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Publication status: This preprint has not been published elsewhere.

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https://doi.org/10.1590/SciELOPreprints.18847

Submitted on: 2026-11-10
Posted on: 2026-11-10 (version 1)
(YYYY-MM-DD)

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e20260024

Original Article

Retrospective cross-sectional study of the lingual concavity of the mandible using cone-beam computed tomography

Estudo transversal retrospectivo da concavidade lingual da mandíbula utilizando tomografia computadorizada de feixe cônico

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How to cite:

Tonini KR, Valle LSEMB, Sol I, Hadad H, Salzedas LM, Ponzoni D. Retrospective cross-sectional study of the lingual concavity of the mandible using cone-beam computed tomography. Rev Odontol UNESP. 2026;55:e20260024. https://doi.org/

Resumo

Introdução: A concavidade lingual e o nervo alveolar inferior são fatores que dificultam a colocação de implantes na região posterior da mandíbula. O conhecimento dessas estruturas pode evitar complicações cirúrgicas. **Objetivo:** O objetivo deste estudo foi analisar e correlacionar características anatômicas de mandíbulas posteriores parcialmente edêntulas utilizando tomografias computadorizadas de feixe cônico das hemimandíbulas a 5, 10 e 15 mm posteriores ao forame mentoniano. **Material e método:** Foram utilizados exames de hemimandíbulas de 39 pacientes (12 homens e 27 mulheres). Os fatores analisados foram: espessura óssea 2 mm acima do canal alveolar inferior (Espessura A), espessura óssea 2 mm abaixo da crista alveolar (Espessura B), angulação e profundidade da concavidade lingual, altura mandibular e formato mandibular (U, C ou P). **Resultado:** A espessura A (P = 0,5355), a espessura B (P = 0,2353), o ângulo de concavidade (P = 0,9806) e a profundidade (P = 0,4977) foram semelhantes em ambos os

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sexos. A altura apresentou valores maiores e significativos em homens (P = 0,0099). O formato em C foi o mais frequente (55%), seguido pelo U (25,0%) e pelo P (20,0%). **Conclusão:** A concavidade lingual foi mais evidente em 25% das tomografias computadorizadas analisadas (formato em U). A altura da mandíbula posterior foi maior nos homens. A espessura e a profundidade das áreas mandibulares posteriores não variaram de acordo com o sexo.

Descritores: Implantes dentários; mandíbula; anatomia comparativa; procedimentos cirúrgicos operatórios.

Abstract

Introduction: The curved shape of the mandible, the lingual concavity and the inferior alveolar nerve are factors that make implant placement difficult in the posterior mandibular region. The knowledge of these structures can help avoid surgical complications. **Objective:** The aim of this study was to analyze and correlate anatomical features of partially edentulous posterior mandibles using cone-beam computed tomography images of the hemimandibles at 5, 10, and 15mm posterior to the mental foramen. **Material and method:** A total of 39 hemimandible specimens from 12 male and 27 female patients were used. The factors analyzed were bone thickness 2mm above the inferior alveolar canal (Thickness A), bone thickness 2mm below the alveolar crest (Thickness B), angulation and depth of the lingual concavity, mandibular height, and mandibular shape (U, C, or P). **Result:** Thickness A (P = 0.5355), thickness B (P = 0.2353), concavity angle (P = 0.9806) and depth (P =0.4977) were similar in both sexes. Height showed higher and statistically significant values in male population (P = 0.0099). The C shape was the most frequent (55%), followed by U (25.0%) and P (20.0%). **Conclusion:** The U-shaped mandibular morphology was observed in 25% of the sample.

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Posterior mandibular height was greater in males. The thickness and depth of the posterior mandibular areas did not vary according to sex.

Descriptors: Dental implants; mandible; anatomy, comparative; surgical procedures, operative.

INTRODUCTION

Due to their high success rate, dental implants have become a routine procedure in dental practice[1]. Successful implant placement, with adequate primary stability, requires accurate planning and assessment of the available bone quality. Therefore, imaging examination is essential for evaluating the anatomical structures and bone available for implant placement.[2]. Among these, cone beam computed tomography (CBCT) enables three-dimensional visualization of the anatomical structures of the mandible [3].

