Research Article

Comparison of inter-radicular distance and buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns

Dr. Samikshya Sangroula[1], Dr. Ravi Kumar Mahto[2], Dr. Rajeev Kumar Mishra[3], Dr. Suja Shrestha[4], Dr. Dashrath Kafle[5]

[1]Lecturer, Department of Orthodontics, B. P. Koirala Institute of Health Sciences, Dharan, Nepal

[2]Assistant Professor, [3]Former Assistant Professor, [4]Lecturer, [5]Professor, Department of Orthodontics, Kathmandu University School of Medical Sciences, Dhulikhel, Nepal

Corresponding author: Dr. Samikshya Sangroula; Email: dr.samikshyasangroula@gmail.com

ABSTRACT

Introduction: Knowledge of the safe zone of mini-implant placement guides clinicians in choosing where to place mini-implants. Several studies evaluated the safe zone for mini-implants placement, but only a very few previous studies have taken different skeletal patterns into account when assessing measurements.

Objective: The purpose of this cross-sectional, comparative study was to compare the inter-radicular distance and buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns.

Materials and Methods: A total of 62 CBCT images of patients with Class I and Class II skeletal malocclusion were obtained from the records of the department of Oral medicine and Radiology, Kathmandu University Teaching Hospital. The inter-radicular distance and buccal cortical bone thickness were measured at four different heights (2, 4, 6 and 8 mm) from the CEJ towards the apex. These measurements were measured between different skeletal pattern and gender with independent t-test. The intergroup comparison at different height from CEJ was done with ANOVA followed by Tukey's post-hoc test to see the difference within the category.

Result: There was a statistically significant difference observed in the inter-radicular distance between the maxillary first and second premolars at a height of 6 mm between Class I and Class II malocclusion patterns ($p = 0.03$). There were differences observed in the inter-radicular distance of the mandible at a different height based on skeletal malocclusion pattern, which was not statistically significant ($p>0.05$). The buccal cortical bone thickness between the maxillary central and lateral incisors at the height of 2 mm from CEJ between Class I and Class II skeletal malocclusion patterns was statistically significant ($p = 0.01$). The buccal cortical bone thickness of the mandible at different heights based on skeletal malocclusion pattern there were differences observed which were not statistically significant ($p>0.05$).

Conclusion: The inter-radicular distance and buccal cortical bone thickness could be influenced by different skeletal patterns and tend to increase from the CEJ to the apex in both Class I and Class II skeletal patterns.

KEYWORDS: buccal cortical bone thickness, cone-beam computed tomography, inter-radicular distance, malocclusion

INTRODUCTION

For decades, the orthodontic specialty is trying to achieve efficient control of anchorage because of its importance in treatment outcome. Clinicians used to spend a lot of time planning the treatment, especially anchorage to move the group of teeth which are desired and to avoid unwanted movements that may occur as a consequence of the resultant reactionary force. With the introduction of miniscrew, the orthodontic field has entered into a new era and more recently the evolvement of infrazygomatic and buccal shelf screws has made it possible to distalize the whole maxillary and mandibular dental arches. There are different sites for placement of mini-implants in the maxilla and mandible, such as inter-radicular area, infrazygomatic region, palatal areas including mid-palatal raphe, maxillary tuberosity region, mandibular symphysis, etc. For these applications, sound knowledge of anatomy as well as the associated risk factors is crucial.[1]

The success criteria of temporary anchorage devices are dependent on the amount of cortical bone present and the safe distance from the vicinity of the roots.[2] So, the inter-radicular distance as well as the buccal cortical bone thickness is of great importance. There are several studies that have been done in an attempt to evaluate the safe zone for mini-implant placement. A study done in Thai patients that evaluated and compared inter-radicular distances and cortical bone thickness showed that the Class II skeletal pattern had significantly greater maxillary inter-radicular distances (between the first and second premolars) and widths of the buccolingual alveolar process (between the first and second molars) than Class I skeletal pattern patients at 10 mm above the CEJ.[3] A similar study conducted in Persian adults to assess the inter-radicular distance and alveolar bone thickness with different sagittal skeletal patterns concluded that the area with maximum inter-radicular distance and optimal alveolar bone thickness for miniscrew insertion varies in different individuals, depending on their sagittal skeletal pattern.[4] A systematic review conducted to investigate the available evidence regarding the presence of sufficient inter-radicular space and adequate cortical bone thickness concluded that the most suitable insertion sites are those from distal to the first premolar to mesial to the first molar, and between the canine and the lateral incisor, all at 6 mm from the CEJ. In the mandible, the preferable vestibular inter-radicular spaces are those between first and second molars and between first and second premolars, both at 5 mm from the CEJ.[5] Globally, very few studies have been conducted taking different skeletal patterns into account when assessing measurements.[6]

Considering the limited number of such type of studies done globally and none in the Nepalese context, this study aimed to use CBCT data to evaluate and compare inter-radicular distance and buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns among the Nepalese population. The primary objective was to compare the inter-radicular distance and buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns. The secondary objective was to determine the difference in inter-radicular distance and buccal cortical bone thickness between male and female.

MATERIALS AND METHODS

This was a cross-sectional, comparative study conducted at the Kathmandu University Teaching Hospital. The CBCT records of patients from the Department of Oral Medicine and Radiology with Class I and Class II skeletal malocclusion patterns were obtained.

