

Mandibular buccal shelf asymmetry and bone density in vietnamese adults: a CBCT study

Trung Nhu Nguyen, Vy T. T. Huynh and Huong Quynh Nguyen

Faculty of Odonto-Stomatology, Pham Ngoc Thach University of Medicine, Ho Chi Minh City, Vietnam

Objectives: To assess using CBCT, the mandibular buccal shelf (MBS) bone thickness asymmetry and its relationship with cortical and cancellous bone density in Vietnamese adults presenting with Class I bimaxillary protrusion (Class I BP) and skeletal Class III malocclusions.

Materials and Methods: CBCT scans of 60 Vietnamese adults (30 Class I BP: 7 males, 23 females, mean age 27.63 years; 30 Class III: 15 males, 15 females, mean age 23.63 years) were analysed. Total bone thickness (dTB) was measured at 6, 9, and 12 mm below the cemento-enamel junction at the mandibular first and second molars (R6G, R6X, R7G, R7X). Cortical (MĐV) and cancellous (MĐX) bone density were evaluated. Left-right asymmetry was tested using Wilcoxon or t-tests, and correlations were assessed using Spearman's rho coefficient ($P < 0.05$).

Results: Class I BP cases showed significant left-right asymmetry in dTB at R6G and R6X (e.g., R6G 6 mm: 1.57 ± 0.93 mm vs. 2.25 ± 1.38 mm, $P = 0.004$). The Class III group showed no asymmetry ($P > 0.05$). No significant correlations were found between dTB and MĐV or MĐX (e.g., Class I BP, R7X 12 mm: $r = -0.087$, $P = 0.646$ for MĐV). No intergroup differences in dTB were observed ($P > 0.05$).

Conclusions: A Class I BP malocclusion exhibited MBS asymmetry at R6G and R6X, unlike a symmetrical Class III malocclusion. No correlation between bone thickness and density suggested independent adaptations, aiding miniscrew placement in Vietnamese adults.

(Aust Orthod J 2025; 41: 275 - 283. DOI: 10.2478/aoj-2025-0026)

Received for publication: April, 2025

Accepted: June, 2025.

Trung Nhu Nguyen: trungnn@pnt.edu.vn; Vy T. T. Huynh: vyhtt@pnt.edu.vn; Huong Quynh Nguyen: huongqnguyen@pnt.edu.vn

Introduction

The mandibular buccal shelf (MBS), located buccal to the mandibular molars, serves as a critical anchorage site for orthodontic miniscrew placement due to its substantial bone volume and cortical thickness, essential for managing complex malocclusions such as Class I bimaxillary protrusion (Class I BP) and skeletal Class III cases.¹⁻³ These malocclusions are prevalent among Asians, with a Class III relationship affecting approximately 15–23% of particular Asian ethnic groups.⁴ Accurate assessment of MBS morphology is vital to optimise miniscrew stability and enhance treatment outcomes.⁵ Cone-beam computed

tomography (CBCT) offers high-resolution, three-dimensional imaging to evaluate bone thickness and density thereby surpassing traditional radiographs.^{6,7} Total bone thickness (dTB), cortical density (MĐV), and cancellous density (MĐX) influence miniscrew primary stability, with cortical bone playing a pivotal role.^{8,9} Variations in mandibular bone morphology may complicate uniform miniscrew placement, potentially increasing failure rates if thinner regions are selected.^{5,10} MBS studies, such as Nucera et al. (2017) on Caucasians and Sreenivasagan et al. (2021) on Dravidian cohorts, are extensive, but data on Vietnamese adults with unique craniofacial traits

remain limited. Variations in cortical bone thickness reflect structural adaptations, with evidence differing across populations.^{5,11–13} Understanding these relationships in Vietnamese adults could refine anchorage strategies and address a gap in population-specific orthodontic research. The present study aims to assess left-right asymmetry in dTB at levels 6, 9, and 12 mm below the cemento-enamel junction (CEJ) at the mesial and distal roots of the mandibular first and second molars, evaluate correlations between dTB and MĐV/MĐX, and compare the findings in Vietnamese adults between Class I BP and Class III malocclusions.

Materials and Methods

This retrospective cross-sectional study analysed the CBCT records of 60 Vietnamese adults (ethnic Kinh, aged ≥ 18 years) from a dental clinic and collected between November 2019 and March 2024. The sample comprised 30 Class I BP patients (7 males, 23 females; mean age 27.63 ± 5.56 years) and 30 Class III patients (15 males, 15 females; mean age 23.63 ± 4.36 years). The gender of the participants was determined based on the clinical records. A Class I BP was defined by molar Class I, skeletal Class I ($0^\circ < \text{ANB} < 5^\circ$) relationships, and protrusive incisors ($\text{U1-NA} > 24.8^\circ$, $\text{L1-NB} > 29.1^\circ$, $\text{I/i} < 123^\circ$).¹⁴ A Class III was defined by a skeletal Class III pattern ($\text{ANB} < 0^\circ$) without a functional mandibular shift.¹⁴ The inclusion criteria required a complete mandibular dentition (excluding third molars) and no prior orthodontic treatment. Exclusion criteria included craniofacial anomalies, systemic bone disorders, or medications affecting bone metabolism. The study was approved by the Institutional Review Board (IRB No. 1082/TĐHYKPNT-HĐĐĐ), adhering to the Declaration of Helsinki. As this was a retrospective study using anonymised CBCT records, the IRB deemed informed consent unnecessary.

