BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 21, Issue 8

DOI: 10.58240/1829006X-2025.21.8-369

ORIGINAL ARTICLE

RELATIONSHIP BETWEEN TRANSVERSE BASAL ARCH WIDTH AND MOLAR INCLINATION: A CBCT STUDY IN YEMENI ADULTS

Badr H. M. Q. Dammag [1],* Naela Al Mogahed [2]

[1] Postgraduate Student, Department of Orthodontics, Pedodontics and Prevention, Faculty of Dentistry, Sana'a University, Sana'a, Yemen.
[2] Associate Professor, Department of Orthodontics, Pedodontics and Prevention, Faculty of Dentistry, Sana'a University, Sana'a, Yemen.
*** Corresponding author:** Dr. Badr H. M. Q. Dammag Email: badrdammag2014@gmail.com
Tel.: +967-770020060 Orcid: https://orcid.org/0009-0001-9211-0017
Dr. Naela Al Mogahed [2], Email: almogahed2000@yahoo.com, Orcid: https://orcid.org/0009-0000-9319-8631.
Received: *Aug 21. 2025;* ***Accepted:*** *Aug 30, 2025;* ***Published:*** *Sep 13, 2025*

ABSTRACT

Background: Transverse skeletal discrepancies in adults are often underdiagnosed, particularly when masked by dentoalveolar compensation such as molar inclination. This study aimed to evaluate the relationship between transverse basal arch width and molar angulation in Yemeni adults using cone-beam computed tomography (CBCT).

Methods: A retrospective CBCT analysis was conducted on 87 untreated Yemeni adults (17–40 years). Participants were classified into normal and narrow maxilla groups based on the maxillary–mandibular basal width difference (Mx–Mn). Skeletal widths were measured on standardized basal planes, and first molar inclination was recorded relative to skeletal reference lines. Group comparisons were performed using t-tests, while correlations were assessed with Pearson's r. Intra-examiner reliability was verified with ICC.

Results: The narrow maxilla group demonstrated a significantly smaller maxillary width (54.55 ± 2.8 mm) than the normal group (57.55 ± 3.1 mm; $p < 0.001$), accompanied by a greater mandibular width (57.5 ± 3.3 vs. 55.2 ± 3.1 mm; $p = 0.003$), resulting in a negative Mx–Mn difference. Upper molars exhibited greater buccal inclination (195.2° ± 11.4 vs. 189.8° ± 7.2; $p = 0.028$), whereas lower molars showed more lingual inclination (146.3° ± 10.6 vs. 155.1° ± 8.5; $p < 0.001$). Strong correlations were found between Mx–Mn and molar inclination (upper $r = +0.535$; lower $r = -0.463$; both $p < 0.001$). ICC exceeded 0.90.

Conclusion: Molar inclination functions as a compensatory mechanism in the presence of transverse skeletal imbalance. Incorporating both skeletal and dental assessments through CBCT enhances the detection of concealed transverse disharmony and facilitates more individualized orthodontic treatment planning.

Keywords: CBCT; transverse basal arch width; molar inclination; skeletal discrepancy; dental compensation; Yemeni adults; orthodontic diagnosis

1. INTRODUCTION

Transverse skeletal discrepancies are often less recognized in orthodontic diagnosis than vertical or sagittal problems. While skeletal width is fundamental for maintaining functional occlusion and facial balance, its deficiencies are frequently hidden by dental compensations, particularly through molar inclination.[1,2] Unlike vertical or sagittal discrepancies, transverse problems—such as maxillary constriction—are not always obvious clinically and may remain undetected in patients with apparently normal alignment or compensated crossbites.[3,4] When left unidentified, these discrepancies can contribute to posterior crossbite, functional shifts, and long-term

instability of the occlusion.[5]

Evaluating transverse basal arch width together with molar inclination is crucial for detecting hidden skeletal imbalances and understanding the compensatory changes that teeth may develop in response to transverse deficiencies.[6,7] In particular, buccolingual tipping of the molars often serves as a compensation in maxillary narrowing, masking the underlying skeletal disharmony.[8] While such dental adaptations may provide short-term functional balance, they can compromise long-term stability if the transverse discrepancy is not diagnosed and corrected during treatment planning. [9]

Therefore, precise assessment of both skeletal width and molar angulation is fundamental for achieving stable orthodontic outcomes.

