Anatomical and dimensional evaluation of the incisive canal in brazilians using cone-beam computed tomography

Avaliação anatômica e dimensional do canal incisivo em brasileiros por meio de tomografia computadorizada de feixe côncico

DOI: 10.54022/shsv3n3-021
Recebimento dos originais: 05/05/2022
Aceitação para publicação: 01/07/2022

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ABSTRACT
Objective: To evaluate the dimensions of the incisive canal (IC) and incisive foramen (IF) in dentate and maxillary anterior edentulous (MAE) individuals using cone-beam computed tomography (CBCT). Methods: This retrospective, cross-sectional study analyzed dentate and MAE individuals aged ≥ 50 years of both sexes. Using CBCT, we measured the buccal-palatal (BPW) and mesial-distal (MDW) widths of the IF and the length of the buccal cortical (BC) and palatal cortical (PC) bones and the angulation (A) of the IC in relation to the nasal floor. Results: 151 CBCT were analyzed, of which 74 were MAE and 77 dentate with a mean age of 63.3 ± 7.9 and 61.4 ± 9.3, respectively. Compared to the dentate group, the MAE group showed higher MDW of the IF (p = 0.034) and, in the IC, lower BC (p = 0.000), PC (p = 0.006), and A (p = 0.000). In the MAE individuals, the PC was higher in men when compared to women (p = 0.030). Conclusion: IC dimensions were smaller, MDW of the IF was greater in Brazilian MAE, and the PC was greater in male MAE, highlighting the importance of CBCT in planning, in the absence of maxillary anterior teeth.

Keywords: anatomy, cross-sectional, cone-beam computed tomography, jaw, edentulous, partially, maxilla, incisive canal.

RESUMO
Objetivo: Avaliar as dimensões do canal incisivo (CI) e do forame incisivo (IF) em indivíduos dentados e desdentados anteriores maxilares (MAE) usando tomografia computadorizada de feixe cônico (CBCT). Métodos: Este estudo retrospectivo, transversal, analisou indivíduos dentados e MAE com idade entre ≥ 50 anos de ambos os sexos. Usando a TCFC, medimos as larguras vestibulopalatal (PBW) e mesiodistal (MDW) do FI e o comprimento dos ossos corticais vestibulares (BC) e palatinos (PC) e a angulação (A) da IC em relação ao assoalho nasal. Resultados: 151 CBCT foram analisados, dos quais 74 eram MAE e 77 dentado com idade média de 63,3 ± 7,9 e 61,4 ± 9,3, respectivamente. Em comparação com o grupo dentado, o grupo MAE apresentou MDW mais alto do IF (p = 0,034) e, no CI, BC mais baixo (p = 0,000), PC (p = 0,006), e A (p = 0,000). Nos indivíduos do MAE, o PC era mais alto nos homens quando comparado com as mulheres (p = 0,030). Conclusão: As dimensões do CI eram menores, o MDW do IF era maior no MAE brasileiro, e o PC era maior no MAE.
masculino, destacando a importância da TCFC no planejamento, na ausência dos dentes anteriores maxilares.

**Palavras-chave:** anatomia, transversal, tomografia computadorizada de feixe côncico, mandíbula, desdentada, parcial, maxila, canal incisivo.

**1 INTRODUCTION**

The anatomical structures that compose the anterior region of the maxilla include the incisive canal (IC), canalis sinuosus, accessory foramina, and the nasal cavities. Among these structures, the IC, nasopalatine canal or anterior palatine canal (Kikuta et al., 2019), stands out as the connection between the nasal and oral cavities (Gönül et al., 2016; Görürgöz, Öztaş, 2021; Kim et al., 2017). Several surgical procedures are performed in the maxillary anterior region (Bornstein et al., 2011; Walter et al., 2009), therefore, it is important to know the anatomy of the IC and its adjacent structures.

