Journal of Oral Biology and Craniofacial Research 13 (2023) 13–18

Contents lists available at ScienceDirect

Journal of Oral Biology and Craniofacial Research

journal homepage: www.elsevier.com/locate/jobcr

Morphometric aspects and proposal of a new classification of genial tubercles in cone-beam computed tomography in a Brazilian population

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ARTICLE INFO

Keywords:
Genial tubercle
Cone-beam computed tomography
Mandible
Anatomy

ABSTRACT

Objective: This study evaluated epidemiological and morphological aspects of genial tubercles (GTs) using cone-beam computed tomography (CBCT).
Methods: This retrospective, observational and cross-sectional study evaluated 276 tomographs of adult dentate individuals (18–69 years). The presence and absence of GTs were evaluated, and in cases in which this structure was observed, linear measurements (length, height, and width), and anatomical distances. In addition, a GT classification was proposed based on the presence, number, and location of the tubercles.
Results: Of the 276 CT scans, 28 (10.14%) had absence of GTs and in 248 CT scans GTs were present, of which 42 (57.5%) were from females and 106 (42.5%) from males. Regarding the number of GTS, the most prevalent variant was the two-tubercle-variant (143, 57.7%), followed by the presence of a single tubercle (n = 62, 25.0%), 3 tubercles (n = 40, 16.1%) and 4 tubercles (n = 3, 1.2%). The most prevalent classification was IIIA (n = 96, 38.7%), followed by IIIB (n = 60, 36.3%), IIA (n = 53, 21.4%) and IIB (n = 9, 3.6%).
Conclusion: A prevalence of GT of approximately 90% was observed, with two GTs per exam as the most frequent finding. Men had a longer mean GT length compared to women. Female individuals exhibited a shorter distance from the base of the GT to the base of the mandible.

1. Introduction

Genial tubercles (GTs) are small bone eminences found close to the midline, in the lingual region of the mandible. These anatomical protuberances serve as insertion of the geniohyoid muscles in its lower portion and the genioglossus muscle in its upper portion. These muscles are related to tongue mobility and swallowing function and are essential for speaking and eating.[1,2]

GTs can be viewed on conventional radiographs, especially in occlusal radiographs; however, it is not possible to evaluate them with linear measurements. CBCTs enable the visualization and evaluation of the GT morphology, size and position based on the best assessment in the three dimensions of this anatomical structure.[3,4]

Although classically described as four eminences distributed in an upper and a lower pair, GTs demonstrate different anatomical patterns regarding shape and position, such as two upper and one lower eminences, two upper eminences, and a single elongated median eminence.[5,6] Cone-beam computed tomography (CBCT) is considered an accurate method for assessing the morphology, size, and position of the GTs.[3]

GTs are in a region that until recently was considered a safety zone in invasive procedures, such as the insertion of implants in the interforaminal region of the mandible. In addition, the GT position has been used in surgical planning for maxillomandibular repositioning, especially in mandibular advancement for the treatment of obstructive sleep apnea syndrome (OSAS).[7]

There are reports of GT fractures, ranging from spontaneous to cases associated with trauma as etiological factors.[8] This fact was observed in a systematic review encompassing 24 studies that showed these fractures were mostly observed in hypertrophied GT, regardless of the

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https://doi.org/10.1016/j.jobcr.2022.09.016
Received 12 February 2021; Received in revised form 19 September 2022; Accepted 29 September 2022
Available online 3 October 2022

cause.[8]

In this context, imaging exams are an important tool for studying the morphology of GTs and their relationship with the mandible and the adjacent lower anterior teeth.[5] Although the position and imaging aspects of GTs have been already described,[9] to the best of our knowledge, no topographic classification has been established to characterize GTs. Thus, the aim of the present study was to evaluate radiomorphometric and epidemiological aspects of GTs in a Brazilian population using CBCT and to propose a topographic classification of GTs.