Failure to account for anatomical limitations during the placement of mandibular dental implants can result in significant surgical complications or damage to vital structures[2]. The posterior region of the mandible presents a challenge for successful implant placement due to the positioning of the inferior alveolar canal and the lingual concavity, which houses the submandibular gland[2,3]. These anatomical factors may limit the available bone volume, potentially leading to injury of the inferior alveolar nerve or perforation of the lingual cortical bone during implant surgery[1,4-6].

Inadvertent instrumentation of the lingual cortical bone of the mandible may cause arterial injury, leading to a sublingual or submandibular hematoma or infection[6,7]. Puncturing an artery with a 2.0 mm diameter with a blood flow of 0.2 mL per beat can cause profuse bleeding, resulting in a blood loss of 420 mL over 30 minutes[8-11].

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Consequently, upper airway obstruction can occur, requiring urgent medical intervention[1].

The curved shape of the mandible, the lingual concavity, and the inferior alveolar nerve are factors that complicate implant placement in the mandibular molar region and may increase surgical duration[12]. These factors require more attention, planning, and angulation during osteotomy preparation for the implant to avoid perforating of the lingual cortical plate and compromising bone stability[12,13].

CBCT is usually performed after tooth extraction and before implant placement to assess the bone volume and regional morphology [9,14]. It serves as an important planning tool when immediate implant placement in the posterior region of the mandible is being considered[15-17]. Additionally, CBCT provides valuable information about the mandibular shape. The UCP classification, based on the cross-sectional shape of the mandible, facilitates clinical practice. Type U refers to cases where the alveolar bone crest is wider than the base of the mandible; type C describes cases where the lingual and buccal surfaces converge; and type P refers to cases where the lingual and buccal surfaces are parallel[12]. The depth and angle of the concavity tend to be greater in U-shaped mandibles.

Currently, CBCT is integrated with CAD/CAM software, allowing for superimposition with digital models and the fabrication of customized surgical guides. This offers advantages such as three-dimensional visualization of lingual concavities, simulation of the ideal implant position, and a reduced risk of perforation and complications. The current trend in implant dentistry is an increasing reliance on digital workflows, which enhances the predictability and safety of procedures. However, this technology remains out of reach for the majority of the Brazilian population, as it adds to treatment costs[18,19].

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Given the extensive racial and ethnic admixture that characterizes the Brazilian population, the aim of this study was to analyze and correlate the anatomical characteristics of the posterior mandible, including lingual concavity, bone height, and bone thickness, in this population. Specifically, the study aimed to evaluate whether these anatomical characteristics differ between sexes and to determine the prevalence of different mandibular shapes in the posterior region. These findings may provide clinicians with information to help prevent complications and develop safe treatment plans in implant dentistry. The study hypothesized that the depth of the lingual concavity varies according to mandibular shape and sex in the posterior region.

MATERIAL AND METHOD

Research design

This is a retrospective, observational cross-sectional study, conducted in accordance with the STROBE guideline. CBCT images obtained using the CBCT - SCANORA 3Dx® (3DMax, Soredex, Helsinki, Tusula, Finland) were analyzed. These images were provided by the Radiology Center of the School of Dentistry, Araçatuba, São Paulo. This study was approved by the local Human Research Ethics Committee (54192421.1.0000.5420). Informed consent was obtained for all records to confirm patient participation for retrospective use of data.

The CBCT used in this study had been requested for implant treatment planning or trauma - related purposes between 2013 and 2019. Only CBCT of partially edentulous patients in the posterior region (particularly the area of the missing lower first molar), with a minimum bone height of 10 mm (from the alveolar crest to the upper edge of the inferior alveolar nerve) and a minimum bone thickness of 5.0 mm for implant anchorage were included. CBCT associated with intraosseous pathology in the region of interest, of

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patients under 18 years of age, maxillary exams, total edentulous patients, and unclear images of the mandibular canal were excluded. The sample size was estimated a priori for comparing two means using G*Power software (v. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). Based on a previous study by Watanabe et al.[13] (2010), the horizontal length from lingual cortex to the buccal cortex to 2 mm above the mandibular canal was 14.0 ± 1.8 mm (M) and 12.8 ± 1.5 mm (F). To achieve a statistical power of 0.80 with a significance level of 5% (two-tailed hypothesis) and an effect size of 1.20 for the evaluation of two independent groups, the minimum recommended sample size per group was n=12.