Conventional two-dimensional imaging methods, such as posteroanterior cephalograms or occlusal radiographs, have well-known limitations when assessing transverse dimensions. Projection errors and the lack of three-dimensional visualization reduce their accuracy in evaluating true skeletal width and molar inclination.[10] By contrast, cone-beam computed tomography (CBCT) provides high-resolution volumetric images that allow measurement of basal bone width and dental angulation from stable anatomical landmarks with superior precision.[11,12] Several studies have confirmed that CBCT yields more consistent and reproducible measurements of transverse width and buccolingual molar inclination in both clinical and research settings.[13]

Despite growing recognition of the importance of transverse diagnosis, limited research has examined the combined evaluation of basal arch width and molar inclination using CBCT. Most existing studies have analyzed these variables separately, often within small or ethnically homogenous samples.[14,15] Consequently, the compensatory mechanisms that may link skeletal transverse width to molar angulation remain insufficiently understood. Exploring this relationship is essential to advance knowledge of transverse balance and to provide more accurate, individualized orthodontic treatment planning across diverse populations. Therefore, the present study aimed to evaluate transverse basal arch width and molar inclination using CBCT, and to investigate the relationship between these two parameters in a sample of untreated Yemeni adults. By focusing on this population, the study seeks to provide new insights into transverse skeletal discrepancies and dental compensations within an underrepresented group in the literature.

2. MATERIALS AND METHODS

2.1 Study Design and Ethics

This retrospective cross-sectional study was conducted in 2024 at the Department of Orthodontics, Faculty of Dentistry, Sana'a University. CBCT scans were acquired between 2020 and 2023 from Al-Waleed 3D X-ray Center, a private dental radiology facility in Sana'a, Yemen. Over 500 archived scans were reviewed, and 87 cases that met the inclusion criteria were selected. Ethical approval was obtained from the Institutional Medical Ethics Committee at Sana'a University (Approval No.: OR:15/12/2023), and all data were anonymized in accordance with institutional research protocols. This study was conducted in accordance with the Declaration of Helsinki.

2.2 Sample Selection

The study sample included Yemeni adults aged 17–40 years who had full permanent dentition up to the second molars. Selection focused on cases suitable for transverse skeletal analysis, excluding those with prior orthodontic intervention, prosthetic restorations (e.g., crowns or implants), extensive carious lesions, large fillings, or compromised occlusal anatomy such as impacted teeth, severe spacing or crowding, and pronounced rotations. Scans lacking image clarity or anatomical consistency were also eliminated. After reviewing 98 eligible cases, 11 were excluded due to extreme transverse discrepancy (>5 mm), resulting in a .final sample of 87 individuals.

2.3 CBCT Protocol

CBCT scans were acquired using a PaX-i3D Green system (Vatech, Korea) with 15×15 cm field of view and 0.2–0.3 mm voxel size. Scans were taken in full-face view at maximum intercuspation, with the Frankfort horizontal plane parallel to the floor to ensure proper head positioning."Exposure settings were 50–99 kV, 4–16 mA, and 15 seconds scan time, as per the manufacturer's guidelines. Images were analyzed using Ez3D-i software (Ewoosoft, Korea) following multiplanar reconstruction. Orientation was standardized using the midpalatal suture (vertical) and functional occlusal plane (horizontal).

2.4 Measurement Protocol and Grouping

Skeletal transverse width was evaluated using standardized CBCT slices in both axial and coronal views. A modified mid-basilar reference line was used for maxillary width assessment, defined midway between the jugale-based plane [16] and the buccal concavity plane [17], following orientation guidelines derived from the University of Pennsylvania protocol.

The mandibular width was measured at the basal level using the WALA ridge reference (mandibular width plane), which served as the definitive skeletal baseline for comparison. The transverse skeletal discrepancy was calculated as the difference between maxillary and mandibular widths, and participants were classified into two groups: "normal" (0–5 mm difference) and "narrow" (maxillary width ≤ mandibular width).

