured size. The implant size selected in the CBCT-cross images was then compared to the selected implant size in the other two modalities (CBCT-cross/D-PAN and CBCT-cross/CBCT-pan) for the four implant systems separately. Thereby, it was determined how many "steps" an implant would change in width and length if the size was calculated on CBCT-cross images instead of D-PAN or CBCT-pan images.

Results

The observers differed somewhat in their measurements of the implant-to-be (Table 3). Obs1 in general recorded the largest implant size except for implant length in D-PANs. Obs2 in general recorded shorter implants than the other two observers. Obs3 recorded narrower implants than did the other two observers, except in CBCT-cross. However, the differences in implant size between the observers were on average less than a millimeter except for implant width in CBCT-pan images and length in D-PANs.

The implant-to-be (average measurements among observers) was significantly narrower when measured in CBCT-cross compared with both D-PANs and CBCT-pan images (Table 4). For premolar sites, width also differed significantly between D-PAN and CBCT-pan modalities, i.e. CBCT-pan allowed wider implants. This was not the case for molar sites. The implant-to-be was also significantly shorter when recorded in CBCT-cross than in D-PAN images (Table 4). This was the case when all implant sites were considered, and also when molar sites were assessed separately. Moreover, significantly shorter implants were planned in CBCT-pans than in D-PANs in molar sites. In premolar sites there were no significant differences in implant length among the three image modalities.

Tables 5 and 6 show the number of steps an implant changed in width or length, respectively, when recorded on CBCT-cross images compared to D-PAN or CBCT-pan images. In a number of cases, there was no space for an implant based on any of the radiographic methods (8 cases using CBCT-pan and D-PAN for N, 6 cases using CBCT-pan and D-PAN for S, 23 cases using CBCT-pan and 25 cases using D-PAN for 3i, and 13 cases using CBCT-pan and 14 cases using D-PAN for T). It mattered little for the change in steps whether CBCT-cross was compared to D-PAN or CBCT-pan images since these views showed quite similar performance in relation to implant size selection. Regarding the width, the implant would change in 7-21% of cases - if planned by D-PAN to a narrower size than with CBCT-pan. Regarding the length, the implant would change in only few percent (range 7-9%).

Considering all four implant systems, 9-14% changed to a wider size implant and 13-36% changed to a longer size implant. The majority of the changes were therefore to a narrower (24-54%) or shorter (26-53%) size, which is in accordance with the overall linear measurements that on average resulted in significantly smaller implants in CBCT-cross.

The change from a panorama modality (D-PAN or CBCT-pan) to CBCT-cross resulted in an implant size that was not available in the stock of implants in 20% (N), 14.5% (S) and 34% (T), respectively, of the cases. For 3i, no cases fit that situation. In total, the cases that could not receive an implant when planned in either CBCT-cross or panoramic views were 28% (N), 20% (S), 24% (3i), and 48% (T).

Discussion

The aim of this study was to assess the impact of different radiographic methods on the selection of implant size in four worldwide used implant systems by comparing the size of the implant-to-be when measured in digital panoramic radiographs, CBCT generated panoramic views, and CBCT cross-sections. Thus, our study design corresponds to level 3 in the suggested hierarchic efficacy model for testing diagnostic imaging methods, coined as changes in diagnostic thinking level (Fryback & Thornbury, 1991). The present study was not designed to provide evidence on when a CBCT examination should be performed, or whether higher success rates are obtained choosing the implants based on one or the other technique.

Apparently, no previous studies exist comparing panoramic radiography and CBCT images for implant treatment planning. Previous studies comparing conventional cross-sectional radiography and panoramic imaging for implant treatment planning have found that the selected implant size differed considerably when planned on panoramic or conventional cross-sectional tomograms (Schropp et al., 2001; Schropp et al., 2011), and also that conventional spiral tomography increased the clinician's certainty of the need for additional surgical procedures, such as bone grafting (Diniz et al., 2008). In one study (Schropp et al. 2001) the implant length and width were determined pre-surgically and compared with the dimensions of the installed implants. In 70% of the cases, the implant length or width, or both, was changed after the tomograms were available. The implant dimensions determined with tomography were maintained at surgery in 87% of the cases, while only in 33% of the cases without tomography, showing that the use of tomograms increased the efficacy of predicting the appropriate implant size. Another study concluded that conventional spiral tomography had a minor impact on the treatment planning of implant dimensions in posterior mandibular cases since it was found that the planning was identical in 96% of the cases (Frei et al., 2004). It must be mentioned that in that particular study narrow-ridge patients were excluded. Also, in that study (Frei et al., 2004), the specified implant system was Straumann®, which is the one with the smallest range of implant sizes to choose among, so it may be expected that it would be less affected by the radiographic method. One disadvantage with conventional tomography can be the rather degraded image quality as a result of disturbing ghost shadows from surrounding structures (Curry et al., 1984). Particularly, one may encounter difficulties in defining the borders of the alveolar crest, the maxillary sinus, or the mandibular canal (Schropp et al., 2011).