2. Materials and methods

2.1. Study design, ethical considerations, and context

This cross-sectional, multicenter, and retrospective study was approved by the Research Ethics Committee of the Federal University of Ceará (approval number 1.757.620), and followed the guidelines proposed by the STROBE Initiative (*Strengthening the reporting of observational studies in epidemiology*).[10] CBCTs were obtained between January 2015 and August 2017 from two well-recognized reference dental imaging centers located in northeastern Brazil (Fortaleza, Ceará).

2.2. Eligibility criteria

CT scans of dentate patients (considering the region between the lower premolars) of both sexes, aged between 18 and 69 years, as well as those with clearly observation of the bilateral anterior region, lower edge, and alveolar cortex of the mandible were included. The exclusion criteria were: (1) duplicate CT scans; (2) images suggesting pathological processes, fractures and/or malformations that could alter the local bone architecture; (3) metallic artifacts (e.g., dental implants, plates, and fixation screws); (4) low quality diagnostic images.

2.3. Variables

The variables analyzed in the present study were: (1) sex, (2) age, (3) presence or absence of GTs, (4) GT classification based on the number and position of eminences, (5) linear measurements related to GTs.

2.4. Data source/evaluation criteria

The CT scanners used in the present study were I-CAT Next Generation (Imaging International Sciences, Hatfield, Pennsylvania, USA) and i-CAT classic (Imaging International Sciences, Hatfield, Pennsylvania, USA) (Table 1). *Digital Imaging and Communications in Medicine* (DICOM) files from CBCT images were stored for further evaluation by a single observer that used the Carestream Dental Institute Software (CDIS) 3D Software (Kodak Dental Systems, Carestream Health, Toronto, Canada). Initially, a panoramic reconstruction was performed using the lower edge of the mandible as a reference point and the GTs were identified using 1 mm cross-sections.

GTs were initially classified according to the number of tubercles found in 3-D reconstructions. Then, oblique multiplanar reconstruction (MPR) images were used to manipulate the sagittal reconstructions to locate the GTs. In an anteroposterior direction, the GT with the largest dimensions was selected. Parasagittal reconstructions allowed to obtain the measurements adopted in a previous studies.[3,11] Figs. 1 and 2 detailed this information. Additionally, a classification based on the absence or presence of GT was proposed: type I = absent (Fig. 3a); type II = 1 GT (Fig. 3b); type III = ≥ 2 GTs (Fig. 3c).

This classification also included a complementary information to types II and III, with IIA for cases of a single GT centralized in relation to the midline and IIB for those lateralized in relation to the midline. Type III was divided into IIIA for multiple GTs with different dimensions and IIIB for multiple GTs with similar dimensions.

Table 1
Characterization of cone-beam computed tomographs according to image acquisition parameters.

	i-CAT Next Generation	i-CAT classic
kVp	90-140 kVp	90-140 kVp
mA	5 mA	8 mA
FOV	8 × 8cm to 16 × 8cm	8 × 8cm to 16 × 8cm
Voxel	0.3 mm	0.2 mm
	0.25 mm	0.25 mm

FOV, field of view.

2.5. Evaluation of method error

Measurements error was performed by an observer that was trained and calibrated by a gold-standard researcher to conduct this study. The observer reassessed and remeasured 30 randomly selected images after an interval of 15 days, and Dahlberg's formula[12] estimated the methodological errors.

To assess reproducibility errors, Cohen's kappa statistic (presence/absence of GT) and the intraclass correlation coefficient (ICC) were performed. The kappa coefficient was interpreted according to the Lands & Koch classification (0.00, poor; 0.00–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial and 0.81–1.00, almost perfect). The ICC adopted a bidirectional random factors model with a 95% confidence interval and $p < 0.05$ to be satisfactory.

