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Intra- and Inter-examiner Reliability of the Genial Tubercle Versus Menton as Landmarks in Symmetric and Asymmetric Mandibles: A Cone-Beam Computed Tomography Study

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Abstract

Objective: This study aimed to assess intra- and inter-examiner reproducibility in identifying the genial tubercle (mental spine) and menton on cone-beam computed tomography (CBCT) images of adults with symmetric or asymmetric mandibles.

Materials and methods: Forty CBCT datasets (20 per group) were evaluated independently by an orthodontist with more than five years of experience and a second-year orthodontic resident. Each examiner repeated the assessments after one week. Landmark positions were recorded relative to three orthogonal reference planes. Intraclass correlation coefficients and Bland-Altman agreement statistics were reported.

Results: The reported intra-examiner coefficients ranged from 0.827 to 1.000 and inter-examiner coefficients from 0.829 to 0.998 across landmark-axis combinations. Patterns varied by axis and assessment; neither landmark was uniformly superior. The agreement analysis suggested small mean measurement differences; however, discrepancies in the reported values require verification. Group-level comparisons cannot currently be interpreted as evidence of equivalent diagnostic performance because the reported transverse values conflict with the stated >2-mm asymmetry criterion.

Conclusions: Both landmarks demonstrated generally high reported reliability coefficients across repeated measurements in this cohort. The study does not establish anatomical accuracy, diagnostic interchangeability, or superiority of one landmark; these require independent validation and access to the underlying measurement data.

Categories: Anatomy, Dentistry
Keywords: cbct, genial tubercle, mandibular asymmetry, menton, midsagittal reference plane

Introduction

Three-dimensional craniofacial analysis requires reproducible landmark localization. Cone-beam computed tomography (CBCT) reduces superimposition associated with conventional projections but does not eliminate uncertainty in landmark selection. Menton is conventionally identified at the most inferior point of the mandibular symphysis; its location may be difficult to reproduce on a broad or rounded inferior contour. CBCT landmark reproducibility studies show that precision depends on the landmark, reference plane, and viewing method [1-4]. CBCT has also facilitated three-dimensional characterization of mandibular asymmetry in different craniofacial patterns [5-8].

The genial tubercle, also termed the mental spine, is an internal bony prominence on the lingual aspect of the anterior mandibular symphysis associated with genioglossus and geniohyoid attachments. Its anatomical distinctness may facilitate localization, although morphological variability and occasionally paired prominences preclude assuming inherent stability or superiority [9,10]. Lee et al. evaluated the genial tubercle as a landmark in mandibular asymmetry [11]. The present work evaluates repeated identification by observers of differing clinical experience in two predefined symmetry categories, without an independent anatomical gold standard.

We hypothesized that landmark localization would show high within- and between-examiner agreement, with potentially different reproducibility profiles for the genial tubercle and menton across three spatial axes.

Materials And Methods

This prospective, single-center observational reliability and agreement study, reported with reference to

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GRRAS recommendations [12], enrolled participants from June through November 2025 after approval from the Institutional Ethics Committee of GSL Dental College (approval number: GSLDC/IEC/2023/18) with CTRI registration (registration number: CTRI/2025/05/087377). Written informed consent was obtained. The study involved independent landmark measurements by two calibrated examiners.

The study included 40 patients seeking orthodontic treatment at the Department of Orthodontics, GSL Dental College and Hospital, Rajahmundry, Andhra Pradesh, India. Participants were divided into two groups of 20 each based on the presence or absence of mandibular asymmetry. CBCT scans were obtained as part of the patients' required radiographic examinations.

The inclusion criteria were as follows: (1) age > 18 years; (2) participants with an apparently symmetric mandible (2 mm) relative to the midsagittal reference plane (MSR plane); and (3) subjects with an asymmetric mandible (>2 mm) with reference to the MSR plane.

The exclusion criteria were as follows: (1) ongoing or previous orthodontic treatment; (2) dental asymmetries (dental midline shifts); (3) trauma to the jaws and teeth; (4) pseudo-mandibular shifts (latero-occlusion); (5) temporomandibular joint anomalies and dysfunctions; (6) craniofacial anomalies; (7) previous orthognathic surgery or implant placement; (8) metal artifacts in the symphyseal region; and (9) poor scan quality.