Molar inclination was measured in the coronal view by calculating the angle between the long axis of the first molars (from buccal cusp tip to root furcation midpoint) and the corresponding skeletal reference line. The mid-basilar plane was used for maxillary molars, and the WALA plane for mandibular molars. Right and left measurements were averaged.

The skeletal and angular reference structures used in the study are illustrated in Figure 1.

"Further details of the CBCT measurement protocol and supplemental figures are provided in Appendix A."

2.5 Statistical Analysis and Reliability

To evaluate intra-examiner reliability, all measurements were repeated by the same examiner in a subset of 20 cases after a two-week interval. All statistical analyses were performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (means and standard deviations) were calculated for all skeletal and dental variables. The Kolmogorov–Smirnov test was used to assess normality.

Independent samples t-tests were used to compare transverse widths and molar inclinations between the two groups (normal vs. narrow). One-way ANOVA and chi-square tests were applied where applicable. Pearson's correlation coefficient was used to assess the linear relationship between transverse skeletal discrepancy and molar inclination.

Intraclass correlation coefficients (ICC) were calculated, with values above 0.90 indicating excellent agreement.

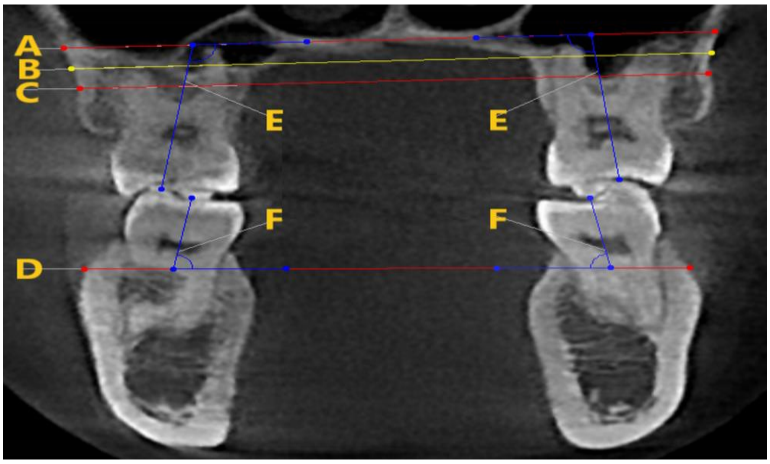

Figure 1. The skeletal and dental reference structures are used in measurement.

The components include:

A: Maxillary basilar plane – transverse skeletal line connecting the bilateral jugale points at the level of the zygomatic buttress.

B: Mid-basilar plane – a newly defined horizontal reference plane located midway between the basilar and width planes, providing a balanced skeletal reference for maxillary width assessment. C: Maxillary width plane – line passing through the buccal concavity region, approximately between the alveolar crest and root apex of the maxillary first molars.

D: Mandibular width plane – transverse skeletal line drawn at the WALA ridge level, representing the basal width of the mandibular arch.

E: Maxillary molar axis – line drawn from the buccal cusp tip to the center of the root furcation of the first maxillary molar, used for inclination analysis.

F: Mandibular molar axis – line connecting the buccal cusp tip to the midpoint between the mesial and distal root apices of the first mandibular molar.

3. RESULTS

3.1. Sample Characteristics and Group Distribution

This study analyzed 87 CBCT scans of untreated Yemeni adults. Participants were categorized into normal (n = 58) and narrow maxilla groups (n = 29) based on the skeletal transverse width difference (Mx–Mn). Table 1 presents the distribution of gender, skeletal classification, and posterior crossbite across both groups. The narrow group included a higher proportion of females and Class II subjects compared to the normal group. Posterior crossbite, particularly the bilateral form, was predominantly found in the narrow group, while it was rare among subjects with normal transverse width.

Table 1. Illustrates the flow of sample selection and crossbite distribution.