The sample size was calculated to detect a 1.0 mm difference in total bone thickness (dTB) between Class I BP and Class III malocclusions, with a standard deviation of 1.6 mm based on prior CBCT studies of mandibular buccal shelf morphology.¹⁵ Using a Mann-Whitney U test with a two-sided $\alpha = 0.05$, 80% power, and a 15% adjustment for non-parametric efficiency, approximately 31 patients per group were required. A sample of 30 patients per group (60 total) was selected due to practical constraints, and to maintain adequate power

($>75\%$) for assessing intergroup differences, left-right asymmetry, and correlations between bone thickness and density. Scans were obtained using a KaVo OP 3D Vision unit (KaVo, Germany; FOV 190×210 mm, 110 kVp, 6.33 mA, 3.5 s exposure, 0.3 mm slice thickness, 0.3 mm^3 voxel size). DICOM files were analysed using OnDemand3D software (Cybermed, Korea). The images were standardised using axial (tangent to RCL1/RCL2 bifurcation), sagittal (through root midpoints), and coronal (parallel to RCL2 mesial root) planes.¹⁶ Total bone thickness (dTB) was bilaterally measured at 6, 9, and 12 mm below the cemento-enamel junction (CEJ) at the mesial (R6G, FDI 36M, 46M) and distal (R6X, FDI 36D, 46D) roots of the mandibular first molar and mesial (R7G, FDI 37M, 47M) and distal (R7X, FDI 37D, 47D) roots of the mandibular second molar on sagittal slices, parallel to the occlusal plane. Cortical density (MĐV) and cancellous density (MĐX) were quantified within thickness rectangles of 3 mm at these sites.¹⁵ MĐV and MĐX were averaged across 30° , 45° , and 60° angulations to account for angular variability. Measurements were performed by a single examiner with high intra-rater reliability ($\text{ICC} > 0.9$, 6 cases re-measured after 2 weeks). Data normality was assessed using Shapiro-Wilk tests. Left-right asymmetry was evaluated with Wilcoxon signed-rank tests (non-normal data) or paired t-tests (normal data). Correlations between dTB and MĐV/MĐX were tested using Spearman's rho coefficient. To compute correlations at each site and level, dTB, MĐV, and MĐX values were averaged between the left and right sides for each patient to obtain a single representative value per individual. For MĐV and MĐX, the mean density across the 30° , 45° , and 60° angulations was calculated for each side before bilaterally averaging. The bilateral averages were used to calculate Spearman's rho correlation coefficients and corresponding *P*-values for the relationships between dTB and MĐV, and between dTB and MĐX, at each specified site and level (R6G at 6 mm and 9 mm, R6X at 9 mm, R7X at 12 mm). Intergroup comparisons employed Mann-Whitney U or independent t-tests. Significance was set at $P < 0.05$. The statistical analyses were conducted using SPSS 25.0 (IBM, USA). A heat map of total bone thickness (dTB) was generated using the Seaborn library in Python (<https://github.com/mwaskom/seaborn>) to visualise the distribution of bone thickness across sites and depths.

Results

The Class I BP group had a higher female population (76.7% vs. 50% in the Class III group), with no significant age difference between the groups ($P=0.123$). Significant left-right asymmetry was observed at R6G and R6X in the Class I BP group. The asymmetry is clearly illustrated in a heat map (Figure 3), which demonstrates greater bone thickness on the right side at R6G (mean 2.25 mm at 6 mm) and R6X (mean 3.82 mm at 9 mm) compared to the left side in Class I patients. However, Class III patients exhibit uniform thickness across both sides. At R6G 6 mm, left dTB was mean 1.57 ± 0.93 mm vs. right mean 2.25 ± 1.38 mm, median 1.70 mm (IQR 1.22–3.00), $P=0.004$; at 9 mm, left mean 2.13 ± 1.27 mm, median 1.85 mm (IQR 1.40–2.40) vs. right mean 2.90 ± 1.60 mm, median 2.63 mm (IQR 1.85–3.53), $P=0.008$; at 12 mm, left mean 2.77 ± 1.62 mm vs. right mean 3.57 ± 1.90 mm, $P=0.049$. At R6X 6 mm, left mean 2.09 ± 1.08 mm vs. right mean 2.77 ± 1.51 mm, $P=0.002$; at 9 mm, left mean 3.30 ± 1.46 mm vs. right mean 3.82 ± 1.72 mm, $P=0.032$. The differences in bone thickness between the left and right sides at R6X are illustrated in a representative CBCT sagittal view (Figure 1). No asymmetry was found at R7G or R7X (e.g., R7X 12 mm: mean 8.79 ± 2.48 mm vs. 8.86 ± 1.73 mm, $P=0.866$) (Table I). In the Class III group, no significant asymmetry was found across all sites (e.g., R6G 6 mm: mean 1.75 ± 1.13 mm, median 1.54 mm [IQR 1.07–2.04] vs. mean 1.78 ± 1.00 mm, $P=0.376$; R7X 12 mm: mean 8.52 ± 1.77 mm vs. 8.84 ± 2.31 mm, $P=0.331$) (Table I). No significant