Eligible participants were informed about the study, and CBCT scans were acquired using a DENTRI CBCT system (HDX WILL Corporation, Korea). The images were reconstructed using WillMaster software (version 1.0.0; HDX WILL Corporation, Korea). The CBCT data were saved in Digital Imaging and Communications in Medicine (DICOM) format. Multiplanar reformatted (MPR) images were generated from the DICOM files using OnDemand3D software (version 2016.12, Cybermed, Korea).

Specialized imaging software was used to process CBCT scans and generate multiplanar reconstructions in the axial, sagittal, and coronal planes. The generated images were used to identify the anatomical landmarks of the genial tubercle and menton and determine their three-dimensional coordinates. The genial tubercle was identified in the axial, coronal, sagittal, and three-dimensional volume-rendered views (Figure *1A*-*1D*), while menton was identified in the corresponding views (Figure *2A*-*2D*). The perpendicular distances of each landmark from the midsagittal, coronal, and Frankfort horizontal reference planes were measured to obtain the transverse, anteroposterior, and vertical coordinates, respectively, enabling precise three-dimensional localization. Measurements were recorded as nonnegative distances, without directional sign coding. The use of multiplanar views was informed by the landmark-assessment approach described by Lee et al. [11].

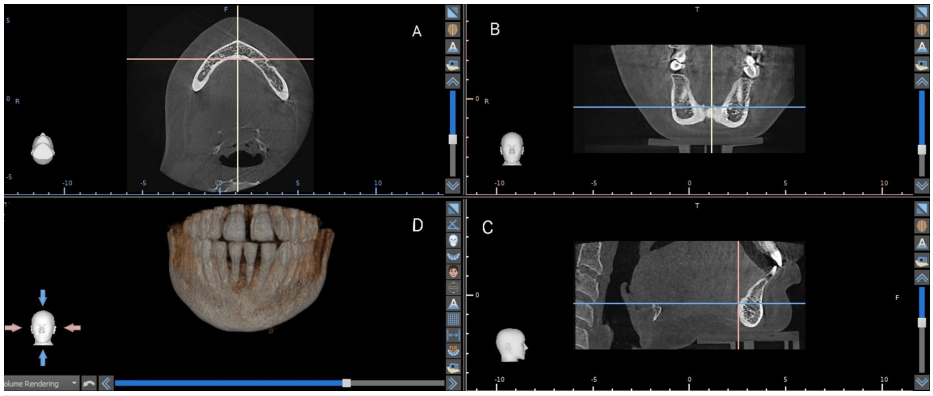


FIGURE 1: Identification of the genial tubercle in (A) axial, (B) coronal, (C) sagittal, and (D) three-dimensional volume-rendered views

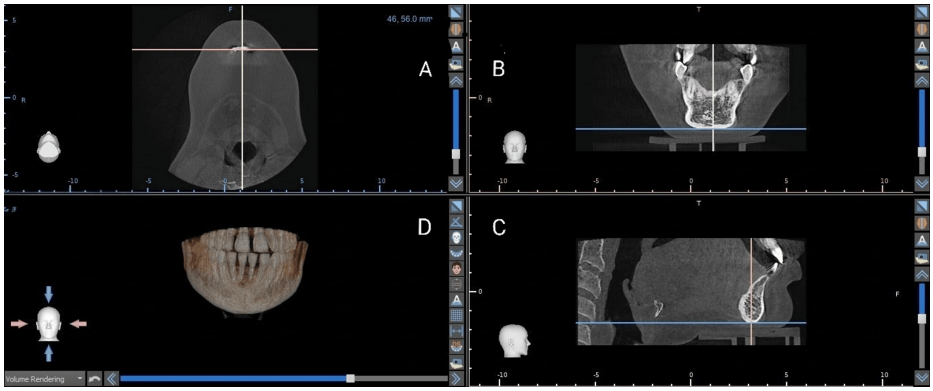


FIGURE 2: Identification of menton in (A) axial, (B) coronal, (C) sagittal, and (D) three-dimensional volume-rendered views

Two examiners independently identified landmarks and recorded measurements. Examiner A was an experienced orthodontist with over five years of practice, and Examiner B was a second-year orthodontic resident. The examiners were calibrated before measurements and blinded to each other's readings. After one week, de-identified CBCT files were presented in randomized order, with earlier landmark placements and measurements hidden to assess intra-examiner reliability.