Variable	Normal Maxilla (n = 58)	Narrow Maxilla (n = 29)	Total (n = 87)
Gender – Male	29	12	41
Gender – Female	29	17	46
Skeletal Class I	36	12	48
Skeletal Class II	16	11	27
Skeletal Class III	6	6	12
No Posterior Crossbite	52	11	63
Unilateral Crossbite	6	10	16
Bilateral Crossbite	0	8	8

3.2. Transverse Skeletal Widths

The skeletal transverse width measurements showed significant differences between the two groups. Subjects with a narrow maxilla had a significantly reduced maxillary width (54.55 ± 2.8 mm) compared to those with a normal maxilla (57.55 ± 3.1 mm; $p < 0.001$). Conversely, mandibular width was greater in the narrow group (57.5 ± 3.3 mm) than in the normal group (55.2 ± 3.1 mm; $p = 0.003$). This reversal in maxillo-mandibular width confirmed a true skeletal transverse discrepancy in the narrow group (negative Mx–Mn).

Table 2. Comparison of skeletal transverse widths between normal and narrow groups (mm).

Variable	Normal Maxilla (n = 58) Mean ± SD	Narrow Maxilla (n = 29) Mean ± SD	p-value
Maxillary width	57.55 ± 3.1	54.55 ± 2.8	< 0.001*
Mandibular width	55.2 ± 3.1	57.5 ± 3.3	0.003*
Mx–Mn width difference	+2.35 ± 1.5	–2.95 ± 1.2	< 0.001*

*Denotes statistical significance ($p < 0.05$).

3.3. Molar Inclination

The inclination of the first molars showed significant differences between the two groups. Maxillary molars were more buccally inclined in the narrow maxilla group (195.2° ± 11.4) compared to the normal group (189.8° ± 7.2; $p = 0.028$). Mandibular molars, in contrast, showed greater lingual inclination in the narrow group (146.3° ± 10.6) than in the normal group (155.1° ± 8.5; $p < 0.001$). These findings indicate a transverse compensatory pattern, with opposing inclinations in the upper and lower molars among subjects with skeletal maxillary constriction.

Table 3. Comparison of molar inclination angles between normal and narrow maxilla groups

Variable	Normal Maxilla (n = 58) Mean ± SD	Narrow Maxilla (n = 29) Mean ± SD	p-value
Maxillary molar inclination (°)	189.8 ± 7.2	195.2 ± 11.4	0.028*
Mandibular molar inclination (°)	155.1 ± 8.5	146.3 ± 10.6	< 0.001*

*Denotes statistical significance ($p < 0.05$).

Figure 2. Representative CBCT coronal images illustrating general differences in maxillomandibular transverse skeletal relationships and molar inclinations among subjects. The image reflects the range of patterns observed across the classified groups, including skeletal width variation and dental compensation.

3.4. Correlation Between Width and Inclination

Pearson correlation analysis revealed a strong positive association between the maxillary–mandibular width difference (Mx–Mn) and the maxillary molar inclination angle ($r = +0.535$, $p < 0.001$). A moderate negative correlation was found with mandibular molar inclination ($r = –0.463$, $p < 0.001$). These results indicate that greater skeletal transverse deficiency (i.e., more negative Mx–Mn values) is associated with increased buccal tipping of upper molars and compensatory lingual tipping of lower molars.

Table 4. Correlation between maxillo-mandibular width difference (Mx–Mn) and molar inclination angles.

Correlated Variables	Pearson correlation (r)	p-value
Mx–Mn width vs. Maxillary molar inclination	+0.535	< 0.001*
Mx–Mn width vs. Mandibular molar inclination	−0.463	< 0.001*

*Denotes statistical significance ($p < 0.05$).

4. DISCUSSION

This CBCT-based study aimed to investigate the relationship between transverse basal arch width and molar inclination in untreated Yemeni adults, using a standardized skeletal reference plane at the mid-basilar level. This methodological approach improved diagnostic precision by minimizing the influence of crown angulation and alveolar remodeling, as previously highlighted Tamburrino et al. [18]. The primary outcomes demonstrated that individuals with narrow maxilla presented both skeletal constriction and notable dentoalveolar compensation through buccolingual molar tipping.

