Original Article

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Safe sites for buccal shelf bone screw placement in various skeletal malocclusions: A CBCT study

Athira V M, Keerthan Shashidhar, M N Kuttappa, U S Krishna Nayak, M S Ravi and Neevan D' Souza[1]

Abstract

INTRODUCTION: The mandibular buccal shelf area is an extra-alveolar anchorage site that has high quality and quantity of bone, provides biomechanical benefits and has low failure rates. It is essential to place the implant in the region of bone with optimal thickness. The aim of this study was to determine the suitable site of the mandibular buccal shelf for bone screw insertion at 90 degrees and 30 degrees angles of insertion and various heights, angulations, areas of the buccal shelf in prognathic and retrognathic mandibles, and vertical and horizontal growth patterns.

METHODS: In this retrospective study, we evaluated the cone-beam computed tomography (CBCT) images of 48 patients in the age range of 18–30 years, divided into four groups. Seven sectional sites were examined at 3, 5, and 7 mm from the alveolar crest at 90 degrees and 30 degrees. The angulation and area of the buccal shelf were examined.

RESULTS: Cortical bone thickness increased distally from the first to the second molar in all four groups.

CONCLUSIONS: The preferred site for buccal shelf implant placement was distal to the mandibular second molar. The maximum amount of cortical bone was observed distal to the second molar, 7 mm vertically from the alveolar crest, when the buccal shelf implant was placed at 30 degrees angulation to the long axis of the tooth.

Keywords:

Anchorage, cone-beam computed tomography, mandibular buccal shelf, mini-screws, orthodontic treatment

Department of Orthodontics and Dentofacial Orthopaedics, NITTE (Deemed to be) University, A B Shetty Memorial Institute of Dental Sciences, [1]Department of Humanities, NITTE (Deemed to be) University, KS Hegde Medical Academy, Deralakatte, Mangalore, Karnataka, India

Address for correspondence:
Prof. M N Kuttappa, Department of Orthodontics and Dentofacial Orthopaedics, NITTE (Deemed to be) University, AB Shetty Memorial Institute of Dental Sciences, Deralakatte, Mangalore, Karnataka – 575 018, India.
E-mail: kuttappa27@gmail.com

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Introduction

Anchorage control is of paramount importance in orthodontic therapy.[1,2] Hence, anchorage planning is often associated with improved results. Skeletal anchorage devices such as buccal shelf bone screws, and Infrazygomatic Crestal Implants (IZC) have emerged as absolute anchorage devices. Using mini-screws, many surgical cases were permuted to non-surgical cases and borderline extraction cases to non-extraction cases. None of these outcomes are considered achievable with conventional methods.[1,3,4]

Primary stability is crucial for successful mini-screw placement. Various anatomical factors affect the stability of mini-screws, including bony characteristics such as density, depth, and critical bone thickness and soft tissue characteristics such as thickness, mobility, proximity to the frenum, and proximity to certain anatomical structures such as nerves, vessels, sinus/nasal cavities, and roots.[5,6] Bone screw is

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another name for mini-implants that are placed in the extra-alveolar areas.

In any clinical scenario, orthodontic bone screws can be used as a substitute for mini-implants. The two most specific indications are full-arch distalization of the maxillary and mandibular dentition to camouflage Class ll and Class lll malocclusion and distalization of the arches in retreatment cases of anchor loss. Bone screws are approximately 10 and 14 mm in length with a diameter of 2 mm. Based on the manufacturer, bone screws used in the mandible are available in two sizes, 10 mm and 12 mm in length with a diameter of 2 mm.[4]

Mandibular buccal shelf thickness can be assessed using cone-beam computed tomography (CBCT). CBCT is preferred over other modalities as it can quantify the skeletal structure of the buccal shelf, placement angle of the bone screw, and quantity of the cortical and cancellous bone contact at the bone screw interface lateral to the molar root. However, obtaining CBCT images before bone screw placement is expensive, and the amount of radiation exposure is high compared to two-dimensional (2D) radiography. Nevertheless, intricate anatomical structures demand the use of CBCT because it is the most reliable modality in such cases.[7]