The sampling technique was non-probability convenient sampling. The sample size was calculated using G*power software[7] and it was further calculated using data from the study of Khumsarn et al[3]. The parameters were as follows; the pooled standard deviation of 0.711[3], alpha of 0.05, power of 80 %, and absolute error or precision 0.5. Thus, the sample size in each group was decided to be 31.

The inclusion criteria were skeletal Class I pattern (A point-Nasion-B point [ANB] angle = 2° ± 2°) and skeletal Class II pattern (ANB > 4°), patients with all permanent dentition excluding third molars, good quality and undistorted CBCT images in DICOM format. The exclusion criteria were history of previous orthodontic treatment, congenitally missing teeth (excluding the third molars), any known genetic or craniofacial disorders, severe periodontitis or periapical lesions, bone disorders.

The CBCT images were obtained using a rainbow TM (Dentium, Korea), and were oriented using a standardized protocol at 94 kVp, 8 mA, and 16cm × 10cm field of view, and a voxel size of 300μm. The lateral cephalogram of the same patient was used to determine the skeletal malocclusion pattern. rainbow TM Image Viewer (Dentium,Korea) was used for orthogonal tomographic image construction and measurements. When examining axial images, the CBCT image was oriented so that the orange line provided by the software was perpendicular to the buccal bone surface and bisected the inter-radicular area to be measured (Fig 1). For the sagittal images, the CBCT image was oriented so that the occlusal plane was parallel to the blue line (Fig 2). For each inter-radicular area in the maxilla and the mandible, from the distal aspect of the central incisors to the mesial aspect of the second molar, the inter-radicular distance and the buccal cortical bone thickness were measured. These measurements were repeated at four different heights from CEJ to the apex; 2 mm, 4 mm, 6 mm, and 8 mm. Inter-radicular distance was defined as the distance between parallel lines tangent to the adjacent proximal root surfaces in axial images (Fig. 3A). Buccal cortical bone thickness was defined as the distance between the external and internal aspects of the buccal cortex midway between the lines tangent to the proximal root surface (Fig 3B).

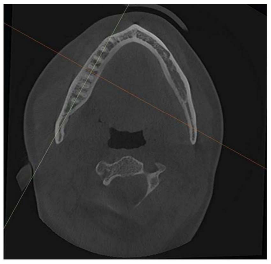

Fig 1. Axial images

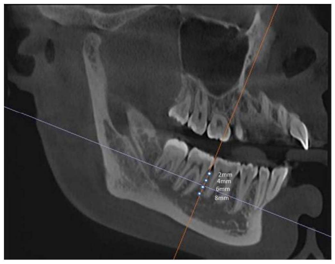

Fig 2. Sagittal images showing different level from CEJ

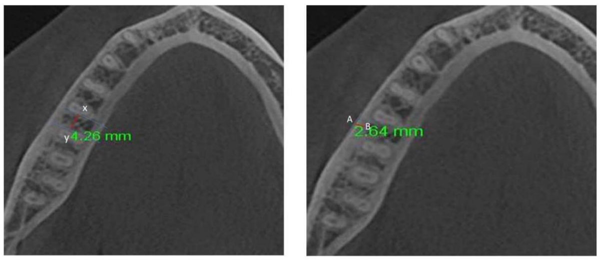

Fig 3 A. Measurements of the inter-radicular distance (X-Y). B.The buccal cortical bone thickness (A-B).

The measurements were recorded in the proforma and transferred into an excel sheet. The data was analyzed using SPSS software (version 26, IBM, USA). To check the normality of distribution of the data, Shapiro-Wilk test was applied. As p-value was more than 0.05, the data for different variables were normally distributed. The mean and standard deviation (SD) were measured. Independent t-test was applied for comparison of inter-radicular and buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns at different height from CEJ. ANOVA was applied for intergroup comparison at different height from CEJ within Class I and Class II skeletal malocclusion pattern. Multiple comparisons were also performed using Tukey's Post-Hoc test to see the difference within the category at a different height from CEJ when ANOVA yielded significant results indicating that there was a difference. P-value < 0.05 was considered statistically significant.

RESULTS

The sample comprised a total of sixty-two CBCT images of patients between ages 12 to 38 years. The mean age (SD) of the total sample was 23.89 (6.08) years. The total subjects were divided into two groups based on ANB angle. Class I skeletal malocclusion pattern group comprised of 12 males and 19 females. Class II skeletal malocclusion pattern group comprised of 10 males and 21 females. The highest mean values for the inter-radicular distance in Class I and Class II skeletal malocclusion patterns were between the maxillary second premolar and first molar at the height of 8 mm from CEJ; 3.50 ± 0.99 mm and 3.51 ± 0.97 mm respectively. The highest mean value of inter-radicular distance in Class I skeletal malocclusion pattern was between the mandibular first and second molars (4.10 ± 1.55 mm) and for Class II skeletal malocclusion pattern was between the first and second premolars (4.55 ± 1.46 mm) at the height of 8 mm from CEJ. There was statistically significant difference observed in the inter-radicular distance between the maxillary first and second premolars at the height of 6 mm between Class I and Class II skeletal malocclusion patterns (p = 0.03). However, the inter-radicular distance of the mandible at different height based on skeletal malocclusion pattern was not statistically significant (p > 0.05). (Table 1)

Table 1: Mean (SD) comparison of inter-radicular distance (mm) at different height from CEJ (mm) based on skeletal malocclusion pattern for maxilla and mandible.