The IC is a long and thin structure, surrounded by thick cortical bone, and located in the midline of the palate, in the premaxilla region, posteriorly to the roots of the upper central incisors (Görürgöz, Öztaş, 2021; Thakur et al., 2013; Soumya et al., 2019). The upper opening of the IC has two openings divided by the nasal septum, known as the nasopalatine foramen. The inferior opening in the anterior palate is called incisive foramen (IF) (Kikuta et al., 2019; Görürgöz, Öztaş, 2021; Soumya et al., 2019; Al-Amery et al., 2015). The IC connects the floor of the nasal cavity with the anterior hard palate, allowing a vascular nerve bundle to vascularize and innervate those structures. The sphenopalatine artery and the nasopalatine nerve pass within the IC and reach the anterior region of the hard palate so as to anastomose with the artery and the greater palatine nerve, respectively. The adipose tissue, connective tissue, and minor salivary glands are also found along the IC (Görürgöz, Öztaş, 2021; Al-Amery et al., 2015).

Factors such as age, sex, trauma, ethnicity, and tooth loss may anatomically alter the IC (Thakur et al., 2013; Gil-Marques et al., 2020; Güncü et al., 2013). Among these factors, tooth loss is the most significant, because as the resorption of the alveolar ridge evolves, the anatomical location of the IC can be modified. In this case, the risk of surgical complications is higher; therefore, complementing the therapeutic planning with cone-beam computed tomography (CBCT) is
recommended (Soumya et al., 2019; Mardinger et al., 2008). CBCT allows a cross-sectional and three-dimensional analysis with undistorted, high-quality images and it is thereby considered the gold standard to expose, confirm, classify, define, and locate anatomical variations (Friedrich et al., 2015; Wright, Bidra, Kuo, 2020).

Thus, it is important to investigate the use of CBCT, associated with knowledge of the anatomy and the dimensional variations of the IC and IF, to have a better predictability in the therapeutic planning of the premaxilla region in the absence of anterior teeth and, this way, prevent possible complications in that area (Görürgöz, Öztaş, 2021).

The objective of this study was to evaluate the anatomical and dimensional variations of the IC and IF using CBCT in Brazilians aged 50 years or older, dentate and maxillary anterior edentulous (MAE), and the differences between sexes.

2 MATERIALS AND METHODS
2.1 SAMPLE SELECTION

This study was approved by the Ethics Committee in Research of our University with the number 2.449.545. Due to the retrospective nature of the study, the requirement for written informed consent was waived.

This retrospective, cross-sectional study used images of Brazilian individuals aged 50 years or older, dentate and MAE, of both sexes who underwent CBCT examinations at UFPR's dental radiology service. In the MAE individuals, the four incisors were absent.

The CBCT scans included in the sample were those with high quality and undistorted image definition, without signs of syndromes, diseases with bone repercussion, nasopalatine duct cyst, tumors in the premaxilla region, maldevelopment of the maxilla, or indications of recent dental extraction, implants in the upper central region, and presence of stabilization plates and pins in the anterior region of the maxilla.

The linear correlation test was used for sample calculation (Sakpal, 2020). The minimum sample size was calculated considering an alpha error of 5% and test power of 85%. After linear correlation analysis, the correlation coefficient for the variables analyzed was 1.99, resulting in a sample of 75 individuals for each group.
2.2 IMAGE ACQUISITION

The CBCT scans were obtained by the same experienced radiology technician, using iCAT Next Generation machines (Imaging Sciences International, Hatfield, Pennsylvania, USA) with the following exposure regime: field of view (FOV) of 16 cm X 13 cm; resolution: 0.25 voxel size; 20 mA; 120 kV; scan time: 26.9 seconds. The scans were archived in the image bank of the Imaging Teaching and Research Laboratory of UFPR’s Dentistry Course.

2.3 CALIBRATION

The examiner researcher was trained and calibrated by an expert professional in CBCT imaging. For the calibration process, the measurement criteria were established based on the study by Al-Amery et al. (2015).

The original DICOM files of the scans were imported into InVesalius™ 3.1.1 Software (©2007-2012 Centro da Tecnologia e da Informação Renato Archer — CTI). The examiner standardized some image parameters using the “brightness and contrast” tool. In the “bone” option, masking was performed using the segmentation tool in the first axial section in which was possible to observe the total cortical contour of the IF. The head rotation was adjusted so that the cortical bone of the palate was parallel to the ground.

Ideal standardized sections from each CBCT image of the dentate and MAE individuals were evaluated for the diameter of the incisive foramen: the buccal-palatal width (BPW) and the mesial-distal width (MDW). In the IC, the buccal cortical (BC), palatal cortical (PC), and angulation (A) were measured.