correlations were observed between dTB and M Δ V or M Δ X in either group. For Class I BP cases, at R7X 12 mm, Spearman's $r=-0.087$ ($P=0.646$) for M Δ V and $r=-0.002$ ($P=0.991$) for M Δ X (Figure 2, Table II). Similarly, in the Class III group, correlations were non-significant (e.g., R7X 12 mm: M Δ V $r=-0.147$, $P=0.439$; M Δ X $r=0.003$, $P=0.986$) (Table II). Table II presents correlation data for selected sites and levels (R6G at 6 mm and 9 mm, R6X at 9 mm, R7X at 12 mm) that are representative of the overall trends observed across all measured sites; the sites were chosen due to their clinical relevance, as R6G and R6X showed significant asymmetry in the Class I BP group, and R7X at 12 mm is a common site for miniscrew placement. No significant differences in dTB were found between the Class I BP and Class III groups at any site or level (e.g., R6G 6 mm: mean 1.91 ± 1.02 mm, median 1.47 mm [IQR 1.28–2.35] vs. mean 1.77 ± 0.90 mm, median 1.58 mm [IQR 1.15–2.14], $P=0.652$; R7X 12 mm: mean 8.82 ± 1.83 mm vs. 8.68 ± 1.86 mm, median 8.48 mm [IQR 7.74–9.48], $P=0.520$) (Table III).

Discussion

The present study provides a pioneering analysis of mandibular buccal shelf (MBS) bone thickness asymmetry and density relationships in Vietnamese adults with Class I bimaxillary protrusion (Class I BP) and skeletal Class III malocclusions and addresses a critical gap in population-specific orthodontic research. Significant left-right

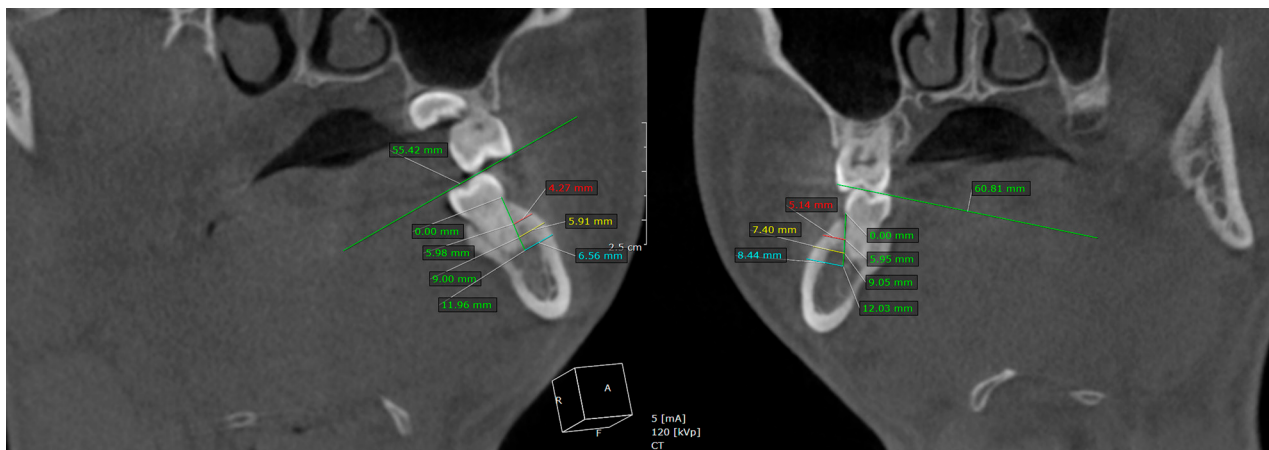


Figure 1. CBCT sagittal view of dTB asymmetry in a single patient. Sagittal slice comparing left and right total bone thickness (dTB) at R6X (distal root of the mandibular first molar, FDI 36D, 46D) in Class I bimaxillary protrusion. Measurements are taken at 6 mm, 9 mm, and 12 mm below the cemento-enamel junction (CEJ). Left side: 4.27 mm (6 mm), 5.91 mm (9 mm), 6.56 mm (12 mm). Right side: 5.14 mm (6 mm), 7.40 mm (9 mm), 8.44 mm (12 mm).

Table I. Left-Right Asymmetry in dTB below CEJ Levels (mm)