Although numerous studies have been conducted to establish the ideal site for mini-screw placement in the buccal shelf of the mandibular area, studies that have been performed explicitly to perceive the information regarding the variation of the buccal shelf region in various sagittal and vertical malocclusions are limited. The possibility of variations in buccal shelf thickness and malocclusion among various populations within a country cannot be neglected. Therefore, the objectives of this study are as follows:

1. To measure the cortical bone thickness and bone depth at 90-degree and 30-degree angles of insertion and various heights.
2. To determine the most suitable site for mandibular buccal shelf for bone screw insertion.
3. To determine the angulation of the mandibular buccal shelf in the prognathic and retrognathic mandibles and vertical and horizontal growth patterns.
4. To determine the area of the buccal shelf in the prognathic and retrognathic mandibles and vertical and horizontal growth patterns.

Materials and Methods

Data source

In this retrospective study, CBCT images of male and female patients (prognathic and retrognathic mandibles and vertical and horizontal growth patterns) were collected from the archives of the Department of Orthodontics and Dentofacial Orthopedics at the A. B. Shetty Memorial Institute of Dental Sciences, Mangalore. Ethical approval for this study was obtained from the primary institution (Cert no: ABSM/EC 38/2019). All subjects signed a written consent form at the beginning of their orthodontic treatment and were informed that the data would be used for research purposes.

Sample Size: Based on a 5% level of significance and 80% power effect size of 0.5, the required sample size was 48. G* power software was used to calculate the sample size.

Inclusion criteria

CBCTs of subjects aged 18–30 years with prognathic mandible (n = 12), retrognathic mandible (n = 12), vertical growth pattern (n = 12), and horizontal growth pattern (n = 12).

Exclusion criteria

Systemic illness and endocrine disorders, severe skeletal and facial abnormalities, absence of first mandibular molars, periodontal disease (determined from radiographic signs of alveolar bone resorption), bone pathologies in the mandible, and faulty radiographs.

Medium and methods

A total of 48 full FOV CBCT scans of patients satisfying the inclusion and exclusion criteria were collected from the archives of the Department of Orthodontics in the A.B. Shetty Memorial Institute of Dental Sciences. CBCT images were obtained using the Planmeca ProMax Machine (230–240 V, 50 Hz, 16 A) manufactured by Planmeca OY (Helsinki, Finland). The images were in DICOM file format and analyzed using the Planmeca Romexis Viewer (Version 5.1.0.4). All records were analyzed by a single observer.

Lateral cephalograms derived from CBCT images were used to further divide the records into individuals with horizontal growth pattern (Frankfurt mandibular plane angle <21°), vertical growth pattern (Frankfurt mandibular plane angle >29°), a prognathic mandible (SNB angle >82°), and retrognathic mandible (SNB angle <78°).

Measurements on CBCT

A fully reconstructed three-dimensional (3D) image of the mandible in the sagittal, coronal, and axial planes was generated.

All 3D CBCT slices selected for the measurements were aligned perpendicular to the sagittal plane. In the sagittal view, the axial plane was aligned at the mean mandibular alveolar crest level. In the axial view, the sagittal plane was aligned by bisecting the mandibular first and second molars symmetrically. The following measurements were taken on the right side of the mandible:

- The planes selected for cortical bone measurement in the first molar region were the mesial (6 Ms), middle of the crown through the furcation area (6 Md), distal to the root (6 D), inter radicular bone between the molars (67 IR), the mesial plane of the second molar (7 Ms), middle of the second molar (7 Md), and distal to the second molar (7 D) [Figure 1].
- The planes were coded to correspond to the subsequent bone measurement data collected in the coronal plane in the prognathic and retrognathic mandibles and horizontal and vertical growth patterns [Figure 2].
- The angle of the mandibular buccal shelf was measured between the long axis of the mandible and a tangent drawn to the outermost border of the cortical plate in the coronal plane [Figure 3].
- Cortical bone thickness was measured at 90-degree (blue line) and 30-degree angles (green line), as shown at 3, 5, and 7 mm from the alveolar bone crest [Figure 4]. Safe depth for bone screw insertion at 90-degree (yellow line) and 30-degree angles (blue line), as shown at 3, 5, and 7 mm from the alveolar bone crest [Figure 5].
- The buccal shelf area was measured as the widest area extending from the mesial surface of the mandibular first molar to the external oblique ridge in the axial plane [Figure 6].