Site	Height	Malocclusion	1-2	2-3	3-4	4-5	5-6	6-7
MAXILLA	2 mm	Class I Class II	1.50 ± 0.50 1.71 ± 0.58 p = 0.14	1.78 ± 0.55 1.96 ± 0.72 p = 0.27	1.98 ± 0.48 2.10 ± 0.46 p = 0.33	2.24 ± 0.55 2.15 ± 0.47 p = 0.47	2.67 ± 0.47 2.65 ± 0.55 p = 0.83	2.23 ± 0.75 1.98 ± 0.50 p = 0.13
	4 mm	Class I Class II	1.78±0.56 1.99±0.68 P=0.20	2.35±0.60 2.24±0.66 P=0.47	2.31±0.62 2.41±0.54 P=0.52	2.74±0.58 2.49±0.59 P=0.10	2.85±0.60 2.79±0.69 P=0.70	2.18±0.88 1.94±0.65 P=0.23
	6 mm	Class I Class II	1.98±0.69 2.16±0.76 P=0.33	2.76±0.79 2.38±0.75 P=0.05	2.47±0.62 2.58±0.70 P=0.53	3.05±0.61 2.69±0.69 P=0.03*	3.07±0.81 3.09±0.80 P=0.92	2.12±1.04 1.82±0.66 P=0.17
	8 mm	Class I Class II	2.17±0.70 2.48±1.05 P=0.18	3.09±1.06 2.87±0.95 P=0.40	2.61±0.81 2.67±0.77 P=0.74	3.12±0.63 2.85±0.87 P=0.17	3.50±0.99 3.51±0.97 P=0.95	2.35±1.31 2.00±1.31 P=0.29

MANDIBLE	2 mm	Class I Class II	1.41±0.54 1.37±0.61 P=0.77	1.54±0.48 1.78±0.58 P=0.08	2.03±0.52 2.10±0.65 P=0.64	2.73±0.66 3.01±0.85 P=0.14	2.65±0.44 2.75±0.69 P=0.50	3.09±0.79 3.00±0.61 P=0.65
	4 mm	Class I Class II	1.49±0.40 1.41±0.49 P=0.43	1.86±0.53 2.03±0.72 P=0.31	2.45±0.70 2.34±0.74 P=0.54	3.28±0.72 3.61±1.09 P=0.17	2.89±0.52 3.06±0.76 P=0.31	3.31±1.08 3.22±0.79 P=0.72
	6 mm	Class I Class II	1.60±1.45 1.38±0.44 P=0.08	2.03±0.55 2.25±0.79 P=0.20	2.69±0.95 2.59±0.86 P=0.66	3.74±0.93 4.16±1.37 P=0.16	3.09±0.83 3.30±1.01 P=0.38	3.53±1.34 3.64±0.89 P=0.69
	8 mm	Class I Class II	1.69±0.69 1.45±0.54 P=0.12	2.24±0.96 2.53±0.94 P=0.22	2.83±1.02 2.90±1.02) P=0.79	4.05±1.03 4.55±1.46 P=0.12	3.48±0.81 3.50±1.13 P=0.95	4.10±1.55 4.13±1.16 P=0.72

1-2: between central incisor and lateral incisors, 2-3: between lateral incisor and canine, 3-4: between canine and 1st premolar, 4-5:between 1st premolar and 2nd premolar, 5-6: between 2nd premolar and 1st molar, 6-7: between 1st molar and 2nd molar. P value < 0.05- significant (*), P value <0.01- highly significant (**).

The highest mean values for the buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns were between the maxillary first and second molars at the height of 8 mm from CEJ; 1.79 ± 0.80 mm and 1.66 ± 0.37 mm respectively. However, the buccal cortical bone thickness between the maxillary central and lateral incisors at the height of 2 mm from CEJ was statistically significant (p = 0.01). The highest mean values for the buccal cortical bone thickness in Class I and Class II skeletal malocclusion patterns were between the mandibular first and second molars at the height of 8 mm from CEJ; 3.52 ± 0.84 mm and 3.42 ± 0.59 mm respectively. While comparing the buccal cortical bone thickness of the mandible at different height based on skeletal malocclusion pattern, there were differences observed which were not statistically significant (p > 0.05). (Table 2)

Table 2: Mean (SD) comparison of buccal cortical bone thickness (mm) at different height from CEJ (mm) based on skeletal malocclusion pattern for maxilla and mandible.