Today more advanced 3-dimensional methods, like CBCT, are available to dentists for cross-sectional imaging. Studies have demonstrated a high performance of CBCT in visualizing anatomical landmarks (Angelopoulos et al., 2008; Lofthag-Hansen et al., 2009) or bone defects (Stavropoulos & Wenzel, 2007). Especially for implant planning, it was concluded that CBCT was as reliable as multislice CT for linear measurements (Suomalainen et al., 2008). Besides that, this modality provides lower radiation dose (Lofthag-Hansen et al., 2008; Ludlow et al., 2006; Timock et al., 2011) and costs (Suomalainen et al., 2008) compared to TCFL examination.

Our results showed that the majority of the implants changed to a smaller size in either width or length, when the planning was made using CBCT-cross compared to D-PAN or CBCT-pan views. The length was changed more often than the width. This is in agreement with the results of Schropp and coworkers (Schropp et al., 2011).

The CBCT panoramic view has previously been compared to digital panoramic radiography with the intention to visualize the mandibular canal. CBCT reformatted pan-images outperformed the digital panoramic images in the identification of the mandibular canal (Angelopoulos et al., 2008) and also performed better in the diagnosis of specific lesions, whereas panoramic radiography provided a higher image quality for the general overview of the regions (Mischkowski et al., 2007). In the present study, we found differences in width in the premolar region and in length in the molar region; however, the differences were small and towards a “safer” implant size, i.e. the implant-to-be was significantly shorter when recorded in CBCT-pan than in D-PAN images. It may be suggested that in case that a CBCT is required for the preoperative implant planning, a panoramic radiograph should not be recorded since the reformatted panoramic image could display the mesio-distal view. CBCT images should of course not in all situations replace digital panoramic images since a CBCT examination gives a higher radiation dose (4 to 20 times greater) than panoramic radiography. Which imaging modality to select for diagnostic purposes should be determined for the diagnostic yield expected and in accordance with the ALARA (As Low as Reasonably Achievable) principle (Ludlow et al., 2003).

In order to simulate a clinical situation, we decided in this study to use three worldwide used implant brands and one of the most used implant systems in Brazil. Depending on the system used, it was possible to choose among 16 to 30 sizes of implants. Among the implant systems evaluated in the present study, the Straumann® implant system, with the smallest number of implant sizes to choose among, was logically less affected by the radiographic method compared with the other systems while more differences were observed for the 3i system with the largest assortment of implant sizes. When the implant brand offers more choices of combinations of length x width, it likely increases the treatment options for the patients, since in fewer cases it would not be possible to place an implant. Nevertheless, the change from a panorama modality (D-PAN or CBCT-pan) to CBCT-cross, in some cases resulted in an implant size that was not available in the stock of implants systems evaluated herein.

In conclusion, the present study demonstrates that preoperative selection of implant size is influenced by the type of radiographic method used for treatment planning and the implant system to be used. Implant size should thus not be determined only on images displaying the mesial-distal plane since in most cases implant size measured on cross-section images was both narrower and shorter than implant size measured on a panoramic image or CBCT-panoramic view.

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Figure legends

Fig. 1. One of the cases evaluated in the study. **A:** D-PAN focusing on the region of the tooth 25. **B:** Same region displayed in the CBCT-pan. C: CBCT-cross of the same region of interest, displaying the bucco-palatal aspect of the region.

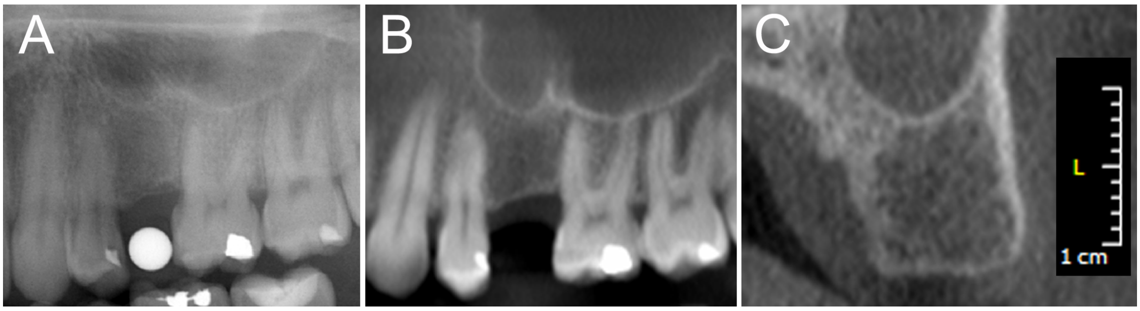

Table 1. Distribution of implant sites, according to gender, in the study population