Statistical analysis

An Independent sample *t*-test was applied to compare the horizontal and vertical groups and the prognathic and retrognathic mandible groups. $P < 0.05$ was considered significant.

Study design

[Figure 7].

Results

This study aimed to anatomically assess the mandibular buccal shelf in different skeletal malocclusions using CBCT to improve the length and angulation of bone screw insertion. The results were based on measurements performed on 48 CBCTs, which were divided into the horizontal growth pattern ($n = 12$), vertical growth pattern ($n = 12$), prognathic mandible ($n = 12$), and retrognathic mandible ($n = 12$) groups in patients aged 18–30 years. Data were computed and subjected to statistical analysis. The following conclusions were drawn:

Comparison of cortical bone thickness between the horizontal and vertical groups

- At 90 degrees in 6 Ms, the mean values were higher in the vertical direction than in the horizontal direction at 5 mm. In 6 Md, 6 D, 67 IR, 7 Ms, 7 Md, and 7D, the mean values were 5 mm higher in the horizontal direction than in the vertical direction. In 67 IR and 7 Ms, there was a statistically significant difference between the horizontal and vertical groups ($P < 0.05$).

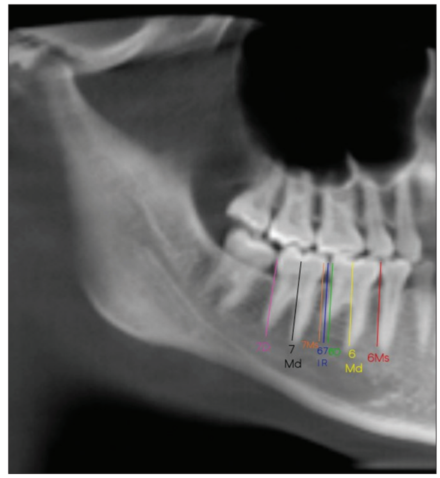

Figure 1: Planes selected for the measurement of cortical bone thickness

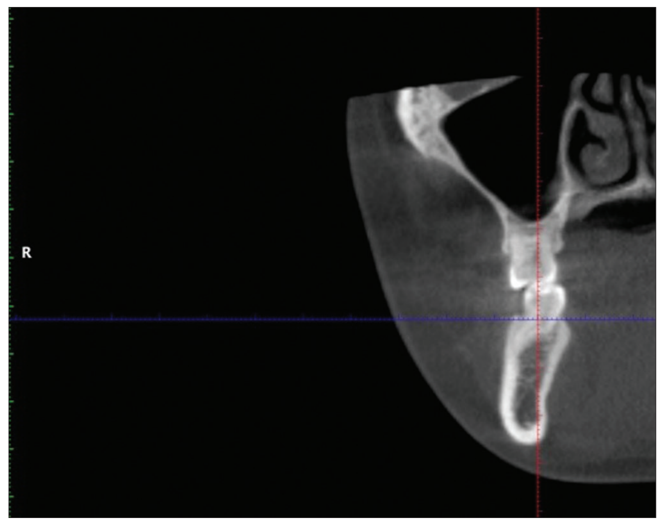

Figure 2: Coronal plane coded for corresponding bone measurement data

Figure 3: Angulation of mandibular buccal shelf

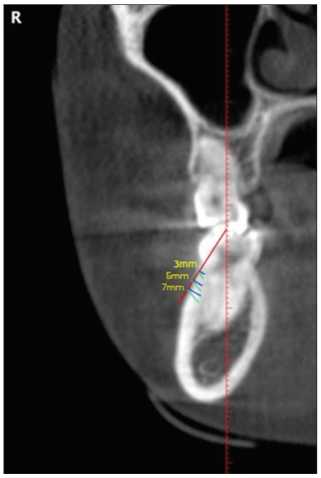

Figure 4: Cortical bone thickness measured at 90° and 30° at 3, 5, and 7 mm

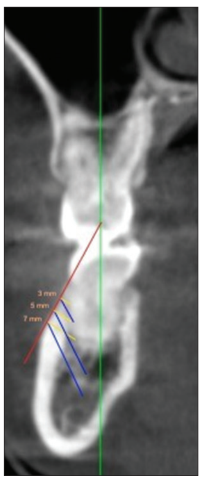

Figure 5: Safe depth for bone screw insertion at 90 degrees (yellow) and 30 degrees (blue) at 3, 5, and 7 mm