Quantitatively, the narrow maxilla group exhibited a significantly reduced transverse width of the maxilla (54.55 ± 2.8 mm) compared to the normal group (57.55 ± 3.1 mm, P < 0.001), while the mandibular width was paradoxically greater in the narrow group (57.5 ± 3.3 mm) versus the normal group (55.2 ± 3.1 mm, P = 0.003). This skeletal disproportion produced a negative Mx–Mn difference in the narrow group (–2.95 ± 2.5 mm) compared to a positive value in the normal group (+2.35 ± 1.6 mm), indicating a true transverse deficiency in the maxilla. These skeletal changes were accompanied by a consistent pattern of dental compensation: maxillary molars in the narrow group showed greater buccal inclination (195.2° ± 11.4 vs. 189.8° ± 7.2, P = 0.028), while mandibular molars were significantly more lingually inclined (146.3° ± 10.6 vs. 155.1° ± 8.5, P < 0.001).

These findings confirm that molar inclination acts as a compensatory response to skeletal transverse imbalance. This is in agreement with observations reported by Albalawi et al. [19] in Saudi adults, and by Kim et al. [20] and Rathi et al. [21] in similar CBCT-based investigations.

A significant statistical correlation was found between the maxillary–mandibular width difference and molar inclination. Specifically, a positive correlation existed with upper molar inclination ($r = +0.535$), while a negative correlation was found with lower molar inclination (r = –0.463), both of which were statistically significant. These results highlight the adaptive mechanism of molar tipping in response to skeletal disharmony, supporting the conclusions of Kim et al. [20] and Rathi et al. [21], who emphasized the role of molar angulation in maintaining occlusal function when mild transverse discrepancies are present.

This consistent correlation pattern raises a critical clinical concern: transverse skeletal deficiencies may go undetected in the presence of compensatory dentoalveolar inclinations. In such cases, clinicians may be misled by apparently aligned occlusion, overlooking the underlying skeletal disharmony. This phenomenon was also highlighted by Gribel et al. [22] and Proffit et al. [23], who stressed the diagnostic risk of relying solely on dental arch form or occlusal appearance without CBCT-based skeletal assessment

When analyzing subgroups by sagittal skeletal classification, clinically meaningful variations in transverse compensation were observed. Class II individuals demonstrated the narrowest maxillary widths and the most pronounced buccal inclination of upper molars, consistent with the pattern of maxillary underdevelopment described in previous literature.[24] Conversely, Class III subjects presented with wider mandibular arches and more evident lingual tipping of lower molars—likely a compensatory response to skeletal mandibular prominence, in agreement with findings from López-Areal et al. [25] and Rong et al. [26]

Posterior crossbite was observed in 62% of individuals with narrow maxillae; however, many cases lacked this sign despite evident skeletal deficiency. Molar tipping likely masked the discrepancy, creating a misleading occlusal appearance. As Proffit et al. [23] emphasized, crossbite absence does not rule out underlying transverse disharmony.

This study has several limitations. Its retrospective, cross-sectional design restricts the ability to assess longitudinal changes or determine causal relationships. The sample included only adults aged 17–40 years, excluding growing children and prepubertal individuals who may exhibit different skeletal growth patterns and dentoalveolar compensation. Additionally, functional factors such as tongue posture, muscular forces, and airway volume were not assessed, though they may influence transverse development and molar inclination.

5. CONCLUSIONS

In this study, we found that skeletal maxillary constriction is not always obvious during clinical examination. Molar inclination may play a role in compensating for the transverse skeletal deficiency, which can make the condition more difficult to detect, especially in the absence of clear clinical signs like posterior crossbite. Our measurements of skeletal width and molar angulation using CBCT helped us detect discrepancies that might not have been noticed in a routine clinical exam. This highlights the importance of looking at both the skeletal and dental structures together, especially when planning for stable and individualized orthodontic treatment.

6. DECLARATIONS

Funding

This research received no external funding or financial support.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Medical Ethics Committee at Sana’a University (Approval No.: OR:15/12/2023).

Acknowledgments

The author gratefully acknowledges the Faculty of Dentistry, Sana’a University, and Dr. Naela Al Mogahed for their valuable guidance, as well as Al-Waleed 3D X-ray Center for their support in data collection.