	Premolar	Molar	Total
Men	19	13	32
Women	28	43	71
Total	47	56	103

Table 2. Mean variation in absolute pixels from duplicate measurements by each observer in each image modality

	D-PAN	CBCT-cross	CBCT-pan
Obs1	3.29	2.51	1.50
Obs2	2.01	0.75	1.00
Obs3	3.02	1.00	1.00

Table 3. Mean, standard deviation (SD), minimum (Min) and maximum (Max) values in millimeters for width and length of the implant-to-be, recorded by the three observers in each imaging modality

	D-PAN							
	Width				**Length**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Obs1	6.03	1.85	3.08	10.70	10.95	2.63	2.58	17.79
Obs2	5.96	1.65	3.18	11.15	9.64	2.15	2.81	14.37
Obs3	5.11	0.92	3.04	6.88	11.10	2.74	2.82	15.78
	CBCT-cross							
	Width				**Length**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Obs1	4.99	1.48	2.42	9.68	10.16	2.92	2.51	17.85
Obs2	4.10	0.56	2.32	6.78	9.97	3.10	2.43	17.41
Obs3	4.25	0.83	2.22	6.33	10.16	3.03	2.06	18.72
	CBCT-pan							
	Width				**Length**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Obs1	6.94	1.59	3.88	12.04	10.54	2.53	3.21	18.25
Obs2	6.20	1.37	3.62	10.93	9.91	2.37	3.02	16.17
Obs3	4.73	0.67	3.16	6.21	10.25	2.47	3.03	15.42

Table 4. Mean (among the observers), standard deviation (SD), minimum (Min) and maximum (Max) values in millimeters for width and length of the implant-to-be recorded in D-PAN, CBCT-pan and CBCT-cross images

Modality	Width (all teeth)				Length (all teeth)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
D-PAN	$5.70^{A,B}$	1.40	3.19	9.08	10.57^{D}	2.37	2.74	15.46
CBCT-pan	$5.96^{A,C}$	1.15	3.63	9.33	10.24	2.35	3.09	16.61
CBCT-cross	$4.45^{B,C}$	0.89	2.43	7.27	10.10^{D}	2.94	2.33	17.93

$^{A}P < 0.017$; $^{B,C}P < 0.001$; $^{D}P < 0.04$

Modality	Premolars							
	Width				Length			
	Mean	SD	Min	Max	Mean	SD	Min	Max
D-PAN	$4.70^{A,B}$	0.92	3.19	6.94	10.29	2.89	2.74	15.46
CBCT-pan	$5.18^{B,C}$	0.83	3.63	7.60	10.29	2.85	3.09	16.61
CBCT-cross	$4.07^{A,C}$	0.82	2.43	6.17	10.55	3.36	2.33	17.93

$^{A,B,C}P < 0.001$

Modality	Molars							
	Width				Length			
	Mean	SD	Min	Max	Mean	SD	Min	Max
D-PAN	6.54^{A}	1.15	3.63	9.08	$10.79^{C,D}$	1.81	5.04	14.64
CBCT-pan	6.61^{B}	0.95	4.50	9.33	10.18^{D}	1.86	4.19	13.76
CBCT-cross	$4.77^{A,B}$	0.82	3.24	7.27	9.72^{C}	2.51	4.84	15.41

$^{A,B,C}P < 0.001$; $^{D}P < 0.02$

Table 5. Number of steps that an implant changed when **width** recorded in D-PAN or CBCT-pan was compared to the **width** recorded in CBCT-cross, according to the implant system. In the column "No change", the numbers in brackets are cases in which there was no space for an implant based on any of the radiographic methods evaluated

Nobel - Brånemark	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	21	-	1	8	26	30 + (8)	5	2	2
CBCT-cross – CBCT-pan	21	-	3	8	31	30 + (8)	2	0	0
Straumann	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	15	-	-	14	25	34 + (6)	5	2	2
CBCTcross – CBCT-pan	15	-	-	18	27	34 + (6)	2	0	1
3i Hybrid Osseotite	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	0	3	6	24	14	20 + (25)	8	3	0
CBCT-cross – CBCT-pan	0	3	11	21	21	20 + (23)	4	0	0
Titamax Ti Neodent	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	35	-	4	7	14	20 + (14)	2	3	4
CBCT-cross – CBCT-pan	35	-	5	9	14	23 + (13)	0	1	3

Negative values mean that the implant was one or more steps narrower in CBCT-cross images. "No implant" means that when size was recorded in CBCT-cross images, no implant of such small dimension existed in this specific implant system. Positive values mean that the implant was one or more steps wider in CBCT-cross images. "Implant" means that when size was recorded on CBCT-cross images, it was possible to place an implant in a case where the space was too small when measured in D-PAN/CBCT-pan.