Selection and evaluation of cross-sectional images

The images were acquired using the SCANORA 3Dx® CBCT system. (3DMax, Soredex, Helsinki, Tusula, Finland), with the following acquisition protocol: 8×10cm field of view (FOV), high resolution, 0,15 mm voxel size, and 90kVp, 10mA, focal spot 0,5 mm. The density and contrast adjusted used a pattern predetermined with 900 Window Width e 400 Window Level. Based on a previous study by de Souza et al.[3] (2016), reconstructions of parasagittal sections were made with 1 mm thickness and without spacing between sections. For image analysis, the reference adopted was the axial section in which the mental foramina from both sides appeared jointly. In relation to the median sagittal plane, the reference line should have passed between the lower central incisors, parallel to the long axis of these teeth. A parabola was drawn from the center of the ridge in the axial section defined above, defining the parasagittal sections. 3 Images were analyzed using implant planning software (OnDemand 3D®, Cybermed Inc. USA). The region of interest extended from the occlusal plane to the inferior edge of the mandible[12]. All morphological assessments and measurements were performed by a calibrated

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examiner. To ensure data reliability and rater calibration, repeated measurements were performed with a 4-week interval, yielding an intraclass correlation coefficient of 0.8 and a Kappa coefficient of 0.7.

From the distal margin of the mental foramen, three cross-sections of the posterior region of the mandible were selected: 5 mm, 10 mm and 15 mm^3. The evaluated region extended from the alveolar bone crest to 2 mm above the upper edge of the mandibular canal, as the general recommendation is to place the implant at least 1.5 mm above it [20]. In each cross-section, the following lingual concavity characteristics [12] were analyzed (Figure 1):

- Thickness A: length of a horizontal line, 2 mm above the mandibular canal, from the lingual cortex to the buccal cortex.
- Thickness B: horizontal thickness, 2 mm below the bone crest from the buccal cortex to the lingual cortex.
- Point P: the most prominent point of the lingual aspect of the mandible.
- Point A: intersection between the Thickness A line and the lingual aspect of the mandible.
- Line B: line drawn from point P to point A.
- Depth: horizontal distance between point A and point P.
- Angle: measured from the triangle formed between line B and Depth.
- Height: distance from the alveolar bone crest to 2 mm above the mandibular canal.

All these factors were compared using the three cross-sectional images of 5 mm, 10 mm and 15 mm distances from the mental foramen. The angle and lingual concavity are inversely proportional; that is a greater angle corresponds to a shallower lingual concavity, while a smaller angle results in a deeper lingual concavity. The differences between the presence of lingual concavity and the mandibular shapes were compared

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using the 10 mm cross-sectional images, corresponding to a geometric approximation of the mandibular first molar position in the posterior region.

Assessment of the shape and transverse mandibular inclination

From the selected cross-sections, three types of mandibular shape and inclination were determined based on the following criteria[12] (Figure 2):

1) Type C: when the walls of the lingual and buccal surfaces converge, Thickness A is greater than Thickness B.

2) Type P: when the walls of the lingual and buccal surfaces are parallel, Thickness A and Thickness B are similar.

3) Type U: when the alveolar bone crest is wider than the base of the mandible, creating a more prominent Point P on the lingual surface, Thickness B is greater than Thickness A.

Statistical analysis

The collected data was organized and analyzed using Prism software. Data normality was assessed using the Shapiro-Wilk test. For each outcome (thickness A, thickness B, height, angle, and depth), differences between males and females were assessed using an unpaired Student's t-test for parametric data or the Mann-Whitney U test for non-parametric data.

To assess differences in mandibular shape and foraminal distance among the groups for each outcome (thickness A, thickness B, height, angle, and depth), one-way ANOVA followed by Tukey's post hoc test was performed for parametric data, whereas the Kruskal-Wallis test followed by Dunn's multiple comparisons test was used for non-parametric data.

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RESULT

A total of 852 CBCT scans performed between 2013 and 2019 were analyzed, of which only 39 were included in the study. The remaining 813 were excluded for the following reasons: 140 were from individuals under 18 years of age, 164 were maxillary CBCT, 124 belonged to totally edentulous patients, 68 showed lesions in the area, and 317 had unclear images of the mandibular canal.