2.6. Sample size

Considering a prevalence of 96.6% of GTs[13] and a three-year collection period, the evaluation of 143 CT scans from a total of 1380 were deemed necessary CT scans to obtain a sample with 5% accuracy and 99% confidence to represent the images from the imaging centers (n = [Np (1-p)]/[(d2/Z21-α/2 * (N-1) + p * (1-p)]). Additionally, we included further 12 CTs (approximately 10%), totaling 155 tomographs. A simple randomization mechanism was designed as a sampling process for selecting the images.

2.7. Statistical analysis

GT measurements were expressed as means and standard deviations and submitted to the Kolmogorov-Smirnov normality test (parametric data). Comparisons between sexes used the Student's *t*-test. GT classifications and age groups used the ANOVA/Bonferroni tests. The measurements were also correlated with age through Pearson's correlation.

All analyses were performed using 95% confidence intervals (95% CI) in the Statistical Package for the Social Sciences (SPSS) software version 20.0 for Windows (*IBM Corporation, Sommers*, NY).

3. Results

The sample was initially consisted of 300 CT scans. Twenty-four CTs were excluded because they did not met the inclusion criteria: 20 exams showed the absence of at least one of the lower central incisors, 2 with extensive periapical lesions in the anterior region of the mandible, and 2 CT scans with low diagnostic quality (Fig. 4). Of the 276 remaining tomographs, 28 (10.14%) were classified as type I based on the absence of GT.

GTs were present in 248 CT scans, of which 142 (57.5%) were found in female and 106 (42.5%) male patients. The mean age was 47.4 ± 12.77 (range: 21–69) years, and they were distributed according to age groups: 21–30 (n = 28, 11.4%), 31–40 (n = 50, 20.4%), 41–50 (n = 56, 22.9%), 51–60 (n = 62, 25.3%), and 61–69 (n = 59, 20.0%) years old. Most patients (n = 143, 57.7%) had 2 GTs, followed by 1 GT (n = 62, 25.0%), 3 GTs (n = 40, 16.1%), and 4 GTs (n = 3, 1.2%). The most prevalent classification was IIIA (n = 96, 38.7%), followed by IIIB (n =

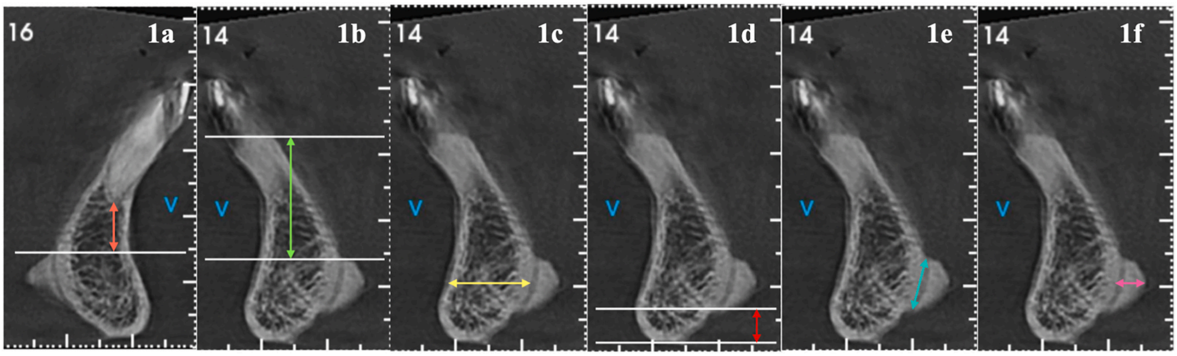

Fig. 1. 1a) Cross-sectional view on CBCT: distance from the apex of the central incisor adjacent to the GT; 1b) Distance from GT to the cortex of the alveolar crest; 1c) thickness of the mandible in the GT region; 1d) distance from the lower edge of the mandible to the lowest point of the base of the GT; 1e) measurement of the base of the GT; 1f) measurement from the base to the apex of the GT.