Site	Level	Class I BP Left	Class I BP Right	<i>P</i> (Left vs Right)	Class III Left Mean	Class III Right	<i>P</i> (Left vs Right)
		Mean (Median) (IQR)	Mean (Median) (IQR)		(Median) (IQR)	Mean (Median) (IQR)	
R6G	6 mm	1.57±0.93 (1.37) (0.95-1.99)	2.25±1.38 (1.70) (1.22-3.03)	0.004*	1.75±1.13 (1.54) (1.07-2.04)	1.78±1.00 (1.57) (1.22-2.06)	0.376
	9 mm	2.13±1.27 (1.85) (1.40-2.42)	2.90±1.60 (2.63) (1.85-3.53)	0.008*	2.68±1.68 (2.47) (1.59-3.31)	2.46±1.23 (2.24) (1.76-2.98)	0.696
	12 mm	2.77±1.62 (2.53) (1.77-3.46)	3.57±1.90 (3.29) (2.24-4.33)	0.049*	3.78±2.09 (3.58) (2.51-4.52)	3.39±1.54 (3.16) (2.35-4.38)	0.299
R6X	6 mm	2.09±1.08 (1.88) (1.57-2.50)	2.77±1.51 (2.53) (1.49-3.49)	0.002*	2.09±1.16 (2.10) (1.12-2.61)	2.36±0.97 (2.11) (1.84-2.77)	0.180
	9 mm	3.30±1.46 (3.29) (2.55-3.98)	3.82±1.72 (3.57) (2.54-5.16)	0.032*	3.31±1.58 (3.16) (2.52-3.81)	3.52±1.30 (3.77) (2.77-4.16)	0.644
	12 mm	4.19±1.66 (4.15) (3.11-4.96)	4.68±1.81 (4.89) (3.58-5.74)	0.063	4.48±1.78 (4.15) (3.55-5.42)	4.64±1.57 (4.82) (3.17-6.73)	0.538
R7G	6 mm	4.65±2.15 (4.26) (3.34-6.24)	4.91±1.81 (4.51) (3.36-6.39)	0.437	4.36±2.26 (4.06) (2.83-5.35)	4.22±2.56 (3.65) (2.61-4.98)	0.586
	9 mm	6.58±2.24 (6.67) (5.35-8.08)	6.81±1.84 (6.87) (5.46-9.25)	0.515	6.27±1.96 (5.88) (5.26-7.32)	6.18±2.32 (5.87) (4.82-7.18)	0.845
	12 mm	7.96±2.38 (8.27) (6.81-9.51)	8.07±1.83 (7.99) (6.80-9.49)	0.801	7.67±1.96 (7.72) (6.39-8.53)	7.52±2.10 (7.34) (6.38-8.05)	0.629
R7X	6 mm	6.16±2.54 (5.92) (4.68-7.67)	6.72±2.07 (6.53) (5.14-8.16)	0.195	6.08±2.23 (6.14) (3.99-7.49)	6.02±2.59 (5.94) (4.02-8.68)	0.858
	9 mm	7.84±2.37 (7.80) (6.85-8.98)	8.10±1.86 (7.92) (6.80-9.35)	0.504	7.70±1.84 (7.86) (6.51-8.35)	7.81±2.32 (7.61) (6.39-8.97)	0.731
	12 mm	8.79±2.48 (8.69) (7.15-10.43)	8.86±1.73 (8.81) (7.80-9.85)	0.866	8.52±1.77 (8.49) (7.42-10.62)	8.84±2.31 (8.57) (7.61-9.65)	0.331

**P*<0.05 (Wilcoxon signed-rank or paired *T*-tests); dTB, total bone thickness.

Note: IQR = Interquartile Range; M±SD = Mean±Standard Deviation.

asymmetry in total bone thickness (dTB) was observed in the Class I BP group at the mesial (R6G) and distal (R6X) roots of the mandibular first molar (e.g., R6G 6 mm: *P*=0.004). This finding complements studies reporting anatomical variations in mandibular bone morphology, which may influence miniscrew placement.⁵ Class I bimaxillary protrusion asymmetry may arise from uneven masticatory forces or occlusal patterns. Hedi Ma et al. (2024) linked unilateral chewing to asymmetrical

temporomandibular joint remodelling.¹⁷ In contrast, Class III patients exhibited no significant asymmetry across all sites (e.g., R6G 6 mm: *P*=0.376), consistent with Liu et al. (2019), who reported symmetrical MBS characteristics in Class III malocclusion cases, potentially due to balanced mandibular forces or the prognathic morphology.² The symmetry may reflect stable bilateral bone distribution, as noted in a study of Class III mandibular anatomy.¹⁸ The absence of significant correlations between dTB and cortical