The obtained data were statistically analyzed using SPSS Statistics version 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY). The reports included correlation/reliability coefficients, independent-samples t tests, and Bland-Altman summary calculations. Reliability and agreement are distinct statistical properties [12-14]. Because the retained analysis does not specify the intraclass correlation coefficients (ICC) model or provide participant-level observations, the original coefficient estimates are presented without reconstructed confidence intervals or unperformed normality tests. No clinically acceptable measurement-error threshold was prespecified. Reported p-values of 0.000 are expressed as $p < 0.001$. A p-value $\leqslant 0.05$ was considered statistically significant for all statistical tests. The Bland-Altman table is presented as originally reported, but signed-difference assumptions and some limits of agreement cannot be independently confirmed [14].

Results

Two examiners assessed 40 CBCT datasets.

Intra-examiner reliability

Table *1* shows high reported intra-examiner reliability for identifying the genial tubercle and menton, with coefficients $\geqslant 0.827$. Both landmarks generally showed high reliability coefficients across all three directions, with coefficients varying by landmark and examination. Examiner A showed equal values for the genial tubercle in the anteroposterior and vertical directions. Examiner B showed higher ICCs in the vertical and anteroposterior directions compared with the transverse direction. Overall, the genial tubercle showed marginally higher ICCs than menton.

	Landmarks	Axis	First examination		Second examination	
			r	p-value	r	p-value
Intra-examiner	Menton	Anteroposterior	0.827	0.000*	0.998	0.000*
		Vertical	1.000	0.000*	0.999	0.000*
		Transverse	0.997	0.000*	0.993	0.000*
	Genial tubercle	Anteroposterior	0.999	0.000*	0.999	0.000*
		Vertical	0.999	0.000*	0.998	0.000*
		Transverse	0.962	0.000*	0.996	0.000*

TABLE 1: Intra-examiner reliability (first examination vs. second examination)

r: ICC or Pearson's correlation coefficient, * p ≤ 0.05 is considered statistically significant

ICC: intraclass correlation coefficient

Inter-examiner reliability

Table 2 shows strong inter-examiner reliability for locating the genial tubercle and menton, with ICCs ⩾0.829. In the first assessment, both landmarks showed higher ICCs in the vertical and anteroposterior directions than in the transverse direction. During the second assessment, the vertical direction showed the highest ICC for menton, whereas the anteroposterior direction showed the highest ICC for the genial tubercle. Overall, the genial tubercle demonstrated slightly higher reported reliability coefficients in several landmark-axis comparisons.

	Landmarks	Axis	First examination		Second examination	
			r	p-value	r	p-value
Inter-examiner	Menton	Anteroposterior	0.996	0.000*	0.829	0.000*
		Vertical	0.997	0.000*	0.997	0.000*
		Transverse	0.967	0.000*	0.959	0.000*
	Genial tubercle	Anteroposterior	0.998	0.000*	0.998	0.000*
		Vertical	0.997	0.000*	0.996	0.000*
		Transverse	0.924	0.000*	0.985	0.000*

TABLE 2: Inter-examiner reliability (Examiner A vs. Examiner B)

r: ICC or Pearson's correlation coefficient, * p ≤ 0.05 is considered statistically significant

ICC: intraclass correlation coefficient

Intra- and inter-examiner measurement differences

Table 3 describes the intra- and inter-examiner differences in millimeters (mm) for genial tubercle and menton in the anteroposterior, transverse, and vertical directions across two assessments. Both landmarks demonstrated small mean differences across all three dimensions. In the anteroposterior direction, mean differences ranged from 0.01 to 0.06 mm for genial tubercle and 0.02 to 0.07 mm for menton. Menton showed greater variability, with standard deviations (SDs) ranging from 0.01 to 0.22 mm, compared with 0.008 to 0.02 mm for the genial tubercle. The reported upper 95% limit of agreement was 0.06 mm for the genial tubercle and 0.49 mm for menton.