Of the 39 CT scans selected, 27 from female patients and 12 from male patients, with a mean age of 52.79 ± 2.1 years. One hemimandible was analyzed from each examination (Figure 3).

The analyzed characteristics of the posterior region of the mandible are presented in Table 1. Thickness A (P = 0.5355), thickness B (P = 0.2353), concavity angle (P = 0.9806) and depth (P = 0.4977) were similar in both sexes. The male population showed higher and statistically significant values compared to the female population in height (P = 0.0099).

Table 1: Anatomical characteristics of the mandibular lingual concavity analyzed in the study: Thickness A, Thickness B, angle, depth and height

	n	**Thickness A (mm)**	**Thickness B (mm)**	**Concavity Angle (°)**	**Concavity Depth (mm)**	**Height (mm)**
Total, mean, ±SD	39	10.95 ±2.01	8.88 ±3.07	60.86 ±23.21	4.76 ±10.15	14.20 ±3.43
Female	27	11.11 ±1.80	8.49 ±3.03	60.78 ±19.09	3.15 ±2.27	13.14 ±2.71
Male	12	10.60 ±2.47	9.79 ±3.04	61.03 ±31.86	8.51 ±18.19	16.66 ±3.77
-value		P=0.535	P=0.235	P=0.980	P = 0.497	P=0.009

SD - standard deviation; mm – millimetres; ° - degrees

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The most frequent mandibular shape was found in Type C (55.0%), followed by Type U (25.0%) and Type P (20.0%), both in the overall sample and according to gender (Figure 4).

Comparison of factors

The comparison between the mandibular shapes and the different cross-sectional images can be observed in Figure 5. Regarding Thickness B, significant differences were found between U-shape and C-shape at distances of 5, 10, and 15 mm (P = 0.0277, P = 0.0074, and P = 0.0113, respectively). Thickness B also showed a significant difference between formats C-shape and P-shape at 10 mm (P = 0.0092).

Mandibular thickness near the alveolar crest tended to increase slightly in the posterior direction, particularly between 5 and 10 mm. Two-way ANOVA revealed significant main effects of shape for depth (P = 0.0455) and height (P = 0.0197). However, post hoc Tukey's multiple comparisons test did not identify statistically significant differences between individual groups. In contrast, angle showed no statistically significant differences among mandibular shapes (P = 0.293; Figure 5).

DISCUSSION

Reverse planning is crucial for dental implant treatment, enhancing the predictability of rehabilitation outcomes. Bone morphology assessments rely on imaging exams, and in patients with atrophic jaws, key anatomical structures are located near the floor of the mouth, making them vulnerable to injury. Surgical planning must be particularly meticulous due to the presence of muscle attachments, a highly vascularized region, and the submandibular gland[12].

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Preoperative CT scans help assess the risk of injury to the inferior alveolar nerve and perforation of the lingual cortical bone during implant placement. Cross-sectional imaging has also been recommended to evaluate potential implant sites[21]. Identifying anatomical constraints during planning increases surgeon's confidence in manipulating tissues, ensuring safer restoration form, function, health, and esthetics[22,23].

For years, implantology has relied on visual and clinical methods, such as palpation and plaster models, to directly evaluate the mandible's lingual region. However, imaging techniques such as CBCT provide an accurate, non-invasive examination [3]. This technology allows three-dimensional visualization of structures without overlaps, distortions, or magnifications inherent in conventional radiographic methods, especially to identify the lingual concavity[3,15,21]. Chan et al.[11] note that only parasagittal tomographic sections effectively assess the depth of the lingual concavity[12]. More recently, digital planning associated with guided surgery has made implant dentistry more predictable. This technology involves high-precision surgical and prosthetic planning and has reduced the risk of lingual cortical plate perforation in the posterior mandible[18,19]. Although requesting computed tomography scans and digital planning prior to implant procedures may be becoming routine, limited availability and high costs can still hinder their widespread use.