Site	Height	Malocclusion	1-2	2-3	3-4	4-5	5-6	6-7
MAXILLA	2 mm	Class I Class II	1.19±0.28 1.39±0.31 P=0.01*	1.29±0.40 1.32±0.32 P=0.78	1.34±0.35 1.48±0.35 P=0.12	1.49±0.41 1.42±0.36 P=0.51	1.58±0.42 1.48±0.28 P=0.31	1.58±0.46 1.42±0.51 P=0.20
	4 mm	Class I Class II	1.33±0.57 1.36±0.29 P=0.79	1.36±0.35 1.45±0.39 P=0.33	1.46±0.31 1.48±0.28 P=0.81	1.49±0.41 1.46±0.30 P=0.69	1.53±0.38 1.51±0.29 P=0.88	1.67±0.56 1.54±0.42 P=0.32
	6 mm	Class I Class II	1.14±0.35 1.31±0.27 P=0.07	1.37±0.32 1.51±0.41 P=0.14	1.56±0.32 1.53±0.27 P=0.76	1.59±0.41 1.56±0.45 P=0.76	1.55±0.41 1.49±0.27 P=0.53	1.68±0.55 1.54±0.38 P=0.26
	8 mm	Class I Class II	1.17±0.28 1.29±0.27 P=0.08	1.36±0.40 1.48±0.32 P=0.20	1.48±0.30 1.57±0.34 P=0.32	1.63±0.40 1.62±0.45 P=0.93	1.50±0.43 1.55±0.31 P=0.59	1.79±0.80 1.66±0.37 P=0.40
MANDIBLE	2 mm	Class I Class II	1.21±0.27 1.25±0.28 P=0.48	1.29±0.36 1.36±0.37 P=0.46	1.38±0.33 1.42±0.30 P=0.56	1.51±0.31 1.54±0.40 P=0.77	1.74±0.45 1.63±0.33 P=0.29	2.47±0.74 2.19±0.55 P=0.09
	4 mm	Class I Class II	1.19±0.31 1.20±0.36 P=0.86	1.25±0.30 1.32±0.39 P=0.41	1.45±0.42 1.51±0.32 P=0.56	1.70±0.39) 1.71±0.44 P=0.94	1.92±0.45 2.00±0.39 P=0.46	2.82±0.70 2.79±0.59 P=0.84

	6 mm	Class I Class II	1.18±0.34 1.21±0.37 P=0.79	1.29±0.26 1.37±0.38 P=0.32	1.58±0.48 1.53±0.40 P=0.65	1.88±0.42 1.80±0.49 P=0.51	2.09±0.65 2.18±0.52 P=0.58	3.36±0.82 3.28±0.71 P=0.85
	8 mm	Class I Class II	1.30±0.31 1.32±0.36 P=0.88	1.43±0.29 1.44±0.31 P=0.92	1.70±0.38 1.72±0.45 P=0.82	2.08±0.50 2.00±0.48 P=0.52	2.52±0.71 2.39±0.54 P=0.42	3.52±0.84 3.42±0.59 P=0.60

1-2: between central incisor and lateral incisors, 2-3: between lateral incisor and canine, 3-4: between canine and 1st premolar, 4-5: between 1st premolar and 2nd premolar, 5-6: between 2nd premolar and 1st molar, 6-7: between 1st molar and 2nd molar. P value < 0.05- significant (*), P value <0.01- highly significant (**).

The highest mean values of inter-radicular distance for male and female groups were between the maxillary second premolar and the first molar at the height of 8 mm from CEJ; 3.56±0.90 mm and 3.47±1.01 mm respectively. The highest mean values of inter-radicular distance for the male and female groups were between the mandibular first and second premolars at the height of 8 mm from CEJ; 4.06±1.01 mm and 4.42±1.39 mm respectively. There was statistically significant difference observed in the inter-radicular distance for the maxillary canine and first premolars at height 4 mm from CEJ between male and female groups (P=0.01). Similarly, there was statistically significant difference observed in the inter-radicular distance for the mandibular canine and first premolars (P=0.01) as well as mandibular first and second premolars (P=0.02) at height 2 mm from CEJ between male and female groups. There was statistically significant difference observed in the inter-radicular distance for the mandibular second premolar and first molar (P=0.01) and mandibular first and second molars (P=0.04) at height 4 mm from CEJ between male and female groups. There was statistically significant difference observed in the inter-radicular distance for the mandibular second premolar and first molar at height 6 mm from CEJ between male and female groups (P=0.01). (Table 3)

Table 3: Mean (SD) comparison of inter-radicular distance (mm) at different height from CEJ (mm) based on gender for maxilla and mandible.