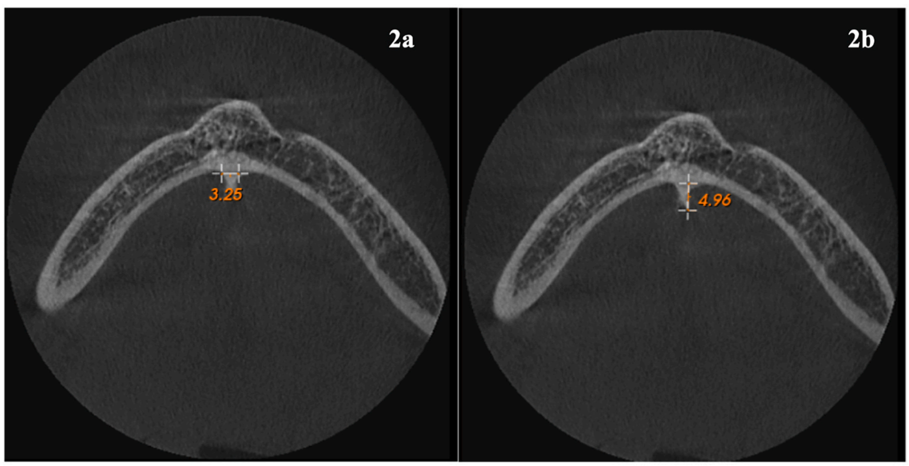

Fig. 2. 2a) Axial view on CBCT: measurement from the base to the apex of the GT. 2b) Axial view on CBCT: measurement of the base of the GT.

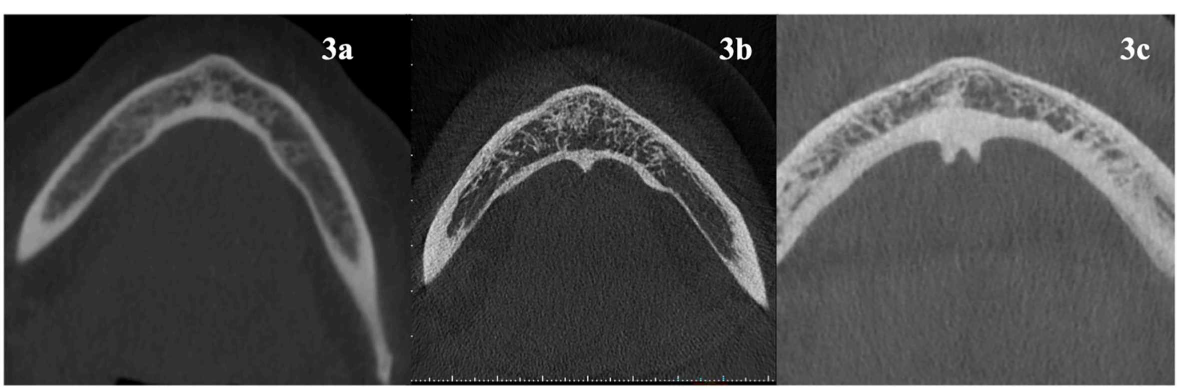

Fig. 3. 3a) Type I GT (Absent). 3b); Type II (single GT). 3c); Type III (multiple GT).

60, 36.3%), IIA (n = 53, 21.4%) and IIB (n = 9, 3.6%).

As shown in Table 2, males showed significantly higher values than females regarding the distances from the highest point of the GT to the alveolar bone cortex – D1 ($p = 0.005$), CEJ of the adjacent tooth – D2 ($p < 0.001$), apex of the adjacent tooth – D3 ($p < 0.001$); mandible thickness – D4 ($p < 0.001$); from the lowest point of the GT to the MB – D5 ($p = 0.005$); from the base of the GT (parasagittal cut) – D6 ($p = 0.083$); from the base of the GT to the apex of the GT (parasagittal cut) – D7 ($p = 0.003$); from the base of the GT (axial cut) – D8 ($p < 0.001$); and the distance from the base of the GT to the apex of GT (axial section) – D9 ($p < 0.001$) (Table 1). The age ranges did not significantly influence the GT means (Table 3), but the GT classified as IIA presented significant mandible thickness – D4 ($p = 0.003$), the smallest distance from the lowest point of the GT to the MB – D5 ($p = 0.002$), greater measure of the base of the GT (parasagittal cut) – D6 ($p < 0.001$), greater distance from the base of the GT to the apex of the GT (parasagittal cut) – D7 ($p = 0.001$), and greater measure of the base of the GT (cut axial) – D8 ($p < 0.001$). The distance from the base of the GT to the apex of the GT (axial section) – D9 showed lower values in group IIB (Table 4).