This study analyzed the morphology and the degree of inclination of the lingual concavity in the local population, aiming to classify the mandible according to the U, C and P shapes[12] and determine the percentage of mandibles with evident lingual concavity. Additionally, the depth and inclination of the lingual concavity, the height and thickness of the mandible 2 mm above the mandibular canal were evaluated.

de Souza et al.[3] found statistically significant differences in the depth of the lingual concavity at sections 5 and 10 mm posterior to the mental foramen.[3,12.] In contrast, the

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present study evaluated whether the depth of the lingual concavity differed according to the mandibular shape (Types U, C, and P) at cross-sectional distances of 5, 10, and 15 mm. No statistically significant differences were found among the mandibular shapes at any of the evaluated distances. Additionally, the presence of the mandibular canal was mandatory in all CT scans analyzed to increase the study's reliability, unlike in the study by de Souza et al.[3].

The lingual concavity of the mandible varies according to the mandibular shape (U, C, or P), with the C-shape being the most frequent, followed by U and P. The depth and angle of the concavity are generally greater in U-shaped mandibles, which increases the risk of lingual perforation during procedures whereas C-shaped mandibles present softer contours.

Watanabe et al. [13] (2010) investigated the Japanese population and reported the C-shape as the most frequent (59–61%), followed by A-shape (concave, with lingual concavity - 36–39%), which would correspond to the U-shape in our study. Chan et al. [11] (2011) reported 16.6% of the jaws as U-shaped. de Souza et al.[3] studied the Brazilian population and found 25.1% to have the U-shape. In our study, 25% of the posterior mandibles were U-shaped. Furthermore, Watanabe et al.[13] (2010) concluded that posterior mandibular height was significantly greater in men than in women, which is consistent with our findings.

This discrepancy in the of lingual concavities prevalence may be attributed to ethnic differences among populations studied, including Japanese[13], Caucasian, and African American[12] populations, compared to a Brazilian population with a diverse mix of indigenous, African, Oriental, European and Asian ethnicities.

Mandibular shape and the depth of the lingual concavity require special attention during implant placement due to the risk of perforating the lingual cortical bone. Studies

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report an increase of up to 31% in the risk of lingual cortical perforation in the mandibular first and second molar regions following immediate implant placement. In the present study, the mean linear depth of the mandibles was 3.15 mm for females and 8.51 mm for males, with no statistically significant difference (P = 0.497). No variation in depth was observed in the anteroposterior direction across the different mandibular shapes. Yildiz et al. [2] (2015) suggested that for lingual concavities ranging from 1.1 to 4.6 mm, a smaller-diameter implant with a tapered design or angled insertion should be used to avoid potential damage to vital structures. One way to prevent such perforation is through virtual planning of the implant angulation. In general, implant systems allow for prosthetic angulation corrections of up to 30 degrees.

Accidental perforation of the lingual aspect of the mandible creates an undesired situation for both the dentist and the patient, but it can be avoided[12]. Even if perforation of the lingual aspect of the posterior mandible does not immediately cause hemorrhage or nerve damage, the implant involved can lead to persistent pain, inflammation, or infection. Infections may progress to deep cervical spaces, causing more severe complications such as mediastinitis and upper airway obstruction[1]. The findings on the prevalence, position, and extent of the lingual concavity in this study may provide additional information for the safe placement of implants in the posterior region of the mandible.

In the study by Froum et al.[17] (2010), it was reported that 7% of mandibular second premolars, 9% of mandibular first molars, and 31% of mandibular second molars presented a high risk of lingual perforation when immediate implants were used. A higher risk was reported in the mandibular second molar region and with larger diameter implants. The authors highlight the risk of serious clinical complications, such as

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hemorrhage and infection, that could be life-threatening to the patient if the perforation is not diagnosed during implant placement.

Bone thickness is also a critical factor in surgical planning. In this study, the mean Thickness B was 8.49 mm for females and 9.79 mm for males; this difference was not statistically significant (P = 0.235). However, a difference in Thickness B was observed between U- and C-shaped mandibles—an anatomically expected finding, given that the C-shaped mandible exhibits converging surfaces as they approach the bone crest. Chan et al.[11] reported results similar to ours. Mandibular thickness near the crest (Thickness B) increases slightly as the bone sections progress posteriorly, regardless of the mandibular shape.