The examiner was calibrated for the variables related to the diameter of the IF (BPW and MDW) and the dimensions of the IC (BC, PC, and A) and the intraclass correlation coefficient (ICC) values were: 0.93 (BPW), 0.91 (MDW), 0.98 (BC), 0.95 (PC), and 0.97 (A). All values indicated optimal agreement (Landis, Koch, 1977), considering the 5% level of agreement, analyzed in the SPSS® Software (v. 20.00 for Windows, IBM Corporation, Sommers, NY).

2.4 IMAGE ANALYSIS AND MEASUREMENT

2.4.1 Incisive foramen

The diameter of the IF in dentate and MAE was measured using the largest
measurement obtained in the vestibular-palatal direction (Fig 1: A) and mesial-distal direction (Fig 1: B) on the axial section at the height where it was possible to observe the full cortical contour of the IF.

Fig. 1 Cone-beam computed tomography images in the axial section, showing measurements of (A) buccal-palatal (BPW) and mesial-distal (MDW) widths of the incisive foramen (IF).

Source: the authors.

2.5 INCISIVE CANAL

The BC and PC cortical thickness were measured from the opening of the IF to the opening of the nasal floor canal on the sagittal section (Fig. 2: A).

Fig. 2 Cone-beam computed tomography images, the sagittal section showing length measurements of the buccal cortical (BC) and palatal cortical (PC) bones and the angulation (A) of the incisive canal (IC) in relation to the nasal floor.

Source: the authors.

In the same section, to obtain the angulation of the IC (Fig. 2: B), a line parallel to the cortices of this canal was drawn through the center of the structure, and another one passing through the anterior and posterior nasal spine, determining the floor of the nasal cavity. The angle used was formed by these two lines. The measurements followed the same standard used in the calibration.

Three measurements for each variable were performed and their mean was considered for statistical purposes. The Shapiro-Wilk test was applied to assess the normality of the data. The Mann-Whitney test was used for the BPW, MDW,
and A variables, and the One-Way ANOVA test for the BC and PC. The significance level adopted was 5% for all analyses.

3 RESULTS

The study sample consisted of 151 patients, of which 77 were dentate and 74 were MAE, with a mean age and standard deviation of $61.4 \pm 9.02$ and $63.3 \pm 7.94$ years, respectively. In the dentate group, 53% were female and 47% were male. In the group of MAE individuals, 58% were female and 42% were male.

There was a statistically significant difference for the following variables evaluated between dentate and MAE (Table 1): MDW of IF and BC, PC, and A of IC. The value of the MDW variable was higher in the MAE group, whereas the BC, PC, and A values were lower in this group. The PC was higher ($p = 0.030$) in male MAE individuals when compared to female MAE individuals (Table 2).

Table 1: Measurements of IC and IF dimensions in dentate and MAE individuals.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dentate (n = 77)</th>
<th>MAE (n = 74)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPW (mm)</td>
<td>$4.60 \pm 1.15$</td>
<td>$4.86 \pm 1.42$</td>
<td>0.301</td>
</tr>
<tr>
<td>MDW (mm)</td>
<td>$4.38 \pm 1.42$</td>
<td>$4.80 \pm 1.44^*$</td>
<td>0.034</td>
</tr>
<tr>
<td>BC (mm)</td>
<td>$23.14 \pm 4.36^*$</td>
<td>$18.34 \pm 4.63$</td>
<td>0.000</td>
</tr>
<tr>
<td>PC (mm)</td>
<td>$12.49 \pm 3.20^*$</td>
<td>$11.08 \pm 3.00$</td>
<td>0.006</td>
</tr>
<tr>
<td>A (°)</td>
<td>$74.64° \pm 9.46$</td>
<td>$66.08° \pm 10.53^*$</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Mann-Whitney test ($p \leq 0.05$); *Statistically significant difference

$M$ - mean, $SD$ - standard deviation, $BPW$ - buccal-palatal width, $MDW$ - mesial-distal width, $PC$ - palatal bone plate length, $BC$ - buccal bone plate length, and $A$ - angulation.