Abbreviations:

The following abbreviations are used in this manuscript:

CBCT	Cone-Beam Computed Tomography
Mx	Maxillary width
Mn	Mandibular width
Mx–Mn	Maxillary–Mandibular Width Difference
WALA	Width At the Level of the Alveolar Ridge (WALA ridge)
ICC	Intraclass Correlation Coefficient
SPSS	Statistical Package for the Social Sciences
ANOVA	Analysis of Variance

REFERENCES

1. Fields, H.W.; Sarver, D.M.; Proffit, W.R. Contemporary Orthodontics. 5th ed; Elsevier Mosby: St. Louis, MO, USA, 2013; pp. 1–984
2. Thilander B, Pena L, Infante C, Parada SS, de Mayorga C. Prevalence of malocclusion and orthodontic treatment need in children and adolescents in Bogota, Colombia. Eur J Orthod. 2001;23(2):153–167.
3. McNamara JA. Components of Class II malocclusion in children 8–10 years of age. Angle Orthod. 1981;51(3):177–202.
4. Betts NJ, Vanarsdall RL, Barber HD, Higgins-Barber K, Fonseca RJ. Diagnosis and treatment of

transverse maxillary deficiency. Int J Adult Orthod Orthognath Surg. 1995;10(2):75–96.
5. Bell RA, Kiebach TJ, Williamson PC. Posterior crossbite in orthodontic patients. Am J Orthod Dentofacial Orthop. 2006;129(3):382–391.
6. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. Angle Orthod. 1961;31(2):73–90.
7. Bishara SE, Staley RN. Maxillary expansion: clinical implications. Am J Orthod Dentofacial Orthop. 1987;91(1):3–14.
8. Handelman CS. Nonsurgical rapid maxillary alveolar expansion in adults: A clinical evaluation. Angle Orthod. 1997;67(4):291–305.
9. Graber TM, Vanarsdall RL, Vig KWL. Orthodontics: Current Principles and Techniques. 5th ed. St. Louis: Elsevier; 2011.
10. Baik UB, Lee HJ, Choi DS, Kim SS. Buccal shelf area for orthodontic mini-implant placement in the mandibular molar region: A CBCT analysis. Korean J Orthod. 2020;50(4):227–234.
11. Baccetti T, Franchi L, McNamara JA Jr. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod. 2001;7(3):119–129.
12. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: A mixed-longitudinal study covering 25 years. J Prosthet Dent. 2003;89(5):427–435.
13. Alkhatib R, Chung CH. Buccolingual inclination of first molars in untreated adults: A CBCT study. Angle Orthod. 2018;88(2):157–163.
14. Tong H, Xu L, Khambay B, Hu W. Validation of a method for assessing molar inclination using cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2012;142(4):597–603.
15. Sato S, Motegi E, Yamaguchi H. Molar inclination in untreated subjects with different skeletal patterns. Eur J Orthod. 2007;29(5):467–472.
16. Kim Y, Park JH, Lee Y, Shin JW. Molar inclination and surrounding alveolar bone change relative to the design of bone-borne maxillary expanders: A CBCT study. Orthod Waves. 2023. doi:10.1016/j.odw.2023.01.004.
17. Lee HY, Choi YJ, Lee KJ, Park YC, Kim KH. Three-dimensional craniofacial changes with maxillary expansion in young adult patients with different craniofacial morphology. APOS Trends Orthod. 2021;11(2):85–92.
18. Tamburrino K. Cone-beam CT analysis of transverse skeletal discrepancy in orthodontics. University of Pennsylvania ScholarlyCommons. 2010. Available from: https://repository.upenn.edu/dental_theses/1
19. Albalawi FA, Alhammadi MS, Alahmari MA, et al. Transverse dentoskeletal features and buccolingual inclination of molars in Saudi adults with skeletal Class I, II, and III: A CBCT study. Diagnostics. 2023;13(3):567.
20. Kim Y, Park JH, Lee Y, Shin JW. Molar inclination and surrounding alveolar bone change relative to the design of bone-borne maxillary expanders: A CBCT study. Orthod Waves. 2023. doi:10.1016/j.odw.2023.01.004.
21. Rathi MK, Khan SR, Alqahtani N. Evaluation of maxillary and mandibular transverse arch widths and molar angulation using cone-beam computed tomography. Int J Orthod. 2021;32(3):133–140.
22. Gribel BF, Gribel MN, Frazao DC, McNamara JA Jr, Manzi FR. Accuracy and reliability of craniometric measurements on CBCT images using different resolution protocols. J Appl Oral Sci. 2011;19(3):259–265.
23. Proffit WR, Fields HW, Larson B, Sarver DM. Contemporary Orthodontics. 6th ed. St. Louis: Elsevier; 2019.
24. Park JH, Kim TW. Transverse dental compensation in skeletal Class III patients with facial asymmetry: A CBCT analysis. Am J Orthod Dentofacial Orthop. 2017;152(5):661–670.
25. López-Areal L, Gandia JL, Cibrian R. Buccolingual inclination of molars in untreated Class III subjects: A CBCT study. Angle Orthod. 2017;87(4):598–604.
26. Rong Q, Chen M, Zhang X. Relationship between skeletal and dental arch widths in Chinese adults: A CBCT-based study. J Craniofac Surg. 2020;31(4):1024–1029.