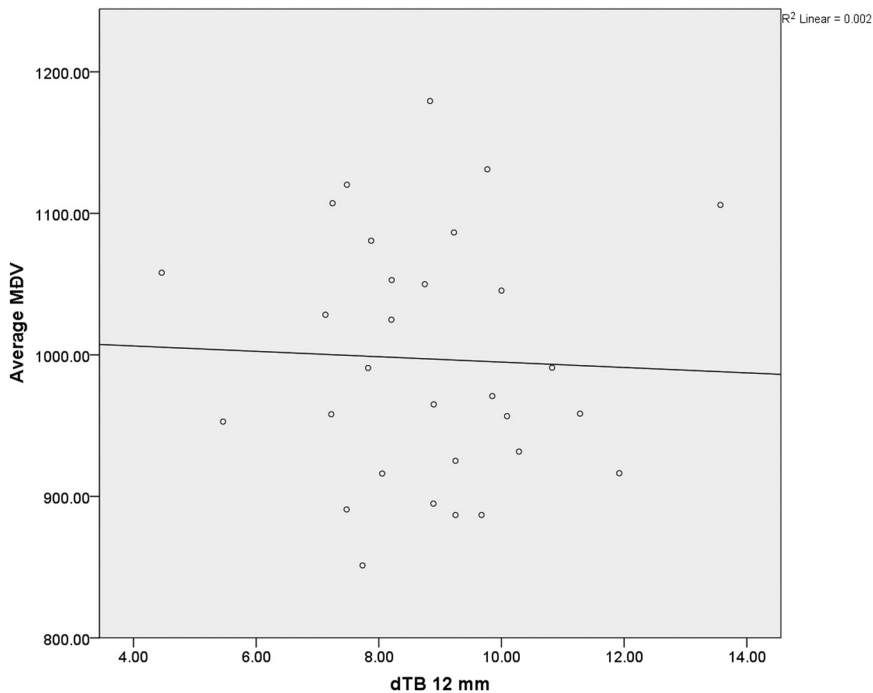


Figure 2. Correlation plot of dTB and MDV at R7X 12 mm. Scatter plot showing no significant correlation (Spearman's $r=-0.087$, $P=0.646$; $R^2=0.002$) between total bone thickness (dTB) at 12 mm below CEJ at the distal root of the mandibular second molar (R7X, FDI 37D, 47D) and cortical bone density (MDV) averaged across 30°, 45°, and 60° angulations in Class I bimaxillary protrusion patients. The x-axis represents dTB (mm), ranging from 4.00 to 14.00 mm, and the y-axis represents MDV (Hounsfield Units, HU), ranging from 800.00 to 1200.00 HU. Data represent 30 patients.

density (MDV) (e.g., R7X 12 mm, Class I BP: $r=-0.087$, $P=0.646$; Class III: $r=-0.147$, $P=0.439$) or cancellous density (MDX) (e.g., Class I BP: $r=-0.002$, $P=0.991$; Class III: $r=0.003$, $P=0.986$) suggests that bone thickness and density are independent factors in the MBS. Cortical bone thickness ≥ 1 mm enhances mini-implant stability (Motoyoshi, 2009). CBCT shows MDV often >800 HU, with ≥ 1000 HU optimal for support, while MDX ranges from 150 -300 HU, offering less stability.^{8,9} In the present study, MDV and MDX values were quantified to

assess their relationship with total bone thickness (dTB), but the lack of correlation suggests that high cortical density alone may not ensure thicker bone for anchorage. Clinically, sites with MDV above 1000 HU, such as R7X at 12 mm, may offer superior primary stability for miniscrews. This aids anchorage site selection, especially in symmetric Class III cases.¹⁹ Motoyoshi (2009) found cortical bone thickness ≥ 1 mm enhances miniscrew stability, without measuring density or confirming thickness-density correlation. Thus, thickness and density

Table II. Correlation Between dTB and Density averaged across all angulations below CEJ Levels

Site	Level	Class I BP dTB vs	Class I BP dTB vs	Class III dTB vs	Class III dTB vs
		MDV (r, p)	MDX (r, p)	MDV (r, p)	MDX (r, p)
R6G	6 mm	-0.024, 0.898	-0.031, 0.871	-0.291, 0.119	-0.174, 0.359
R6G	9 mm	0.057, 0.766	0.067, 0.725	-0.146, 0.441	-0.310, 0.095
R6X	9 mm	0.169, 0.371	-0.056, 0.769	-0.167, 0.378	-0.253, 0.177
R7X	12 mm	-0.087, 0.646	-0.002, 0.991	-0.147, 0.439	0.003, 0.986

Note: r =Spearman's rho correlation coefficient;

* $P<0.05$; dTB: total bone thickness; MDV: cortical density; MDX: cancellous density.

Table III. Intergroup dTB Comparison below CEJ Levels (mm)

Site	Level	Class I BP	Class III	<i>P</i> (I vs III)
R6G	6 mm	Mean±SD: 1.91±1.02 Median (IQR): 1.47 (1.28–2.35)	Mean±SD: 1.77±0.90 Median (IQR): 1.58 (1.15–2.14)	0.652
R6G	9 mm	Mean±SD: 2.51±1.25 Median (IQR): 2.17 (1.80–3.13)	Mean±SD: 2.57±1.21 Median (IQR): 2.32 (1.82–3.18)	0.695
R6G	12 mm	Mean±SD: 3.17±1.41 Median (IQR): 2.94 (2.34–3.76)	Mean±SD: 3.59±1.48 Median (IQR): 3.37 (2.66–4.47)	0.196
R6X	6 mm	Mean±SD: 2.43±1.19 Median (IQR): 2.17 (1.61–2.90)	Mean±SD: 2.22±0.93 Median (IQR): 2.13 (1.55–2.62)	0.652
R6X	9 mm	Mean±SD: 3.56±1.47 Median (IQR): 3.38 (2.73–4.32)	Mean±SD: 3.41±1.27 Median (IQR): 3.29 (2.72–3.85)	0.554
R6X	12 mm	Mean±SD: 4.44±1.60 Median (IQR): 4.46 (3.68–5.28)	Mean±SD: 4.56±1.52 Median (IQR): 4.63 (3.63–5.20)	0.756
R7G	6 mm	Mean±SD: 4.78±1.77 Median (IQR): 4.83 (3.57–5.74)	Mean±SD: 4.29±2.31 Median (IQR): 3.90 (2.75–5.20)	0.119
R7G	9 mm	Mean±SD: 6.70±1.79 Median (IQR): 7.02 (5.74–7.76)	Mean±SD: 6.22±2.01 Median (IQR): 5.97 (5.12–7.01)	0.058
R7G	12 mm	Mean±SD: 8.02±1.81 Median (IQR): 8.36 (6.61–9.21)	Mean±SD: 7.59±1.90 Median (IQR): 7.37 (6.65–8.18)	0.098
R7X	6 mm	Mean±SD: 6.44±2.00 Median (IQR): 6.50 (5.15–7.33)	Mean±SD: 6.05±2.24 Median (IQR): 6.13 (4.43–7.31)	0.333
R7X	9 mm	Mean±SD: 7.97±1.86 Median (IQR): 7.96 (7.00–9.16)	Mean±SD: 7.76±1.88 Median (IQR): 7.56 (6.52–8.42)	0.399
R7X	12 mm	Mean±SD: 8.82±1.83 Median (IQR): 8.86 (7.74–9.85)	Mean±SD: 8.68±1.86 Median (IQR): 8.48 (7.74–9.48)	0.520

P-values from Mann-Whitney U or *t*-tests; dTB: total bone thickness.