Site	Height	Gender	1-2	2-3	3-4	4-5	5-6	6-7
MAXILLA	2 mm	Male Female	1.61±0.50 1.60±0.57 P=0.92	1.93±0.78 1.84±0.56 P=0.57	1.90±0.48 2.12±0.45 P=0.09	2.13±0.55 2.23±049 P=0.48	2.72±0.41 2.63±0.56 P=0.53	1.92±0.64 2.21±0.63 P=0.09
	4 mm	Male Female	1.84±0.57 1.91±0.66 P=0.66	2.41±0.70 2.43±0.58 P=0.30	2.11±0.52 2.50±0.56 P=0.01*	2.60±0.65 2.63±0.56 P=0.85	2.91±0.65 2.77±0.64 P=0.41	1.96±0.92 2.12±0.69 P=0.46
	6 mm	Male Female	2.09±0.63 2.07±0.78 P=0.92	2.71±0.89 2.49±0.73 P=0.29	2.36±0.65 2.61±0.65 P=0.15	3.00±0.77 2.80±0.60 P=0.24	3.19±0.78 3.02±0.81 P=0.44	1.99±1.08 1.96±0.75 P=0.86
	8 mm	Male Female	2.37±0.64 2.30±1.02 P=0.75	3.08±1.06 2.93±0.99 P=0.58	2.45±0.80 2.74±0.76 P=0.16	3.03±0.75 2.96±0.78 P=0.73	3.56±0.90 3.47±1.01 P=0.72	2.17±1.33 2.17±1.31 P=0.99
MANDIBLE	2 mm	Male Female	1.26±0.40 1.46±0.64 P=0.19	1.68±0.59 1.65±0.52 P=0.83	1.82±0.50 2.19±0.59 P=0.01*	2.57±0.60 3.04±0.80 P=0.02*	2.56±0.47 2.77±0.62 P=0.16	2.91±0.63 3.12±0.74 P=0.26
	4 mm	Male Female	1.48±0.40 1.43±0.47 P=0.72	1.97±0.46 1.93±0.72 P=0.83	2.20±0.66 2.50±0.73 P=0.10	3.17±0.93 3.60±0.90 P=0.08	2.70±0.65 3.13±0.61 P=0.01*	2.94±0.84 3.44±0.95 P=0.04*
	6 mm	Male Female	1.57±0.47 1.45±0.45 P=0.30	2.19±0.52 2.11±0.76 P=0.63	2.44±0.81 2.75±0.94 P=0.20	3.57±0.90 4.15±1.27 P=0.06	2.82±0.86 3.40±0.90 P=0.01*	3.22±1.23 3.78±1.03 P=0.06

	8mm	Male Female	1.60±0.66 1.55±0.62 P=0.76	2.51±1.02 2.32±0.92 P=0.45	2.62±0.95 3.00±1.03 P=0.16	4.06±1.01 4.42± 1.39 P=0.29	3.18±1.09 3.66±0.88 P=0.06	3.70±1.49 4.27±1.26 P=0.11

1-2:between central incisor and lateral incisor, 2-3:between lateral incisor and canine, 3-4:between canine and 1st premolar, 4-5:between 1st premolar and 2nd premolar, 5-6:between 2nd premolar and 1st molar, 6-7:between 1st molar and 2nd molar. P value < 0.05- significant (*), P value <0.01- highly significant (**).

The highest mean value for the buccal cortical bone thickness was between the first and second maxillary premolars at the height of 6 mm from CEJ in the male group (1.72 ± 0.49 mm). The highest mean value for the buccal cortical bone thickness was between the first and second maxillary molars at the height of 8 mm from CEJ in the female group (1.82 ± 0.73 mm). There were differences observed in the buccal cortical bone thickness of the maxilla at different height based on gender, which were not statistically significant (p > 0.05). The highest mean value of buccal cortical bone thickness for the male and female groups was between the mandibular first and second molars at the height of 8 mm from CEJ; 3.61 ± 0.85 mm and 3.39 ± 0.64 mm respectively. However, statistically significant differences were found in the thickness of the mandibular buccal cortical bone in between the canine and first premolar at height 6 mm (p = 0.03) and 8 mm (p = 0.01) from CEJ. (Table 4)

Table 4: Mean (SD) comparison of buccal cortical bone thickness (mm) at different height from CEJ (mm) based on gender for maxilla and mandible.

Site	Height	Gender	1-2	2-3	3-4	4-5	5-6	6-7
MAXILLA	2 mm	Male Female	1.25±0.27 1.31±0.33 P=0.46	1.26±0.42 1.33±0.33 P=0.48	1.34±0.37 1.45±0.34) P=0.25	1.54±0.43 1.41±0.35 P=0.23	1.58±0.28 1.50±0.39 P=0.39	1.51±0.55 1.49±0.46 P=0.91
	4 mm	Male Female	1.28±0.2 1.37±0.53 P=0.43	1.30±0.43 1.46±0.33 P=0.11	1.43±0.24 1.49±0.32 P=0.41	1.53±0.38 1.44±0.34 P=0.34	1.57±0.31 1.49±0.35 P=0.34	1.54±0.58 1.64±0.44 P=0.46
	6 mm	Male Female	1.35±0.28 1.18±0.32 P=0.05	1.42±0.43 1.44±0.35 P=0.84	1.59±0.25 1.52±0.32 P=0.44	1.72±0.49 1.49±0.37 P=0.05	1.61±0.32 1.47±0.35 P=0.13	1.53±0.47 1.65±0.48 P=0.33
	8 mm	Male Female	1.24±0.28 1.22±0.28 P=0.84	1.42±0.42 1.42±0.34 P=0.94	1.51±0.30 1.53±0.34 P=0.78	1.61±0.47 1.64±0.40 P=0.78	1.63±0.38 1.46±0.36 P=0.09	1.55±0.29 1.82±0.73 P=0.09
MANDIBLE	2 mm	Male Female	1.31±0.32 1.18±0.23 P=0.07	1.38±0.44 1.30±0.31 P=0.41	1.40±0.41 1.40±0.25 P=0.97	1.60±0.41 1.49±0.32 P=0.24	1.78±0.48 1.64±0.34 P=0.19	2.41±0.67 2.28±0.66 P=0.48
	4 mm	Male Female	1.18±0.39 1.20±0.30 P=0.81	1.34±0.41 1.26±0.30 P=0.39	1.59±0.49 1.42±0.27 P=0.08	1.81±0.44 1.64±0.38 P=0.13	2.07±0.47 1.90±0.3 P=0.15	2.85±0.73 2.78±0.60 P=0.68
	6 mm	Male Female	1.20±0.44 1.19±0.30 P=0.93	1.36±0.32 1.32±0.33 P=0.67	1.72±0.56 1.47±0.33 P=0.03*	1.89±0.54 1.81±0.41 P=0.48	2.33±0.69 2.03±0.50 P=0.05	3.46±0.76 3.24±0.76 P=0.28
	8 mm	Male Female	1.32±0.44 1.30±0.26 P=0.81	1.51±0.33 1.39±0.27 P=0.12	1.89±0.50 1.61±0.33 P=0.01*	2.15±0.59 1.98±0.41 P=0.20	2.58±0.71 2.38±0.58 P=0.23	3.61±0.85 3.39±0.64 P=0.26