Bland-Altman analysis	Menton			Genial tubercle		
	Anteroposterior	Transverse	Vertical	Anteroposterior	Transverse	Vertical
Intra-examiner differences by Examiner A						
Mean ± SD	0.06 ± 0.22	0.02 ± 0.2	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.02	0.05 ± 0.09
Mean + 1.96 SD (95%)	0.49	0.05	0.04	0.04	0.06	0.24
Mean − 1.96 SD (5%)	-0.36	-0.02	0.00	0.00	-0.02	-0.13
Intra-examiner differences by Examiner B						
Mean ± SD	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.008	0.04 ± 0.03	0.02 ± 0.02
Mean + 1.96 SD (95%)	0.05	0.05	0.05	0.03	0.10	0.05
Mean − 1.96 SD (5%)	-0.01	-0.01	-0.01	-0.002	-0.03	-0.01
Inter-examiner differences on first examination (T0)						
Mean ± SD	0.03 ± 0.02	0.03 ± 0.05	0.04 ± 0.05	0.02 ± 0.02	0.03 ± 0.05	0.07 ± 0.12
Mean + 1.96 SD (95%)	0.07	0.13	0.13	0.06	0.12	0.31
Mean − 1.96 SD (5%)	-0.01	-0.06	-0.05	-0.02	-0.06	-0.18
Inter-examiner differences on second examination (T1)						
Mean ± SD	0.07 ± 0.21	0.03 ± 0.05	0.03 ± 0.06	0.02 ± 0.02	0.03 ± 0.07	0.04 ± 0.04
Mean + 1.96 SD (95%)	0.49	0.14	0.14	0.06	0.17	0.12
Mean − 1.96 SD (5%)	-0.35	-0.07	-0.08	-0.02	-0.10	-0.04

TABLE 3: Intra- and inter-examiner differences in millimeters (mm) in the anteroposterior, transverse, and vertical position of the genial tubercle and menton

SD: standard deviation, T0: initial, T1: after one week

In the transverse direction, mean differences were comparable between the genial tubercle (0.02-0.04 mm) and menton (0.02-0.03 mm), with similar SDs. The highest reported upper limits of agreement were 0.17 mm and 0.14 mm, respectively. Vertically, mean differences ranged from 0.02-0.05 mm for the genial tubercle and 0.02-0.04 mm for menton. The genial tubercle showed greater variability, with the highest reported upper limit of agreement reaching 0.31 mm, compared with 0.14 mm for menton. Overall, both landmarks demonstrated minimal measurement differences and good examiner reliability.

Intergroup comparative analysis

Tables *4*-*5* compare the mean distances of menton and the genial tubercle, respectively, in the anteroposterior, transverse, and vertical directions between the symmetric and asymmetric mandibular groups. No significant differences in mean distances were observed between symmetric and asymmetric mandibles.

Examiner	Timing	Sample type	n	Anteroposterior (mean ± SD)	t	p	Transverse (mean ± SD)	t	p	Vertical (mean ± SD)	t	p
Examiner A	T0	Asymmetry	20	0.7660 ± 0.38041	-0.4	0.691	0.9755 ± 0.81681	0.179	0.859	0.4805 ± 0.23823	-0.614	0.543
		Symmetry	20	0.8335 ± 0.65159			0.9335 ± 0.65711			0.5225 ± 0.19219		
Examiner A	T1	Asymmetry	20	0.7285 ± 0.38327	-0.701	0.488	0.9795 ± 0.80896	0.139	0.89	0.4895 ± 0.23433	-0.483	0.632
		Symmetry	20	0.8470 ± 0.65182			0.9470 ± 0.66007			0.5225 ± 0.19604		
Examiner B	T0	Asymmetry	20	0.7855 ± 0.38779	-0.436	0.665	0.9720 ± 0.79263	0.175	0.862	0.4830 ± 0.22415	-0.367	0.716
		Symmetry	20	0.8600 ± 0.65816			0.9320 ± 0.64204			0.5065 ± 0.17816		
Examiner B	T1	Asymmetry	20	0.7765 ± 0.38816	-0.494	0.624	0.9705 ± 0.79843	0.184	0.855	0.4805 ± 0.22500	-0.405	0.688
		Symmetry	20	0.8615 ± 0.66469			0.9285 ± 0.63946			0.5065 ± 0.17857		