The measurement of the base of the GT (parasagittal cut) – D6 ($p = 0.003$) and the measurement of the base of the GT (axial cut) – D8 ($p = 0.012$) were inversely correlated with age in the entire sample and in

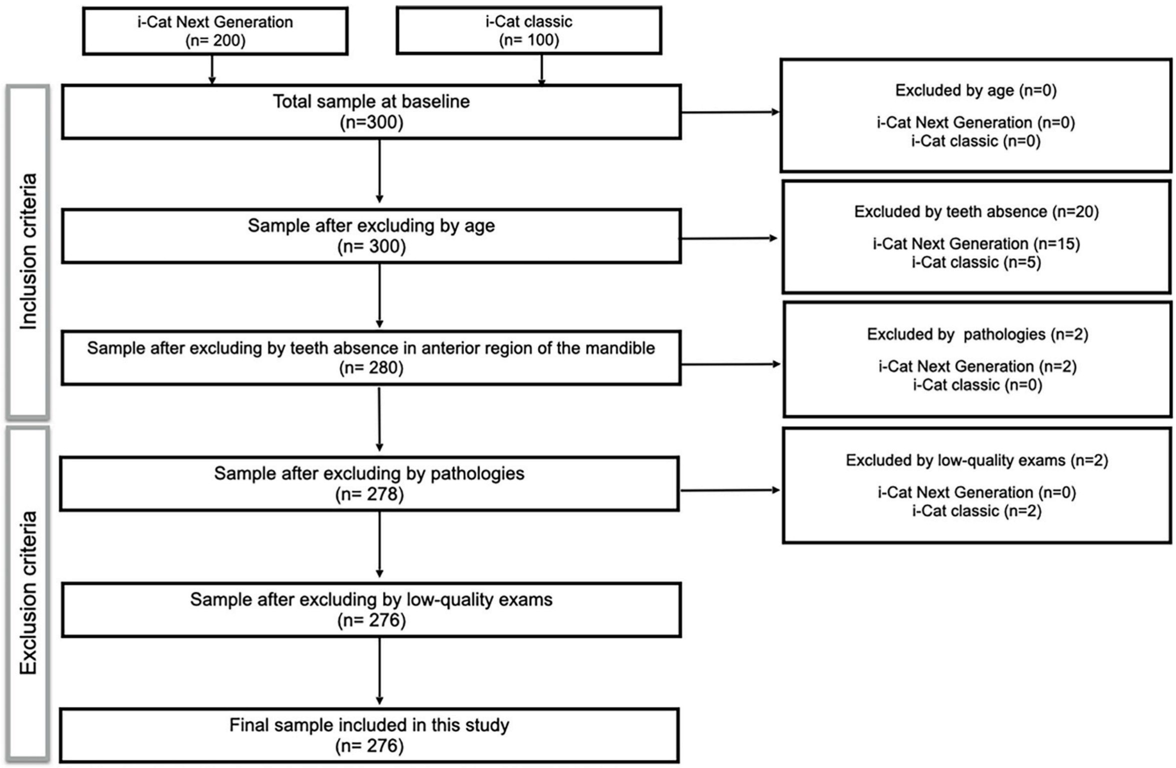

Fig. 4. CBCT methodology selection flow chart.

Table 2
Comparison of the GT-related mean dimension values (mm) between males and females.