Appendix

Appendix A CBCT Measurement Protocol and Supplemental Figures

This appendix includes supplemental figures and technical descriptions that illustrate the detailed CBCT-based measurement procedures utilized in this study. The goal is to provide enhanced clarity and transparency for the steps followed during image reorientation, landmark identification, and transverse/molar inclination measurements.

Appendix A.1. Reorientation and Slice Selection

Figure A1. Multiplanar reorientation using the midpalatal suture and occlusal plane.

This image illustrates the alignment of the CBCT volume using the midpalatal suture as the sagittal reference and the occlusal plane for horizontal correction

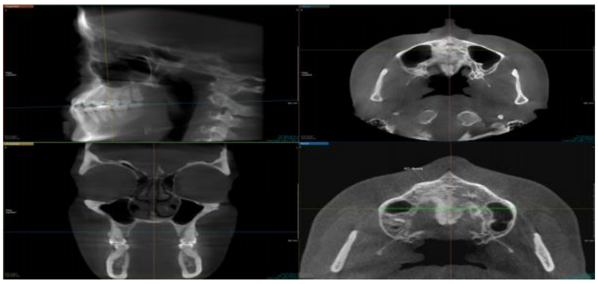

Figure A2. Coronal and axial slice selection through the first molars.

The slice was selected at the level of the root furcation to capture consistent anatomical reference points.

Appendix A.2. Maxillary Basal Width Measurement

After reorienting the scan using the midpalatal suture and the functional occlusal plane, axial slices were reviewed to identify the furcation area just anterior to the palatal root of the maxillary first molars. The optimal axial slice was selected to ensure a symmetric transverse view through both molars.

Figure A3. Axial CBCT slice selected through the furcation of the maxillary first molars.

To locate the anatomical Mx points that define the skeletal maxillary width, two horizontal reference lines were constructed:
(1) the superior line at the jugale level (as described by Tamburrino et al., 2010), and
(2) the inferior line midway between the buccal alveolar crest and root apex of the first molar (as per Albalawi et al., 2023).
A perpendicular vertical line was then established between these two reference planes. The midpoint of this vertical segment defined the position of the mid-basilar plane, from which the bilateral Mx landmarks were selected at the deepest buccal concavity.
This process was visually verified using both axial and coronal CBCT views to ensure anatomical consistency (see anatomical illustration in Figure 1).

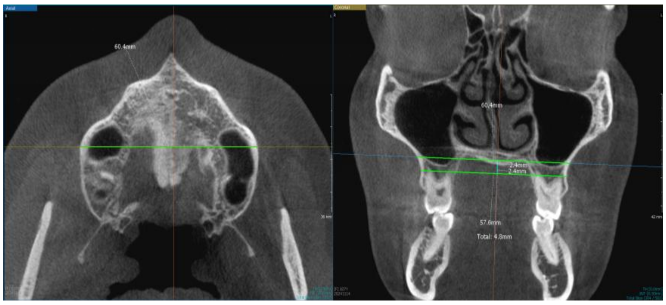

Figure A4. Identification of bilateral basal landmarks (Mx–Mx) on axial and coronal views.

The mid-basilar plane derived from the midpoint between the superior and inferior reference levels provided a balanced skeletal framework for evaluating transverse arch width. The distance between the right and left Mx points along this defined plane was recorded as the maxillary basal arch width for all study participants.