TABLE 4: Comparison of mean distances of menton in the anteroposterior, transverse, and vertical directions between symmetric and asymmetric mandibular groups

Independent-samples t-test, n: sample size, SD: standard deviation, T0: initial, T1: after one week. A p-value ≤0.05 is considered statistically significant.

Examiner	Timing	Sample type	n	Anteroposterior (mean ± SD)	t	p	Transverse (mean ± SD)	t	p	Vertical (mean ± SD)	t	p
Examiner A	T0	Asymmetry	20	0.8025 ± 0.44081	-0.040	0.968	1.0020 ± 0.80752	0.431	0.669	1.6125 ± 0.42046	0.013	0.990
		Symmetry	20	0.8090 ± 0.58053			0.9030 ± 0.63649			1.6110 ± 0.31701		
Examiner A	T1	Asymmetry	20	0.8100 ± 0.43432	-0.071	0.943	1.0075 ± 0.82059	0.408	0.685	1.5840 ± 0.33113	0.032	0.975
		Symmetry	20	0.8215 ± 0.57518			0.9115 ± 0.65835			1.5810 ± 0.26533		
Examiner B	T0	Asymmetry	20	0.8190 ± 0.44074	-0.070	0.944	0.9775 ± 0.80115	0.412	0.683	1.5760 ± 0.30165	0.122	0.904
		Symmetry	20	0.8305 ± 0.58624			0.8840 ± 0.62311			1.5655 ± 0.23966		
Examiner B	T1	Asymmetry	20	0.8160 ± 0.43444	-0.067	0.947	0.9880 ± 0.80086	0.439	0.663	1.5750 ± 0.30083	0.029	0.977
		Symmetry	20	0.8270 ± 0.59140			0.8885 ± 0.62174			1.5725 ± 0.23715		

TABLE 5: Comparison of mean distances of the genial tubercle in the anteroposterior, transverse, and vertical directions between symmetric and asymmetric mandibular groups

Independent-samples t-test, n: sample size, SD: standard deviation, T0: initial, T1: after one week. A p-value ≤0.05 is considered statistically significant.

Discussion

This prospective CBCT study assessed the repeatability of menton and genial tubercle localization in 40 adults, classified into symmetric and asymmetric mandibular groups. The reported intra-examiner coefficients (0.827-1.000) and inter-examiner coefficients (0.829-0.998) indicate generally strong reproducibility across the examined landmark-axis combinations. Nevertheless, these coefficients varied by axis and observer, and neither landmark consistently outperformed the other across all comparisons. Because ICCs are influenced by variability among the individuals being measured, high ICCs should be interpreted together with absolute differences and agreement limits rather than taken as evidence of perfect anatomical localization [12-14].

Lee et al. [11] provide the most directly relevant comparison because they specifically investigated the genial tubercle as a potential landmark for identifying mandibular asymmetry. Their work highlighted the possibility that an internal symphyseal landmark may complement the conventional external landmark, menton, particularly for transverse assessment. Our findings broadly support the feasibility of reproducibly identifying both structures on CBCT. However, unlike a direct diagnostic-validation study, our data primarily address repeated landmark localization by two examiners. The present summary tables do not permit a valid

conclusion that the genial tubercle is diagnostically superior to menton or that the two landmarks can be substituted for one another in individual patients. Thus, our findings extend the existing evidence on these landmarks by evaluating repeated measurements performed by examiners with different levels of experience, without establishing diagnostic interchangeability.