Table 6. Number of steps that an implant changed when **length** recorded in D-PAN or CBCT-pan was compared to the **length** recorded in CBCT-cross, according to the implant system. In the column "No change", the numbers in brackets are cases in which there was no space for an implant based on any of the radiographic methods evaluated

Nobel - Brånemark	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	21	0	10	10	21	12 + (8)	9	6	2
CBCT-cross – CBCT-pan	21	0	11	11	23	10 + (8)	10	7	1
Straumann	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	15	0	0	14	13	24 + (6)	13	7	6
CBCTcross – CBCT-pan	15	0	0	14	16	25 + (6)	12	9	`4
3i Hybrid Osseotite	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	0	9	8	21	11	13 + (25)	6	5	2
CBCT-cross – CBCT-pan	0	9	12	21	13	10 + (23)	7	6	1
Titamax Ti Neodent	**No implant**	**-4**	**-3**	**-2**	**-1**	**No change**	**+1**	**+2**	**Implant**
CBCT-cross – D-PAN	35	0	2	14	17	8 + (13)	7	1	1
CBCT-cross – CBCT-pan	35	0	2	18	15	10 + (13)	6	1	0

Negative values mean that the implant was one or more steps shorter in CBCT-cross images. "No implant" means that when size was recorded in CBCT-cross images, no implant of such small dimension existed in this specific implant system. Positive values mean that the implant was one or more steps longer in CBCT-cross images. "Implant" means that when size was recorded on CBCT-cross images, it was possible to place an implant in a case where the space was too small when measured in D-PAN/CBCT-pan

Ainda hoje na prática clínica observa-se divergência entre os profissionais sobre o exame por imagem a ser realizado no planejamento para implante dentário.

Por diversos motivos, como o custo financeiro, dose de radiação e acesso aos equipamentos; alguns profissionais utilizam a radiografia panorâmica enquanto outros preferem a TCFC.

Este estudo demonstra que a escolha do tamanho do implante é influenciada pela técnica radiográfica empregada no plano de tratamento. Foi observado que o tamanho do implante não deve ser definido apenas com imagens bidimensionais exibindo o plano mesio-distal, visto que, na maioria dos casos, o tamanho do implante adequado nas imagens transversais era mais fino e mais curto que o tamanho do implante medido na radiografia panorâmica digital ou na reconstrução panorâmica.

Estudos que desenvolvam diretrizes baseadas em evidências devem ser estimulados, principalmente aqueles que incluem referência para o uso dos exames por imagens, em especial a TCFC, por tratar-se de uma tecnologia mais recente.

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Termo de Consentimento Livre e Esclarecido

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Prezado (a) Senhor (a),

Estamos realizando uma pesquisa que tem como objetivo comparar os planejamentos para implantes realizados a partir de radiografia panorâmica e tomografia computadorizada de feixe cônico. Por isto, estamos solicitando sua autorização para dispor de uma cópia digital de seus exames por imagens e dos dados das medidas clínicas do osso onde será colocado o implante.

Asseguramos que sua identidade será preservada, seus exames não sofrerão danos, que sua participação será por livre e espontânea vontade, não havendo benefício aos participantes, ou punição àqueles que não o fizerem. Os dados obtidos serão arquivados sob a supervisão do pesquisador principal Drª Heloísa Emília Dias da Silveira e a mesma se responsabiliza pela confidencialidade das informações. Caso queira entrar em contato com o pesquisador a qualquer momento para tirar dúvidas ou desistir de sua participação entre em contato com Letícia Ruhland Correa pelos telefones 48 8411-7010 ou 51 9850-1100.

Este trabalho está vinculado ao Comitê de Ética Central da UFRGS cujo contato se dá pelo telefone 51 3308-3629.

Autorizo a utilização dos meus exames de imagens: radiografia panorâmica e tomografia computadorizada de feixe cônico, assim como, dos dados das medidas clínicas do osso onde será colocado o implante, na pesquisa acima mencionada e em outras que sigam a mesma linha de pesquisa.

Porto Alegre,...

Paciente:...

Pesquisador:..

Aprovação no Comissão de Pesquisa – FO-UFRGS
Aprovação no Comitê de Ética - UFRGS