	Total	Sex		p-value
		Male	Female	
Distance from the uppermost point of the GT base to the alveolar crest (CC)	17.24 ± 3.45	18.23 ± 3.47	16.46 ± 3.26	0.005
Distance from the uppermost point of the BGT to (CEJ) (CC)	18.81 ± 3.64	21.05 ± 3.54	17.31 ± 2.87	<0.001
Distance from the uppermost point of the BGT to the apex of the lower incisor (CC)	6.26 ± 3.26	7.87 ± 3.36	5.12 ± 2.68	<0.001
Mandibular bone thickness in the GT region (CC)	12.20 ± 2.05	12.77 ± 2.11	11.78 ± 1.90	<0.001
Distance from the lowest point of BGT to the BM (CC)	9.48 ± 2.55	10.01 ± 2.38	9.09 ± 2.62	0.005
Length of the BGT (CC)	4.68 ± 1.81	4.91 ± 1.78	4.51 ± 1.81	0.083
Distance between the base and the apex of the GT (CC)	2.01 ± 0.88	2.20 ± 1.00	1.86 ± 0.76	0.003
Length of the BGT (AC)	3.05 ± 1.18	3.37 ± 1.30	2.82 ± 1.03	<0.001
Distance between the base and the apex of the GT (AC)	1.98 ± 0.85	2.20 ± 0.97	1.81 ± 0.72	<0.001

*$p < 0.05$, test t Student (mean ± SD). AC: axial cut; CC cross-sectional cut; BM, base of the mandible; BGT, base of the genial tubercle; CEJ, cement-enamel junction; GT, genial tubercle.

females ($p = 0.001$ and $p = 0.022$, respectively) (Table 5). In IIB, there was a significant inverse correlation between age and the distance from the uppermost point of the GT to the alveolar bone cortex – D1 ($p < 0.001$) and the thickness of the mandible – D4 ($p = 0.006$). In the IIIA (Table 6), the distance from the uppermost point of the GT to the alveolar bone cortex – D1 ($p = 0.013$) and the measurement from the base of the GT (parasagittal section) – D6 ($p = 0.033$) were inversely correlated with age.

4. Discussion

This research carried out an important anatomic and epidemiological analysis of GTs using an appropriate and reproducible methodology, which included a significant sample of 248 CBCTs from two different dental imaging reference centers, justified by the fact that these results are more representative of the studied population, contributing to its external validity.[14] The present study proposed a classification system for GTs evaluating their disposition in the mandible, differing from the unique investigation that had classified the GTs in five categories.[15]

The sample in this study was predominantly female (57.5%), different from other studies in which this prevalence was closer to 50%.[3,16] Additionally, Araby et al.[4] observed GTs in a sample consisting 69.4% of men, which differs diametrically from the sample of the present study. Regarding age group, the highest prevalence was between 51 and 60 years, but it exhibited significant differences compared to the other age groups.

In relation to linear measurements, this is the first study that evaluated the distances from the upper part of the base of GT to the alveolar crest or the CEJ of the adjacent incisor. In both measurements, male patients exhibited significantly greater distances than female patients. Furthermore, in the IIIA and IIB groups, there was a significant inverse correlation between the distance to the alveolar crest and age. Regarding the distance from the upper point of the base to the apex of the adjacent incisor, it was considerably smaller than previous studies.[3,13,17] However, the present research was the only one that found significant differences between groups. This distance was greater in men (7.87 mm), compared to women (5.12 mm), and greater in tubercles with IIA classification (a single centralized tubercle).

The study by Nejaim et al.[17] also evaluated sexual dimorphism, however they found no significant difference between males and females. In the present study, these values were statistically higher in males than females; however, it is not possible to establish a definitive dimorphic pattern because of an intersection area common to both sexes. In addition, samples categorized as IIA also had significantly

Table 3
Comparison of the dimensions of mean values (mm) and standard deviation of GT between age groups.