The study's limitations can be identified by the sample size relative to the cited international studies and the single-center nature of the sample assessment. The disparity in the number of participants between the sexes may limit the robustness of the analyses. The authors acknowledge this sample imbalance as a study limitation and discuss its potential impact on the interpretation of the results. However, they highlight the strict criteria used for selecting the scans, which resulted in the exclusion of a significant portion of the computed tomography scans performed during the period. The strict eligibility criteria and the exclusion of a large proportion of the initially screened examinations may limit the generalizability of the prevalence estimates to broader populations.

Future research should analyze the prevalence of the "U-shaped" mandibular arch across different ethnic groups and identify factors capable of predicting the degree of lingual concavity and the risk of lingual bone perforation. The risk of intraoperative and postoperative complications can be minimized through the use of cone-beam computed tomography (CBCT) and case-specific digital planning.

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CONCLUSION

The most frequent mandibular shape was found in Type C. The U-shaped mandibular morphology was observed in 25% of the sample. Posterior mandibular height was greater in males. The thickness and depth of the posterior mandibular areas did not vary according to sex.

AUTHORS' CONTRIBUTIONS

Karen R Tonini - Conception and design of study; Acquisition of data: laboratory or clinical; Drafting of article and/or critical revision

Laís Sara Egas Muniz Barreto Valle - Analysis of data

Izabella Sol - Analysis of data; Drafting of article and/or critical revision

Henrique Hadad - Analysis of data

Leda Maria Pescinini Salzedas - Conception and design of study; Acquisition of data: laboratory or clinical; Analysis of data

Daniela Ponzoni - Conception and design of study; Analysis of data; Drafting of article and/or critical revision; Final approval of manuscript

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

DATA AVAILABILITY

The study protocol and all data are available from the corresponding author on reasonable request.