Source: the authors.
### Table 2: Measurements of the IC dimensions in dentate and MAE individuals, according to sex.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dentate</th>
<th>MAE</th>
<th>p value</th>
<th>Dentate</th>
<th>MAE</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Women (n = 41)</td>
<td>Men (n = 36)</td>
<td></td>
<td>Women (n = 43)</td>
<td>Men (n = 31)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M ± SD</td>
<td>M ± SD</td>
<td></td>
<td>M ± SD</td>
<td>M ± SD</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>60.8 ± 10.01</td>
<td>62.1 ± 7.82</td>
<td>-</td>
<td>63.4 ± (8.94)</td>
<td>63.1 ± (6.46)</td>
<td>-</td>
</tr>
<tr>
<td>BPW (mm)</td>
<td>4.37 ± 0.76</td>
<td>4.87 ± 1.44</td>
<td>0.236</td>
<td>4.57 ± (1.19)</td>
<td>5.25 ± (1.63)</td>
<td>0.082</td>
</tr>
<tr>
<td>MDW (mm)</td>
<td>4.05 ± 0.80</td>
<td>4.76 ± 1.82</td>
<td>0.131</td>
<td>4.73 ± (1.10)</td>
<td>4.89 ± (1.83)</td>
<td>0.848</td>
</tr>
<tr>
<td>BC (mm)</td>
<td>23.14 ± 3.88</td>
<td>23.14 ± 4.91</td>
<td>1.00</td>
<td>18.16 ± (4.55)</td>
<td>18.58 ± (4.79)</td>
<td>0.703</td>
</tr>
<tr>
<td>PC (mm)</td>
<td>11.97 ± 2.45</td>
<td>13.07 ± (3.83)</td>
<td>0.133</td>
<td>10.45 ± (2.75)*</td>
<td>11.97 ± (3.16)*</td>
<td>0.030</td>
</tr>
<tr>
<td>A (°)</td>
<td>73.90° ± 11.11</td>
<td>75.49° ± (7.22)</td>
<td>0.467</td>
<td>64.61° ± (10.29)</td>
<td>68.13° ± (10.69)</td>
<td>0.158</td>
</tr>
</tbody>
</table>

*Mann-Whitney test (p ≤ 0.05); One-Way ANOVA test (p ≤ 0.05); *Statistically significant difference.

M - mean, SD - standard deviation, MAE - maxillary anterior edentulous, BPW - buccal-palatal width, MDW - mesial-distal width, PC - palatal bone plate length, BC - buccal bone plate length, and A - angulation.

Source: the authors.

## 4 DISCUSSION

This study has demonstrated that MAE Brazilians aged 50 years or older presented decreased dimensions of the IC and increased MDW in the IF. MAE women presented a smaller PC than men.

The present study considered the measurement of the two bone cortices that compose the IC (PC and BC), while other studies have considered only the measurement of the PC (Thakur et al., 2013; Al-Amery et al., 2015; Costa et al., 2019). Bone resorption occurs in different ways in both walls (Botticelli, Berglundh, Lindhe, 2004; Araújo, Lindhe, 2005), which justifies measuring the two bone cortices. Some studies have demonstrated a reduction of the IC’s palatal cortical bone after incisor loss (Bornstein et al., 2011; Mardinger et al., 2008). This detailed analysis helps dental and maxillofacial surgeons to safely proceed in this region — through which neurovascular structures pass — in order to avoid injuries during dental procedures in MAE individuals.

The MDW of the IF was higher in the MAE group compared to the dentate group in this study. This result corroborates the results of previous studies in Lebanese (Kajan et al., 2015) and Spanish (Gil-Marques et al., 2020) populations of dentate and MAE from the same age group and of the study conducted in MAE in Israel by Mardinger et al. (2008). There was no statistically significant difference
in the BPW dimension between dentate and MAE individuals, which is also shown in the study by Gil-Marques et al. (2019). However, the results of the mean diameter of the IF in MAE (BPW) obtained in our study were similar to the results obtained previously by Gönül et al. (2016), Bornstein et al. (2011), and López Jornet et al. (2015).

Costa et al. (2019) presented a study evaluating the influence of the facial profile and age on IC morphology in the Brazilian population. They concluded that the IC was not influenced by the facial profile, but exhibited an increase in volume with aging, especially after 50 years of age (Costa et al., 2019), confirming the results of the present study.