Note: IQR = Interquartile Range; M±SD = Mean±Standard Deviation.

may independently influence stability, challenging assumptions of their direct relationship.⁸ Park (2008) noted cancellous bone density is much lower than cortical bone density in alveolar and basal regions. According to Misch's classification, cancellous bone (D4) contributes little to anchorage stability, unlike critical cortical bone for miniscrew retention. This aligns with Park (2008) for density comparison which enhances classification accuracy.^{9,20} The lack of correlation between cortical bone thickness and bone characteristics may reflect Vietnamese-specific bone microarchitecture. Cortical bone thickness varies by location and gender (Ono, 2008), while trabecular microstructure changes with age (Tabassum,

2022), indicating complex structural influences on miniscrew stability.^{19,21} No significant differences in dTB were found between Class I BP and Class III at any site (e.g., R7X 12 mm: *P*=0.520), which aligns with Escobar-Correa et al. (2021), who reported comparable MBS thickness across malocclusion types in a Colombian population.¹⁵ This contrasts with the findings of Chen et al. (2007), who noted variations in miniscrew failure rates potentially linked to bone thickness differences in specific populations.²² The absence of intergroup differences in the present study may reflect Vietnamese craniofacial traits, in which a Class III relationship often results from maxillary hypoplasia rather than excessive mandibular growth,

thereby minimising MBS thickness variations.¹² Gender imbalance (76.7% female in Class I BP vs. 50% in Class III) may affect mandibular buccal shelf morphology, as gender influences bone thickness and density. Females have reduced cortical bone thickness compared to males (Ono, 2008; Eto, 2023), impacting miniscrew stability and anchorage planning.^{13,16} This imbalance could contribute to the observed asymmetry in Class I at R6G and R6X, in which the higher female proportion may amplify density trends. Supplementary Mann-Whitney U tests found no significant gender-based differences in bone thickness ($P>0.05$), but the limited sample size precluded an Analysis of Covariance. Future studies with balanced gender distributions are needed to confirm these findings and refine population-specific orthodontic strategies.²³ In Class I BP, left-right asymmetry in total bone thickness at R6G and R6X suggest prioritising thicker regions (e.g., right R6X: mean 2.77 ± 1.51 mm) for miniscrew placement to reduce perforation risk and enhance stability, as supported by Ono et al. (2008) emphasising thicker cortical bone for anchorage.¹³ The heat map (Figure 3) visualises this asymmetry, and so aids orthodontists in identifying optimal sites, such as the right R6X, for miniscrew placement based on bone thickness. The significant left-right asymmetry in total bone

thickness at R6G and R6X in Class I bimaxillary protrusion patients (e.g., R6G at 6 mm: left mean 1.57 mm vs. right mean 2.25 mm, $P=0.004$) may reflect anatomical or functional adaptations in the mandibular buccal shelf. Unilateral masticatory or asymmetric occlusal forces may drive asymmetry by resulting in different major pressure areas on bilateral TMJs, causing localised remodelling.⁵ Additionally, variations in mandibular morphology, such as slight deviations in ramus height, may exacerbate asymmetry in bone thickness. Three-dimensional computed tomography studies have demonstrated that patients with facial asymmetry and mandibular retrognathism commonly exhibit significant differences in ramal volume, condylar width and body volume between sides, which can contribute to asymmetrical bone structure in the mandibular buccal shelf region.¹⁸ Unrecorded chewing habits need study to optimise miniscrew placement in unique skeletal groups. Motoyoshi (2009) focused on cortical thickness, but functional factors require further research.⁸ Symmetrical MBS in Class III supports bilateral miniscrew insertion. Cortical thickness (3.54–4.05 mm at 30° angle, Chang, 2016) at sites 5–7 mm below the alveolar crest enhances stability. Thinner cortical bone increases reliance on cancellous bone modulus for