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Received: May 13, 2026

Accepted: November 2, 2026

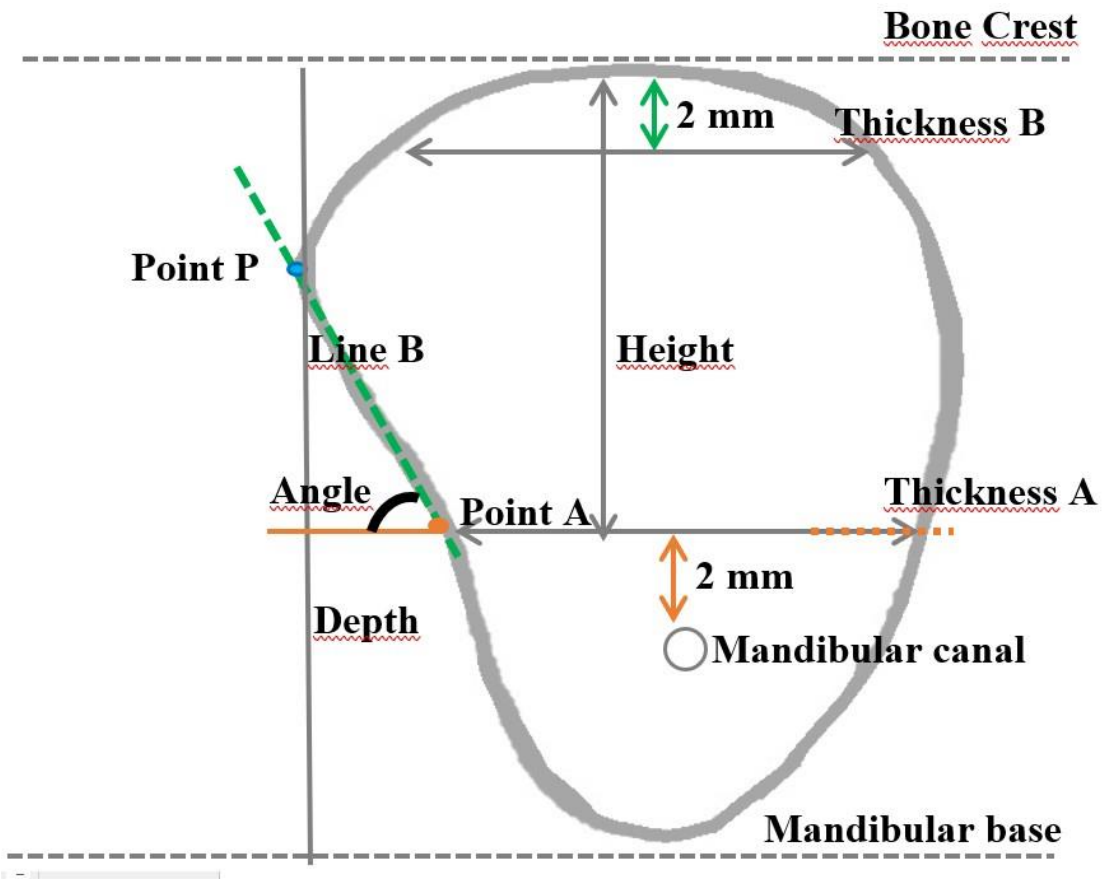


Figure 1 - Illustrative drawing of the measurements performed in the tomographic sections: Thickness B, Point P, Point A, Angle, Depth, Height and Thickness A.

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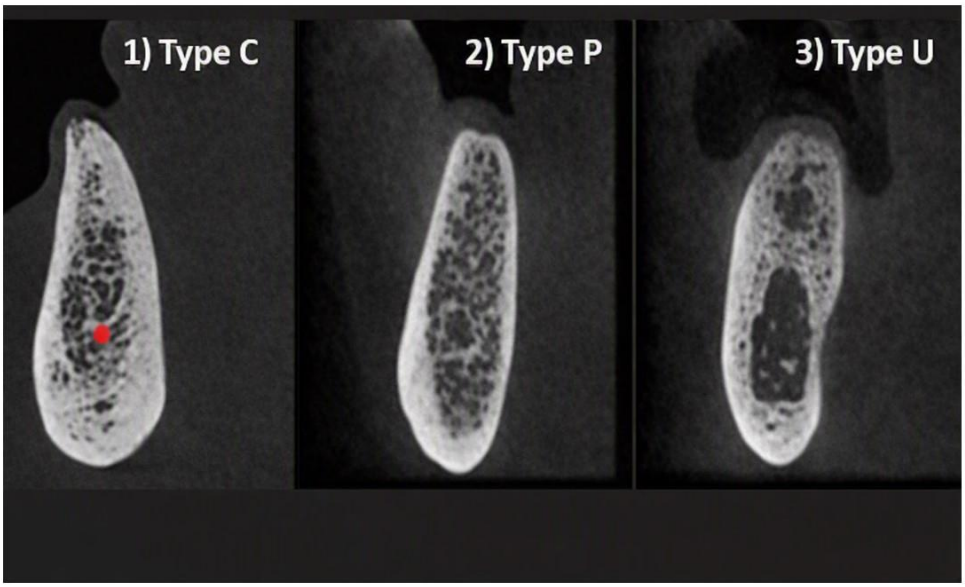


Figure 2 - Three types of posterior mandibular cross-section morphology: (1) Type C, (2) Type P, (3) Type U

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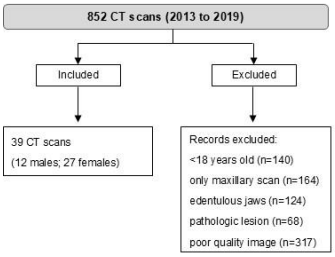


Figure 3 - Patient distribution flowchart.