The general pattern of reproducibility also accords with the broader three-dimensional landmark literature. Schlicher et al. [1] examined the consistency and precision of landmark identification in CBCT scans and noted that reproducibility depends on the landmark. Ludlow et al. [2] compared the precision of landmark identification using CBCT and conventional cephalometric views, reinforcing the relevance of image presentation and landmark definition to measurement precision. Fuyamada et al. [3] likewise studied reproducibility of landmark identification on three-dimensional CBCT images of the jaws and teeth. In relation to these studies, our observation that reliability varies by spatial axis is plausible: a point that is readily localized in one plane may be less clearly delimited in another. The present study does not replicate their landmark sets or imaging comparisons, so numerical equivalence between studies should not be assumed.

Van Vlijmen et al. [4] support the rationale for using CBCT rather than relying solely on projected cephalometric images by comparing two- and three-dimensional cephalometric assessments. These investigations are relevant to measurement methodology rather than direct tests of menton-genial tubercle agreement. They underscore why reference-plane construction, reconstruction settings, and consistent viewing procedures matter when interpreting small positional differences. In our study, the same imaging workflow was used for the repeated landmark assessments, but the available records do not allow us to quantify any effect of acquisition or reconstruction variability.

Anatomical studies also help explain why the genial tubercle warrants separate consideration. Wang et al. [9] evaluated the genial tubercle's position and dimensions using CBCT, while Hueman et al. [10] examined its CBCT localization. Together, these studies support its visibility and anatomical relevance on three-dimensional imaging. At the same time, variation in the tubercle’s configuration, prominence, or paired components could influence where an examiner places a single representative point. Menton, by contrast, is conventionally defined along the inferior mandibular symphyseal contour, which may offer a recognizable boundary but can also present several nearby candidate points depending on orientation. These anatomical explanations may account for the observed axis-specific variability but were not directly evaluated in this study.

Our comparison of symmetric and asymmetric mandibles should also be situated within the broader CBCT literature on facial asymmetry. Cevidanes et al. [5] demonstrated the value of three-dimensional approaches for quantifying mandibular asymmetry, while Leung and Leung [6] addressed three-dimensional evaluation and classification of mandibular asymmetry. Kwon et al. [7] compared craniofacial morphology in individuals with and without facial asymmetry, and Alhazmi [8] examined mandibular asymmetry across skeletal malocclusion and vertical-pattern categories. These studies emphasize that asymmetry is a three-dimensional morphological condition rather than a single isolated linear measurement. In the present work, deviation from the MSR plane was used as the grouping criterion, whereas the repeated landmark measurements addressed reproducibility. Accordingly, an apparently small difference between two landmark positions must not be conflated with a small deviation of either landmark from the reference plane.

Sanders et al. [15] used CBCT to explore skeletal and dental asymmetries in Class II subdivision malocclusions, and Tam et al. [16] assessed hard- and soft-tissue asymmetry in skeletal Class III patients. Although these populations and objectives differ from ours, their findings illustrate the importance of considering the clinical pattern of asymmetry when interpreting a mandibular midline landmark. Our sample was not stratified by malocclusion subtype or skeletal pattern and therefore cannot establish whether reliability changes across those phenotypes. This distinction is clinically important because a reproducible landmark may still reflect only one component of a more complex asymmetric morphology. Hassan et al. [17] also examined how scanning position may affect three-dimensional measurements from CBCT surface-rendered images, emphasizing the importance of acquisition and reconstruction conditions.

The magnitude and interpretation of measurement agreement deserve particular attention. The reported mean paired differences were generally small, but the original summary of limits of agreement contains internal discrepancies that cannot be recalculated without the underlying paired observations. Bland and Altman [14] emphasized the assessment of agreement through the distribution of paired differences, while Koo and Li [13] discussed appropriate ICC selection and reporting. Consistent with the GRRAS framework [12], a complete interpretation would require the ICC model, confidence intervals, and appropriately calculated agreement limits. These details are unavailable in the retained summary output, so the present coefficients are reported descriptively and should not be used to assert a predefined clinically acceptable error.