1-2:between central incisor and lateral incisors, 2-3:between lateral incisor and canine, 3-4:between canine and 1st premolar, 4-5:between 1st premolar and 2nd premolar, 5-6:between 2nd premolar and 1st molar, 6-7:between 1st molar and 2nd molar. P value < 0.05- significant (*), P value <0.01- highly significant (**).

For Class I skeletal malocclusion pattern, there was statistically significant differences observed in the inter-radicular distance from the distal of the central incisor to molars at all the sites except between the maxillary first and second molars (p = 0.84). Similarly in the mandible, there was statistically significant differences were observed ($p < 0.05$). For Class I skeletal malocclusion pattern, there was no statistically significant difference observed in the buccal cortical bone thickness from central incisors to the second maxillary molar at height 2 mm to 8mm from CEJ.

For Class I skeletal malocclusion pattern, there were statistically significant differences observed in buccal cortical bone thickness at different height from CEJ at all the inter-radicular sites considered from distal of mandibular canine to second mandibular molar at height 2mm to 8mm ($p < 0.05$) except between central and lateral incisors and lateral incisors and canine ($p > 0.05$). Intra-group multiple comparison using Tuckey's post-hoc of mean inter-radicular distance and buccal cortical bone thickness of various inter-radicular sites at different height from CEJ for maxilla and mandible was done for Class I skeletal malocclusion pattern.

For Class II skeletal malocclusion pattern, there was statistically significant difference in inter-radicular distance at different height from CEJ considered from central incisors to the first maxillary molar except between maxillary first and second molars ($p > 0.05$). Similarly, in the mandible, there was statistically significant difference in inter-radicular distance at different height from CEJ at all the inter-radicular sites considered from distal to lateral incisors to the second mandibular molar ($p < 0.05$) except between central and lateral incisors ($p > 0.05$). However, there was no statistically significant difference observed in the buccal cortical bone thickness at different heights from CEJ at the inter-radicular site considered from maxillary central incisors to maxillary second molar ($p > 0.05$).

DISCUSSION

Safety and stability are the two major factors that clinicians should consider before mini-implant placement. Safety is related to avoiding root damage during implant placement, whereas initial stability, plays a major role in preventing the premature loosening of mini-implants. Placing mini-implants in alveolar bone with sufficient quantity and quality is the major necessity for obtaining initial stability.[8] The success rate of mini-implants is determined by the inter-radicular distance and buccal cortical bone thickness. Therefore, it is necessary to know these measurements in population-specific samples.

Mini-implant is commonly placed in the maxilla for various orthodontic mechanics. Several authors have reported measurements of the inter-radicular distance and buccal cortical bone thickness of the posterior maxilla taking various reference points among which alveolar crest and CEJ are common.[9-14] In this study, we have measured the inter-radicular distance and buccal cortical bone thickness taking CEJ as a reference point based on the fact that the alveolar crest would vary with the level of alveolar bone resorption.[8] The results of our study showed that the inter-radicular space between the second premolar and the first molar provides the optimal anatomic site for mini-implant placement in the maxilla for both Class I and Class II skeletal malocclusion patterns. These results are in accordance with the results that have been reported.[3, 8, 15-18]

The safe site of the inter-radicular distance in the mandible for Class I skeletal malocclusion pattern was found between the mandibular first and second molar. These results are in accordance with the findings of previous studies.[3, 6, 8, 15, 16, 17] However, for the Class II skeletal malocclusion pattern is between the first and second premolar, similar to the finding of the previous studies.[3, 9] Our study finding has shown that in both the maxilla and mandible, the inter-radicular distance tends to increase from the CEJ towards the apex for both Class I and Class II skeletal malocclusion patterns. These results were in agreement with previous study findings.[3, 8, 16, 17, 19]

Studies conducted by Kuroda et al[20] and Vande et al[21] showed that root proximity is a major factor for screw failure, suggesting a significant correlation between late stability and clearance of the mini-implant. This study also suggests that sufficient inter-radicular distance and relatively small mini-implant diameter is also crucial for both safety and late stability. Based on the study by Schnelle et al[18] and Poggio et al[9], a minimum clearance of 1 mm of bone around the mini-implant is safe. However, they have recommended inter-radicular distance greater than 3.1 mm as safe zones for mini-implants with diameters of 1.2 to 1.3 mm.[9, 18]

In our study, the mean inter-radicular distances were approximately 1.5 to 3.5 mm in the maxilla and 1.3 to

4.5 mm in the mandible. Taking this into consideration, in some locations, there would be less than 1 mm of clearance around the mini-implant, even with a 1.2 mm diameter.[8] The mini-implant might need to be placed further apically in order to obtain some clearance. It will be a challenge for us to place mini-implants in narrower inter-radicular distances in the maxilla.[8] It would be safer to use smaller diameter implants such as 1.2 or 1.3 mm to obtain some clearance around the implant. It is important to evaluate the anatomy of the desired location for implant placement and consider different diameters of mini-implants as great anatomic variations might occur for each patient. In general, it is recommended to place mini-implants 4 mm or more apically from the CEJ.