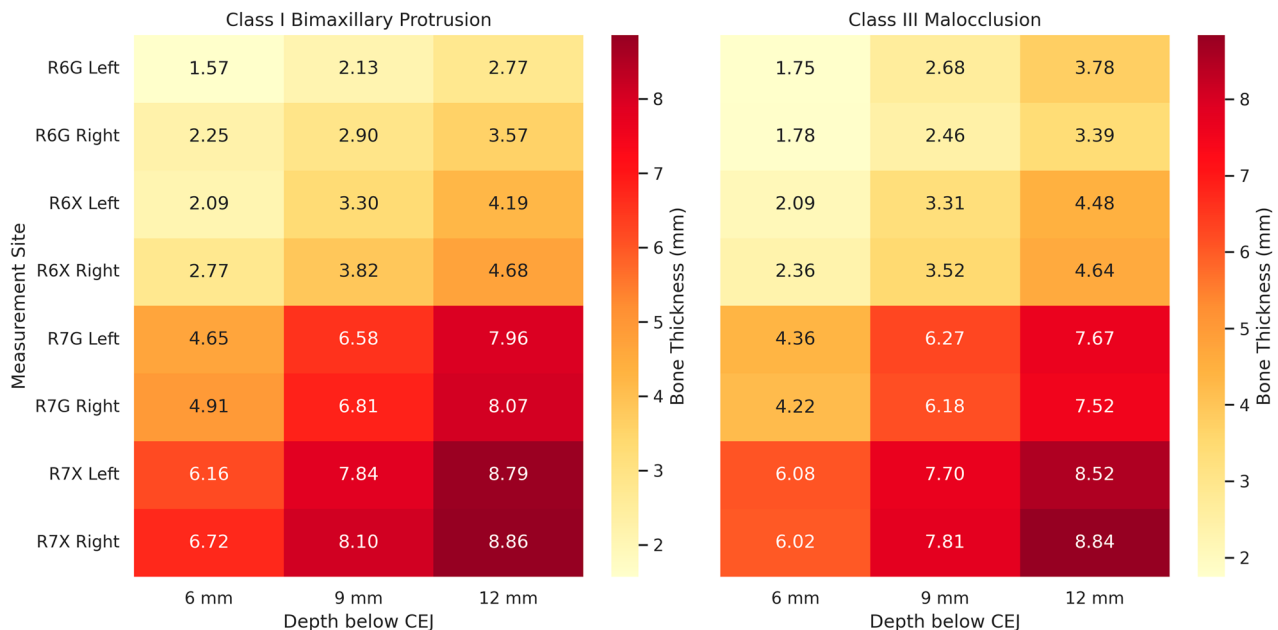


Figure 3. Heat map of total bone thickness (dTB) at sites R6G, R6X, R7G, and R7X at 6 mm, 9 mm, and 12 mm below the cemento-enamel junction (CEJ) in Class I bimaxillary protrusion and Class III patients. The colours represent bone thickness (mm), ranging from yellow (thin) to red (thick). (A) Class I shows pronounced left-right asymmetry at R6G and R6X. (B) Class III displays uniform thickness bilaterally. Data represent 30 patients per group.

miniscrew stability (Stahl, 2009), suggesting longer miniscrews (up to 10 mm) for better outcomes.^{19,24} These findings refine anchorage strategies for Vietnamese patients by addressing population-specific variations critical for miniscrew success. CBCT-based planning remains essential to identify optimal insertion sites, particularly in asymmetrical cases.⁶ The small sample size ($n=60$) limits detection of subtle bone density correlations. Gender imbalance in Class I BP (7 males, 23 females) may affect density results, as gender influences mandibular bone thickness and density.¹³ Measurements were restricted to levels 6, 9, and 12 mm below the CEJ, potentially missing apex-level variations that could reveal further patterns. The sample size was optimised for primary outcomes but may be underpowered for multiple comparisons thereby warranting cautious interpretation. Future studies should include larger, gender-balanced cohorts and employ advanced imaging, such as micro-CT, to explore bone micro-architecture. Longitudinal research could also assess how asymmetry impacts miniscrew stability over time and build on the biomechanical models proposed by Stahl et al. (2009).²⁴

Conclusions

- A Class I bimaxillary protrusion present in Vietnamese adults, exhibits mandibular buccal shelf asymmetry at R6G and R6X, while a Class III malocclusion is symmetrical. The findings of the present study offer practical guidance for site-specific miniscrew placement in Vietnamese adults thereby optimising anchorage stability in clinical orthodontic practice. In Class I bimaxillary protrusion cases, the significant left-right asymmetry at R6G and R6X (e.g., right R6X at 9 mm: mean 3.82 mm vs. left: mean 3.3 mm, $P=0.032$) suggests prioritising the thicker right side, particularly at 9 or 12 mm below the cemento-enamel junction, to enhance primary stability.² Conversely, the symmetry associated with a Class III malocclusion allows flexibility in selecting either side, with R7X at 12 mm recommended due to its robust bone thickness (mean 8.68 mm). The site and depth preferences align with recommendations for extra-alveolar miniscrews, which require sufficient cortical bone for anchorage.⁵ Clinicians should use CBCT to confirm site-specific thickness, especially in Class I patients, to mitigate the risks of miniscrew failure in thinner bone regions.²

- The absence of correlation between bone thickness and cortical or cancellous density suggests independent morphological adaptations, which guide site-specific miniscrew placement.
- The findings enhance orthodontic planning for Vietnamese patients, by emphasising the need for population-specific data to optimise anchorage strategies.

Author contributions

Conceptualisation: T.N.N.; Data curation: V.T.T.H.; Formal analysis: H.Q.N.; Writing - original draft: T.N.N.; Writing - review and editing: T.N.N., V.T.T.H. and H.Q.N.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Funding

None to declare.