Finally, the subgroup results require a distinction between the criterion used to classify asymmetry and the outcome represented by each tabulated distance. The study used a deviation threshold exceeding 2 mm to classify the asymmetric group, whereas some transverse means in Tables *4*-*5* are approximately 1 mm. These

numbers could represent different constructs, such as between-landmark differences rather than individual landmark-to-plane deviations, but the original table labels do not establish that interpretation. Without participant-level records, it would be inappropriate to relabel or modify the values. Therefore, the current study supports generally high repeat-measurement reproducibility for menton and the genial tubercle but does not establish their diagnostic equivalence, a clinically acceptable discrepancy threshold, or superiority in classifying asymmetry.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the relatively small sample size (40 participants: 20 with mandibular symmetry and 20 with mandibular asymmetry) and single-center design may limit the generalizability of the results to larger, more diverse populations. Participant selection based on predefined eligibility criteria and consent-based recruitment may also have introduced selection bias.

Second, although the study demonstrated generally high intra- and inter-examiner reliability for menton and the genial tubercle, landmark identification on CBCT images remains susceptible to observer-related variation. The assessment involved only two examiners, with repeated measurements performed after a one-week interval. Consequently, the findings may not fully represent variations associated with different levels of clinical experience, larger examiner groups, or longer reassessment intervals.

Third, the measurements were performed using a single CBCT imaging system and software workflow. Variations in image resolution, acquisition protocols, reconstruction techniques, and landmark identification methods across different CBCT systems may influence measurement reproducibility. Therefore, the findings should be interpreted within the imaging conditions employed in the present study.

Furthermore, although reliability coefficients indicated generally good reproducibility, the available statistical records did not permit complete verification of the ICC model, confidence intervals, and certain measurement-agreement estimates. The relationship between the transverse measurements reported in the subgroup tables and the deviation threshold used to classify mandibular asymmetry also requires careful interpretation. These limitations restrict definitive conclusions regarding the comparative performance of the two landmarks in symmetric and asymmetric mandibles.

Finally, the study primarily evaluated the reproducibility of landmark identification rather than diagnostic accuracy. Although menton and the genial tubercle demonstrated promising reliability, their diagnostic interchangeability and relative accuracy in identifying mandibular asymmetry could not be established without comparison against an independent reference standard.

Future research directions

Future multicenter studies should include larger, more diverse samples representing different age groups, skeletal patterns, and degrees of mandibular asymmetry. Such investigations would improve the generalizability of the findings and allow a more comprehensive evaluation of the reliability of menton and the genial tubercle across diverse populations.

Future studies should include additional examiners with varying levels of clinical experience to assess how examiner training and expertise affect landmark identification. Standardized landmark definitions, CBCT orientation protocols, and measurement procedures would also facilitate comparisons across different imaging systems and research centers.

Prospective investigations should specifically evaluate the agreement between menton- and genial-tubercle-based assessments of mandibular asymmetry using an independent diagnostic reference standard. Particular attention should be given to cases with deviations close to the 2-mm classification threshold, where small measurement differences may influence diagnostic categorization. Comprehensive statistical analyses incorporating appropriately specified ICCs, confidence intervals, and Bland-Altman limits of agreement would further strengthen the evidence regarding measurement reproducibility and clinical applicability.

Longitudinal studies may also help determine whether changes in the spatial relationships of these landmarks correspond to alterations in mandibular symmetry over time, particularly following orthodontic or orthognathic treatment. Additionally, applying artificial intelligence and automated three-dimensional landmark identification techniques could improve measurement efficiency, reduce observer-dependent variability, and enhance the consistency of CBCT-based assessments.

Finally, correlating three-dimensional landmark measurements with facial aesthetics, occlusal relationships, temporomandibular joint characteristics, and treatment outcomes may provide greater insight into their clinical relevance. Such investigations could help establish whether the genial tubercle offers additional diagnostic value alongside menton in comprehensive orthodontic assessment and treatment planning.

Conclusions

Both the genial tubercle and menton demonstrated generally high reported intra- and inter-examiner reliability coefficients in CBCT-based assessments, with the genial tubercle showing slightly greater reproducibility in certain dimensions. No statistically significant differences in mean landmark distances were observed between the symmetric and asymmetric mandibular groups; however, the interpretation of these comparisons requires clarification of the measurement definitions. The genial tubercle may serve as a supplementary landmark for three-dimensional mandibular assessment, although its diagnostic superiority and interchangeability with menton require further validation.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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