This approach ensures reliable cross-subject comparison and anatomical accuracy in skeletal width assessment.

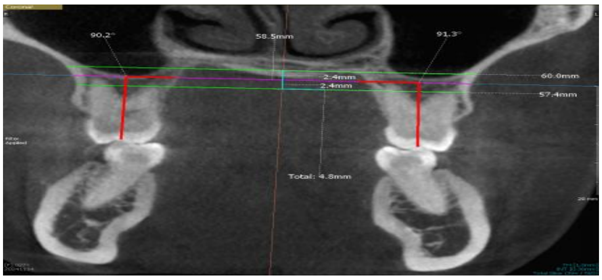

Figure A5. Construction of the mid-basilar skeletal plane and final width measurement.

Appendix A.3. Mandibular Basal Width Measurement

The optimal axial slice was selected to pass through the anatomical level of the WALA ridge, representing the most prominent contour of the buccal alveolar process near the mandibular molars. This level provides a stable reference for basal arch evaluation.

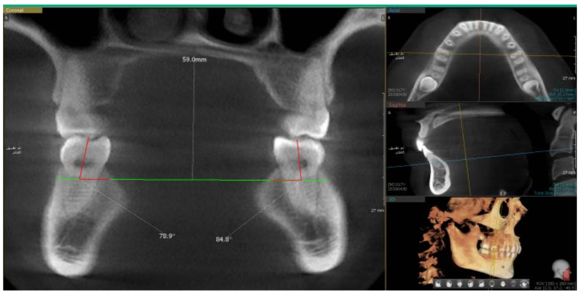

Figure A6. Selection of axial slice passing through the WALA ridge.

Badr H. M. Q. Dammag, Naela Al Mogahed. Relationship Between Transverse Basal Arch Width and Molar Inclination: A CBCT Study in Yemeni. Bulletin of Stomatology and Maxillofacial Surgery. 2025;21(8).369-377
doi:10.58240/1829006X-2025.21.8-369

The transverse width was measured between the innermost curvature points of the buccal cortical plates at the WALA ridge bilaterally. These points were determined in axial view and verified by correlating with sagittal and coronal slices to ensure anatomical consistency.

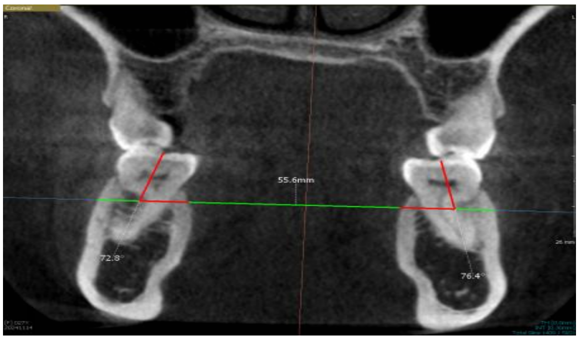

Figure A7. Identification of bilateral WALA points (Mn–Mn) and measurement method.

Appendix A.4. Molar Inclination Measurement Technique

Maxillary Molar Inclination

The long axis of the maxillary first molar was defined as a line connecting the deepest point between the buccal and palatal cusps to the center of the palatal root apex. This axis was identified using sagittal CBCT slices. The inclination angle was measured between this axis and a horizontal transverse skeletal plane passing through the basal buccal contour. This angular relationship indicates the degree of buccal tipping in the maxillary molars, especially in subjects with transverse maxillary constriction(see Figure A5).

Mandibular Molar Inclination.

For mandibular molars, the long axis was traced from the central fossa between buccal and lingual cusps to the bifurcation midpoint of the roots, visualized in sagittal slices. The angle was measured relative to the mandibular transverse plane at the level of the WALA ridge, reflecting the degree of lingual tipping commonly associated with skeletal compensation (see Figure A7).

Badr H. M. Q. Dammag, Naela Al Mogahed. Relationship Between Transverse Basal Arch Width and Molar Inclination: A CBCT Study in Yemeni. Bulletin of Stomatology and Maxillofacial Surgery. 2025;21(8).369-377
doi:10.58240/1829006X-2025.21.8-369