Similarly, numerous studies have attempted to map the cortical bone thickness in the maxilla and mandible using CBCT software.[8,11,16,17] Our study findings has reported the safe site where the highest buccal cortical bone thicknesses in the maxilla present were between the first and second molars for Class I skeletal malocclusion pattern which was in accordance with the findings of previous studies. For Class II skeletal malocclusion patterns the highest buccal cortical bone thicknesses which were present between the first and second premolars. The findings of our results were consistent with those of the previous studies.[3,16] In accordance with several previous studies,[8, 11] our result was consistent with the safe zone of mini-screw placement in the mandible with the highest buccal cortical bone thickness present between the mandibular first and second molars for both Class I and Class II skeletal malocclusion pattern. However, the buccal cortical bone thickness in the maxilla between the maxillary central incisors and lateral incisors at 2 mm height from the CEJ in Class II patients were significantly greater than in Class I patients was a significant finding of our study. And a previous study[15] has also concluded that the optimal site for mini-implant placement in the anterior region is between the central and lateral incisors in the maxilla and between lateral and canine in the mandible at 6 mm and beyond but the implant must be of smaller diameter.

There was a difference observed in the inter-radicular distance and buccal cortical bone thickness between male and female groups, but it was not statistically significant except at few specific sites and levels which were in accordance with some previous studies.[15,22] Dalstra et al[23] have also reported that the major part of the load transfer occurs in the cortical shell, and consequently the thickness of cortical bone has the greatest effect on the load transfer mechanism. The forces acting on mandibular cortical bone as explained by previous studies[24,25] as mandibular molars are inclined lingually, the mandibular molar buccal and lingual structures, particularly the cortical bone thickness is affected by masticatory muscles. Since the male has larger masticatory muscles and maximum bite force than do women.[26] Gender comparisons might not be reliable in the present study due to unequal sample size. Although the differences in measurement observed the generalization cannot be done based on this study. As this study was done in the premises of Kathmandu University School of Medical Sciences, the result cannot be generalized to the larger population group. The sample size is limited, which may not be adequate to represent the larger population. This study has not taken into consideration of other confounding factors such as dental malocclusion, racial variation, BMI, etc. which might play a role on inter-radicular distance and buccal cortical bone thickness.

CONCLUSION

Based on this research, the safe site for mini-implant placement in the maxilla in Class I and Class II skeletal malocclusion pattern was found to be between the maxillary second premolar and the first molar at height of 6 mm from CEJ. However, the safe site for mini-implant placement for the mandible in Class I skeletal malocclusion pattern was found to be between mandibular first molar and the second molar and for Class II was found to be between mandibular first and second premolars at height of 6 mm from CEJ.

Abbreviations:

CBCT: Cone Beam Computed Tomography.
CEJ: Cementoenamel Junction
DICOM: Digital Imaging and Communications in Medicine
IOPAR: Intra Oral Periapical Radiograph
OPG: Orthopantomogram
TADs: Temporary Anchorage Devices

Acknowledgements

We would like to thanks Dr. Deepa Niroula, Dr.Harleen Bali, Department of Oral Medicine and Radiology, for their valuable advice and guidance on CBCT procedure and for their co-operation in performing this study. Special thanks to Dr.Swagat Kumar Mahanta, Raj

Sangroula, Dr. Santosh Kumari Agrawal, Dr. Abanish Singh for making my research into reality for their valuable suggestion regarding statistical analysis. The authors wish to acknowledge Dr. Sanjeev Luintel, Dr. Arjun Karki, and all staffs and assistant of Department of Orthodontics for their continuous support during the organization of this study.

Statement of Ethics

Study approval statement: Ethical clearance was obtained from the Institutional Review Committee, Kathmandu University School of Medical Sciences (Ref no: 17/19).

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

Funding Sources

Self-funded

Author Contributions

Samikshya Sangroula, Dashrath Kafle, Ravi Mahto, Rajeev Kumar Mishra, Suja Shrestha conceptualized the study. Samikshya Sangroula was involved in the data collection, analysis, and preparation of the manuscript. All authors approved the final version of the manuscript.