In our study, the mean IC length, considering only the palatal cortical bone, was shorter in MAE individuals analyzed by CBCT and, therefore, similar to the values found in other studies (Al-Amery et al., 2015; Günkü et al., 2013; Mardinger et al., 2008; Friedrich et al., 2015; Jornet et al., 2015; Tözüm et al., 2012; Khojastepour, Haghnegahdar, Keshtkar, 2017). In the study by Görürgöz and Öztaş (2020) (Görürgöz et al., 2021), although not statistically significant, the IC length was also shorter in the group of edentulous individuals.

In the study by Mardinger et al. 2008, the IC length was 10.7 mm in the group of individuals with complete dentition in the premaxillary region and 9 mm in the group with a higher degree of ridge resorption, indicating a decrease in the length of the canal with tooth loss. This corroborates our study, which indicated that the IC length (BC and PC) was shorter in MAE individuals.

The angulation of the IC in dentate individuals was greater than in the MAE group, suggesting a decrease in angulation of the IC as the resorption of the alveolar ridge evolves in the absence of maxillary anterior teeth. These results disagree with the results found by Panjnoush et al. (2016), which found no differences between the angulation of the dentate and edentulous groups. However, the measurement method did not determine a specific fixed point on the palate, compromising the measurement’s accuracy. The present study also demonstrated a positive correlation with the findings that suggest exposure of the incisive foramen in edentulous buccal ridge due to the decrease in angulation of the IC (Mardinger, et al., 2008).

In this study, the PC was greater in male MAE individuals when compared
to female MAE individuals, similar to the study by Hakkilen and Magat (2018), who observed that sex affected the length of the IC, as well as a number of studies that point out that the mean length of the IC was greater in men than in women (Gönül et al., 2016; Görür göz et al., 2021; Al-Amery et al., 2015; Khojastepour et al., 2017; Nasseh, Aoun, Sokhn, 2017; Etoz, Sisman, 2014). These results can be attributed to skeletal sexual dimorphism, which can be affected by ages (Smith et al., 2021).

In the field of research related to the anatomy and dimension of the IC, it is necessary to consider that there is a wide variability of results inherent to the populations evaluated, methodologies for measuring and analyzing anatomical structures using different softwares, and configuration of CBCT scanners used in the acquisition of images. All these factors interfere with the results and comparison with previous studies. However, this information is useful in dental procedures, especially in MAE, regarding local anesthesia of the anterior maxilla and dental implant planning and other surgical procedures such as dental extraction of impacted teeth, cyst enucleation, and apical root resection (Gil-Marques et al., 2020; Mardinger et al., 2008).

The results of this study provide important information about the dimensional differences of the IC, highlighting the homogeneity of the sample analyzed regarding the reference points of the analyses and obtaining accurate comparisons. Furthermore, the study was of notable importance, given the small number of studies to date on the anatomical and dimensional variations of the IC and IF in dentate and MAE Brazilians over 50 years of age. Thus, according to this study, therapeutic planning of the anterior region of the maxilla requires greater attention in individuals in this age group.

CBCT, which is a diagnostic method that assists in determining the location and dimensions of the anatomical structures of the IF and IC in individuals with maxillary edentulousness, can be used and is recommended prior to any surgical procedure in order to avoid possible complications arising from dimensional variations in this region. This is in line with the statement by Soumya et al. (2019) that careful evaluation and planning with the aid of CBCT can help in the diagnosis of anatomical deficiencies and difficulties and are necessary before immediate implant placement in the anterior region of the maxilla.
5 CONCLUSION

It is concluded, within the limitations of this study, that the dimensions of the buccal and palatal bone cortices, as well as the diameter of the IF (MDW), differ between the sample of dentate and MAE Brazilians. The dimensions of the IC were smaller and the MDW of the IF was greater in Brazilian MAE. MAE women presented a smaller PC than men. Thus, it was possible to demonstrate in this study that factors such as tooth loss, age, and sex can influence the anatomy and dimensions of the IC and IF and to emphasize the importance of CBCT in therapeutic planning in the absence of incisors to avoid damage to the neurovascular bundle that runs through the IC.

ACKNOWLEDGMENTS

The authors would like to thank the Academic Publishing Advisory Center (Centro de Assessoria de Publicação Acadêmica, CAPA – www.capa.ufpr.br) in partnership with UEL for assistance with English language translation and developmental editing.
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