Corresponding author

Trung Nhu Nguyen, DDS, PhD, Faculty of Odonto-Stomatology, Pham Ngoc Thach University of Medicine, Ho Chi Minh City, Vietnam, 1 Duong Quan Trung Street, District 10, Ho Chi Minh City, Vietnam. Email: trungnn@pnt.edu.vn

Acknowledgements

The authors thank the dental clinic staff for data collection support. No external funding was received, and there are no conflicts of interest to disclose. All scientific content, analysis, and conclusions were independently developed by the authors.

References

1. Chang C, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf mini-screws placed in movable mucosa or attached gingiva. *Angle Orthod.* 2015;85(6):905–10.
2. Liu H, Wu X, Tan J, Li X. Safe regions of miniscrew implantation for distalization of mandibular dentition with CBCT. *Prog Orthod.* 2019;20:1–8.
3. Chu Y-M, Bergeron L, Chen Y-R. Bimaxillary protrusion: an overview of the surgical-orthodontic treatment. *Semin Plast Surg.* 2009;23(1):33–40. doi:10.1055/s-0028-1110099
4. Lew KK, Foong WC, Loh E. Malocclusion prevalence in an ethnic Chinese population. *Aust Dent J.* 1993;38(6):442–9.

5. Nucera R, Lo Giudice A, Bellocchio AM, et al. Bone and cortical bone thickness of mandibular buccal shelf for mini-screw insertion in adults. *Angle Orthod.* 2017;87(5):745–51.
6. Kapila S, Nervina J. CBCT in orthodontics: assessment of treatment outcomes and indications for its use. *Dentomaxillofac Radiol.* 2015;44(1):20140282.
7. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. *Am J Orthod Dentofacial Orthop.* 2006;129(6):721.e7–12.
8. Motoyoshi M, Inaba M, Ono A, Ueno S, Shimizu N. The effect of cortical bone thickness on the stability of orthodontic mini-implants and on the stress distribution in surrounding bone. *Int J Oral Maxillofac Surg.* 2009;38(1):13–8.
9. Park H-S, Lee Y-J, Jeong S-H, Kwon T-G. Density of the alveolar and basal bones of the maxilla and the mandible. *Am J Orthod Dentofacial Orthop.* 2008;133(1):30–7.
10. Baumgaertel S. Pre-drilling of the implant site: is it necessary for orthodontic mini-implants? *Am J Orthod Dentofacial Orthop.* 2010;137(6):825–9.
11. Sreenivasagan S, Sivakumar A. CBCT comparison of buccal shelf bone thickness in adult Dravidian population at various sites, depths and angulation—a retrospective study. *Int Orthod.* 2021;19(3):471–9.
12. Ngan P, He H. Effective maxillary protraction for Class III patients. In: *Current Therapy in Orthodontics.* Elsevier; 2010:143–58.
13. Ono A, Motoyoshi M, Shimizu N. Cortical bone thickness in the buccal posterior region for orthodontic mini-implants. *Int J Oral Maxillofac Surg.* 2008;37(4):334–40.
14. Anh T, Dang T, An N, Ngoc V, Phuong N, Anh L. Cephalometric norms for the Vietnamese population. *Apos Trends Orthod.* 2016;6(4):200–4.
15. Escobar-Correa N, Ramírez-Bustamante MA, Sánchez-Urbe LA, et al. Evaluation of mandibular buccal shelf characteristics in the Colombian population: a cone-beam computed tomography study. *Korean J Orthod.* 2021;51(1):23–31.
16. Eto VM, Figueiredo NC, Eto LF, Azevedo GM, Silva AIV, Andrade Jr I. Bone thickness and height of the buccal shelf area and the mandibular canal position for miniscrew insertion in patients with different vertical facial patterns, age, and sex. *Angle Orthod.* 2023;93(2):185–94.
17. Ma H, Zheng T, Shao B. Evaluation of the effect of unilateral mastication on the morphology of temporomandibular joint from the perspective of dynamic joint space. *J Oral Rehabil.* 2024;51(5):795–804.
18. You K-H, Kim K-H, Lee K-J, Baik H-S. Three-dimensional computed tomography analysis of mandibular morphology in patients with facial asymmetry and mandibular retrognathism. *Am J Orthod Dentofacial Orthop.* 2018;153(2):685–91.
19. Chang C, Huang C, Roberts WE. 3D cortical bone anatomy of the mandibular buccal shelf: a CBCT study to define sites for extra-alveolar bone screws to treat Class III malocclusion. *Int J Orthod Implantol.* 2016;41(1):74–82.
20. Misch CE. Bone character: Second vital implant criterion. *Dent Today* 1988;7:39–40.
21. Tabassum A, Singh MKC, Ibrahim N, et al. Quantifications of Mandibular Trabecular Bone Microstructure Using Cone Beam Computed Tomography for Age Estimation: A Preliminary Study. *Biology (Basel).* 2022;11(10):1521.
22. Chen YJ, Chang HH, Huang CY, et al. A retrospective analysis of the failure rate of orthodontic mini-implants. *Clin Oral Implant Res.* 2007;18(6):768–75.
23. Kummer G, Eliades T, Koletsi D. Gender-specific treatment effects and outcomes reported in orthodontic research. A cross-sectional empirical study. *Eur J Orthod.* 2024;46(1):cjad073.
24. Stahl E, Keilig L, Abdelgader I, Jäger A, Bourauel C. Numerical analyses of biomechanical behavior of various orthodontic anchorage implants. *J Orofac Orthop.* 2009;70(2):115–27.