	Age (years)					p-value
	21-30 (n = 28)	31-40 (n = 62)	41-50 (n = 56)	51-60 (n = 62)	61-69 (n = 61)	
Distance from the uppermost point of the BGT to the alveolar crest (CC)	18.31 ± 3.77	17.27 ± 4.08	17.62 ± 2.70	17.17 ± 3.68	16.24 ± 3.43	0.438
Distance from the uppermost point of the BGT to (CEJ) (CC)	18.45 ± 4.28	18.30 ± 3.39	19.64 ± 3.55	19.21 ± 3.67	18.16 ± 3.60	0.441
Distance from the uppermost point of the BGT to the apex of the lower incisor (CC)	5.65 ± 3.70	5.93 ± 2.55	6.96 ± 3.71	6.94 ± 3.54	5.34 ± 2.71	0.248
Mandibular bone thickness in the GT region (CC)	12.43 ± 1.82	12.23 ± 2.22	12.42 ± 2.07	11.79 ± 2.09	12.21 ± 1.90	0.474
Distance from the lowest point of BGT to the BM (CC)	9.39 ± 2.69	9.20 ± 2.61	9.43 ± 2.52	9.25 ± 2.76	10.22 ± 2.17	0.276
Length of the BGT (CC)	4.92 ± 1.83	5.16 ± 2.07	4.82 ± 1.84	4.39 ± 1.59	4.23 ± 1.64	0.059
Distance between the base and the apex of the GT (CC)	2.15 ± 0.81	1.99 ± 0.95	2.01 ± 0.98	1.92 ± 0.69	2.00 ± 0.92	0.859
Length of the BGT (AC)	3.19 ± 1.29	3.31 ± 1.31	3.23 ± 1.40	2.72 ± 0.92	2.94 ± 0.92	0.054
Distance between the base and the apex of the GT (AC)	2.08 ± 0.71	1.91 ± 0.82	1.87 ± 0.78	2.01 ± 0.77	2.09 ± 1.09	0.636

*$p < 0.05$ versus other age groups, ANOVA/Bonferroni test (mean ± SD). AC: axial cut; CC cross-sectional cut; BM, base of the mandible; BGT, base of the genial tubercle; CEJ, cement-enamel junction; GT, genial tubercle.

greater thicknesses, whereas in IIB there was an inverse correlation between the thickness of the mandible and age.

The distance from the lowest point of the GT to the mandible base has also been assessed by other authors. The present data was similar to that found by Kolsuz et al. (8.3–10.1 mm).[15] However, it was higher than the measurements found by Araby et al. (8.13 ± 3.07 mm)[4] and Wang et al. (6.4–8.4 mm).[3] In addition, this distance was significantly greater in males than females and lower in IIA GTs.

The length of GT base in the parasagittal view can be measured through two different methodologies, using the larger GT only (adopted in this study) or through the entire dimension from the beginning of the upper tubercle to the end of the lower one.[4] This may be a factor that caused the result of the present study to be statistically lower, contrasting with other CBCT investigations that obtained higher values.[3,15]

The base of the GT was also evaluated in the axial section. Methodological attention should be advised for future investigations because of potential measurement bias when two or more tubercules are side by side. Only three studies reported this measurement analysis[3,4,15] and they found higher values than the present study. The fact of we had measured only the largest tubercle in the anteroposterior direction may explain this finding. Furthermore, Nejaim et al.[17] also evaluated this measurement and compared it with sexual dimorphism, but found no statistical differences between men and women, differing from the present study that revealed a dimorphic pattern among men.

Table 4
Comparison of the dimensions of the mean values and standard deviation of the GT between according to the type of GT based on the new proposal classification.