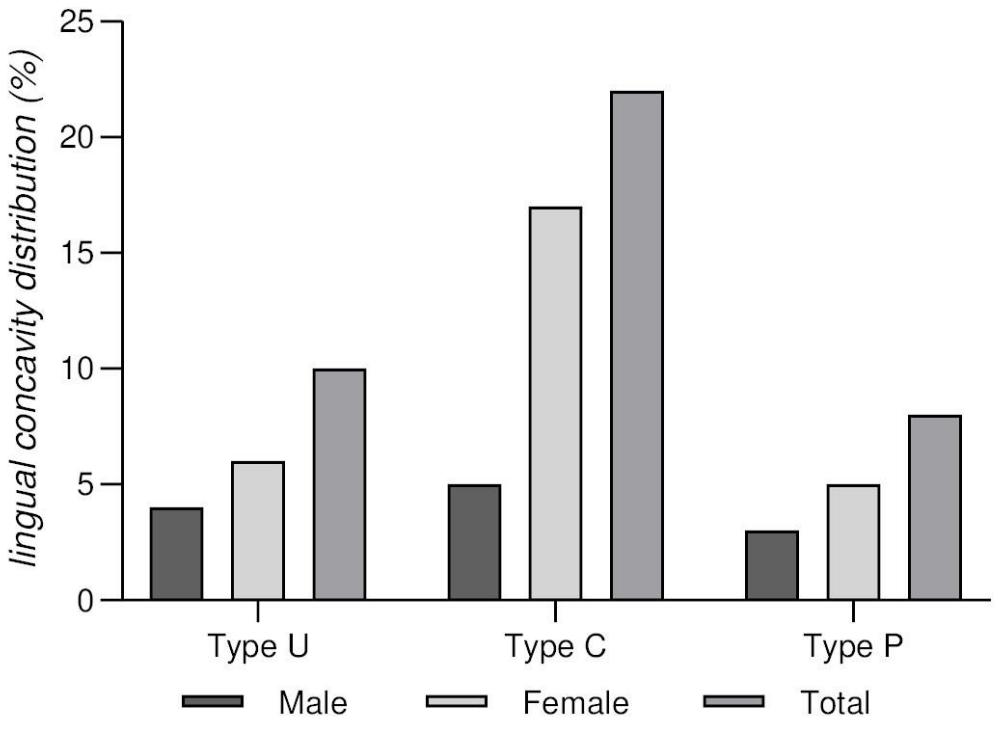


Figure 4 - Distribution of lingual concavity (%)

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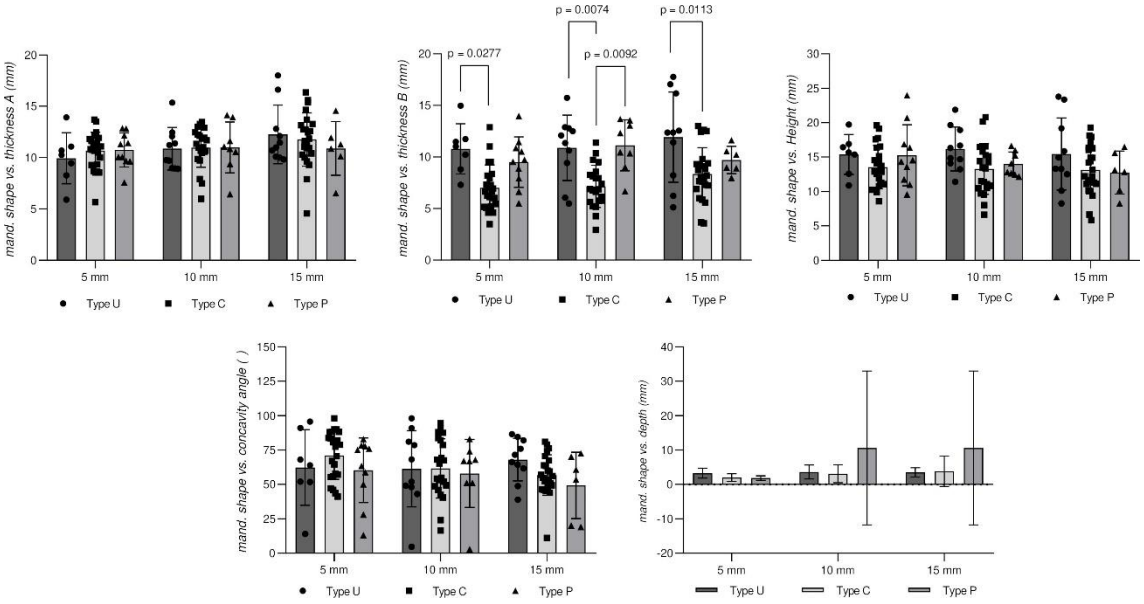


Figure 5 - Comparison of factors in the different mandibular shapes and mental nerve distances. (A) Comparison of the mean thickness A, mandibular shape and mental nerve distance. (B) Comparison of the mean thickness B, mandibular shape and mental nerve distance. (C) Comparison of the mean depth of the lingual concavity, mandibular shape and mental nerve distance. (D) Comparison of the mean height of bone crest 2 mm above mandibular canal, mandibular shape and mental nerve distance. (E) Comparison of the mean angle of the lingual concavity, mandibular shape and mental nerve distance. Statistical differences are indicated by brackets.

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