Data Availability Statement

All the generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

OJN

REFERENCES

1. Mohammed H, Wafaie K, Rizk MZ, Almuzian M, Sosly R, Bearn DR. Role of anatomical sites and correlated risk factors on the survival of orthodontic miniscrew implants: a systematic review and meta-analysis. Prog Orthod. 2018 Sep 24;19(1):36.
2. Leo M, Cerroni L, Pasquantonio G, Condo SG, Condo R. Temporary anchorage devices (TADs) in orthodontics: review of the factors that influence the clinical success rate of the mini-implants. La Clinica therapeutica. 2016; 167 May-Jun;167(3):e70-77.
3. Khumsarn N, Patanaporn V, Janhom A, Jotikasthira D. Comparison of interradicular distances and cortical bone thickness in Thai patients with Class I and Class II skeletal patterns using cone-beam computed tomography. Imaging Sci Dent. 2016 Jun;46(2):117-25.
4. Golshah A, Salahshour M, Nikkerdar N. Interradicular distance and alveolar bone thickness for miniscrew insertion: a CBCT study of Persian adults with different sagittal skeletal patterns. BMC Oral Health. 2021 Oct 17;21(1):534.
5. Tepedino M, Cattaneo PM, Niu X, Cornelis MA. Interradicular sites and cortical bone thickness for miniscrew insertion: A systematic review with meta-analysis. Am J Orthod Dentofacial Orthop. 2020 Dec;158(6):783-798.e20.
6. Chaimanee P, Suzuki B, Suzuki EY. "Safe zones" for miniscrew implant placement in different dentoskeletal patterns. Angle Orthod. 2011 May;81(3):397-403.
7. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007 May;39(2):175-91.
8. Park J, Cho HJ. Three-dimensional evaluation of interradicular spaces and cortical bone thickness for the placement and initial stability of microimplants in adults. Am J Orthod Dentofacial Orthop. 2009 Sep;136(3):314.el-12; discussion 314-5.
9. Poggio PM, Incorvati C, Velo S, Carano A. "Safe zones": a guide for miniscrew positioning in the maxillary and mandibular arch. Angle Orthod. 2006 Mar;76(2):191-7.
10. Lim JE, Lim WH, Chun YS. Quantitative evaluation of cortical bone thickness and root proximity at maxillary interradicular sites for orthodontic mini-implant placement. Clin Anat. 2008 Sep;21(6):486-91.
11. Baumgaertel S, Hans MG. Buccal cortical bone thickness for mini-implant placement. Am J Orthod Dentofacial Orthop. 2009 Aug;136(2):230-5.
12. Germec-Cakan D, Tozlu M, Ozdemir F. Cortical bone thickness of the adult alveolar process--a retrospective CBCT study. Aust Orthod J. 2014 May;30(1):54-60.
13. Veli I, Uysal T, Baysal A, Karadede I. Buccal cortical bone thickness at miniscrew placement sites in patients with different vertical skeletal patterns. J Orofac Orthop. 2014 Nov;75(6):417-29.
14. Moslemzadeh SH, Sohrabi A, Rafighi A, Kananizadeh Y, Nourizadeh A. Evaluation of Interdental Spaces of the Mandibular Posterior Area for Orthodontic Mini-Implants with Cone-Beam Computed Tomography. J Clin Diagn Res. 2017 Apr;11(4):ZC09-ZC12.
15. Fayed MM, Pazera P, Katsaros C. Optimal sites for orthodontic mini-implant placement assessed by cone beam computed tomography. Angle Orthod. 2010 Sep; 80(5):939-51.
16. Sawada K, Nakahara K, Matsunaga S, Abe S, Ide Y. Evaluation of cortical bone thickness and root proximity at maxillary interradicular sites for mini-implant placement. Clin Oral Implants Res. 2013 Aug;24 Suppl A100:1-7.
17. Hu KS, Kang MK, Kim TW, Kim KH, Kim HJ. Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation. Angle Orthod. 2009 Jan;79(1):37-45.

18. Schnelle MA, Beck FM, Jaynes RM, Huja SS. A radiographic evaluation of the availability of bone for placement of miniscrews. Angle Orthod. 2004Dec;74(6):832-7.
19. Monnerat C, Restle L, Mucha JN. Tomographic mapping of mandibular interradicular spaces for placement of orthodontic mini-implants. Am J Orthod Dentofacial Orthop. 2009 Apr;135(4):428.e1-9; discussion 428-9.
20. Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Takano-Yamamoto T. Root proximity is a major factor for screw failure in orthodontic anchorage. Am J Orthod Dentofacial Orthop. 2007 Apr;131(4 Suppl):S68-73.
21. Vande Vannet B, Sabzevar MM, Wehrbein H, Asscherickx K. Osseointegration of miniscrews: a histomorphometric evaluation. Eur J Orthod. 2007 Oct;29(5):437-42.
22. Kim JH, Park YC. Evaluation of mandibular cortical bone thickness for placement of temporary anchorage devices (TADs). Korean J Orthod. 2012 Jun;42(3):110-7.
23. Dalstra M, Cattaneo PM, Melsen B. Load transfer of miniscrews for orthodontic anchorage. J Orthod 2004; 1:53-62.
24. Ichim I, Kieser JA, Swain MV. Functional significance of strain distribution in the human mandible under masticatory load: numerical predictions. Arch Oral Biol. 2007 May;52(5):465-73.
25. Hirabayashi M, Motoyoshi M, Ishimaru T, Kasai K, Namura S. Stresses in mandibular cortical bone during mastication: biomechanical considerations using a three-dimensional finite element method. J Oral Sci. 2002 Mar;44(1):1-6.
26. Horner KA, Behrents RG, Kim KB, Buschang PH. Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. Am J Orthod Dentofacial Orthop. 2012 Aug;142(2):170-8.