	Classification				p-value
	IIA (n = 53)	IIB (n = 9)	IIIA (n = 96)	IIIB (n = 60)	
Distance from the uppermost point of the GT base to the alveolar crest (CC)	18.23 ± 4.04	13.80 ± 0.99	16.90 ± 3.36	17.02 ± 3.04	0.165
Distance from the uppermost point of the BGT to (CEJ) (CC)	19.96 ± 3.90	17.53 ± 1.71	19.02 ± 3.53	18.13 ± 3.70	0.138
Distance from the uppermost point of the BGT to the apex of the lower incisor (CC)	7.69 ± 3.33	5.86 ± 1.82	6.40 ± 3.08	5.46 ± 3.44	0.077
Mandibular bone thickness in the GT region (CC)	13.00 ± 2.32*	11.49 ± 2.22	12.23 ± 1.82	11.76 ± 1.95	0.003
Distance from the lowest point of BGT to the BM (CC)	8.30 ± 2.94*	9.57 ± 2.33	9.77 ± 2.26	9.87 ± 2.44	0.002
Length of the BGT (CC)	5.80 ± 2.42*	4.38 ± 1.20	4.27 ± 1.27	4.51 ± 1.67	0.000
Distance between the base and the apex of the GT (CC)	2.27 ± 1.18*	1.59 ± 0.66	2.13 ± 0.81	1.77 ± 0.69	0.001
Length of the BGT (AC)	4.02 ± 1.65*	2.48 ± 1.08	2.84 ± 0.91	2.75 ± 0.74	0.000
Distance between the base and the apex of the GT (AC)	2.21 ± 0.97	1.53 ± 0.60*	2.17 ± 0.90	1.70 ± 0.64	0.000

*$p < 0.05$ versus other types, ANOVA/Bonferroni test (mean ± SD). AC: axial cut; CC cross-sectional cut; BM, base of the mandible; BGT, base of the genial tubercle; CEJ, cement-enamel junction; GT, genial tubercle.

Table 5
GT dimensions that showed a statistically significant correlation with sex.

	Total sample (n = 248)	Female (n = 142)	Male (n = 106)
Distance from the uppermost point of the GT base to the alveolar crest (CC)	p = 0.112 (r = −0.148)	p = 0.853 (r = −0.023)	**p = 0.013 (r = -0.346)*
Length of the BGT (CC)	**p = 0.003 (r = -0.190)*	**p = 0.001 (r = -0.270)*	p = 0.416 (r = −0.081)
Length of the BGT (AC)	**p = 0.012 (r = -0.159)*	**p = 0.022 (r = -0.192)*	p = 0.172 (r = −0.136)

*$p < 0.05$, Pearson's correlation. AC: axial cut; CC cross-sectional cut; BGT, base of the genial tubercle; GT, genial tubercle.

Table 6
GT dimensions that showed a statistically significant correlation with the new proposed classification.

	IIA (n = 53)	IIB (n = 9)	IIIA (n = 96)	IIIB (n = 60)
Distance from the uppermost point of the GT base to the alveolar crest (CC)	p = 0.397 (r = −0.164)	**p < 0.001 (r = -1.000)*	**p = 0.013 (r = -0.396)*	p = 0.334 (r = 0.146)
Mandibular bone thickness in the GT region (CC)	p = 0.646 (r = −0.066)	**p = 0.006 (r = -0.829)*	p = 0.533 (r = −0.065)	p = 0.394 (r = −0.091)
Length of the BGT (CC)	p = 0.390 (r = −0.123)	p = 0.335 (r = −0.365)	**p = 0.033 (r = -0.219)*	p = 0.058 (r = −0.200)

*$p < 0.05$, Pearson's correlation. CC cross-sectional cut; BM, BGT, base of the genial tubercle; GT, genial tubercle.

5. Conclusion

GT occurred in approximately 90% of the CBCT exams, with the presence of two GTs as the most frequent finding. Men had a longer GT mean length than women. Female individuals exhibited a shorter distance from the base of the GT to the mandible base.

Authors contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by LRM, DAFB, PGBS and LMK. The first draft of the manuscript was written by RCT, FNC and FWGC and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethical approval

This research was approved by the Research Ethics Committee of the Federal University of Ceará (approval number 1.757.620).

Financial support

None.

Declaration of competing interest

The authors report no conflict of interest.

Acknowledgement

None.

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