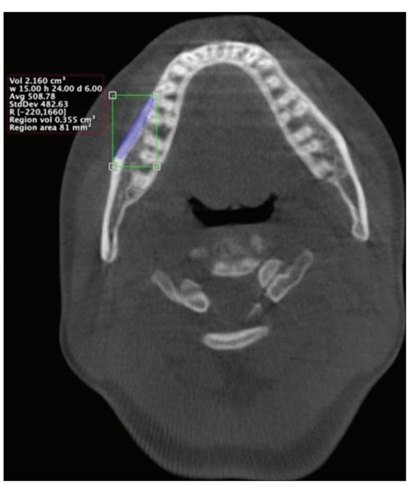

Figure 6: Extent of buccal shelf area in the axial plane

In 6 Ms, 6 Md, 6 D, 7 Md, and 7D, the mean values did not differ significantly between the horizontal and vertical groups ($P > 0.05$; Table 1).

Table 1: Comparison of the cortical bone thickness at a 90-degree angle of insertion between the horizontal (H) and vertical (V) growth patterns at 5 mm

	t-test for equality of means				
	t	*P*	Mean difference	95% Confidence interval of the difference	
				Lower	Upper
6Ms	-0.362	0.721	-0.03333	-0.22455	0.15788
6Md	1.064	0.299	0.11833	-0.11226	0.34893
6D	1.889	0.072	0.29167	-0.02863	0.61196
67 IR	2.247	0.035	0.30667	0.02368	0.58965
7Ms	2.540	0.019	0.34083	0.06250	0.61917
7Md	1.939	0.065	0.27500	-0.01910	0.56910
7D	1.964	0.062	0.26500	-0.01484	0.54484

- At 90 degrees in 6 Ms, the mean values were higher in the vertical direction than in the horizontal direction at 7 mm. In 6 Md, 6D, 67 IR, 7 Ms, 7 Md, and 7D, the mean values were higher in the horizontal direction than in the vertical direction at 7 mm. In 6 Ms, there was a statistically significant difference between the horizontal and vertical groups ($P < 0.05$). In 6 Md, 6D, 67 IR, 7 Ms, 7 Md, and 7D, there were no significant differences between the horizontal and vertical groups ($P > 0.05$; Table 2).
- At 30 degrees in 6 Ms, 67 IR, and 7 Ms, the mean values were higher in the vertical direction than in the horizontal direction at 3 mm. For 6 Md, 6D, 7 Md, and 7D, the mean values were 3 mm higher in the horizontal direction than in the vertical direction. In 7D, there was a statistically significant difference between the horizontal and vertical groups ($P < 0.05$). In 6 Ms, 6 Md, 6 D, 67 IR, 7 Ms, and 7 Md, the mean values did not differ significantly between the horizontal and vertical groups ($P > 0.05$; Table 3).
- At 30 degrees in 6 Ms, the mean values were higher in the vertical direction than in the horizontal direction at 5 mm. For 6 Md, 6D, 67 IR, 7 Ms, 7 Md, and 7D, the mean values were 5 mm higher in the horizontal direction than in the vertical direction. In 6D, 67 IR, 7 Ms, 7 Md, and 7D, there was a statistically significant difference between the horizontal and vertical groups ($P < 0.05$). In 6 Ms and 6 Md, the mean values did not differ significantly between the horizontal and vertical groups ($P > 0.05$; Table 4).

Comparison of safe depth values between the horizontal and vertical groups

- Independent samples *t*-test was applied to compare the horizontal (H) and vertical (V) groups at all three depths at 90 degrees and 30 degrees. Independent samples *t*-test showed a statistically significant difference with respect to 7 mm at 90 degrees between the groups ($P = 0.038$) at 6 Ms [Table 5].
- At 6D, the independent samples *t*-test showed a statistically significant difference with respect to

Table 2: Comparison of the cortical bone thickness at a 90-degree angle of insertion between the horizontal (H) and vertical (V) growth patterns at 7 mm

	t-test for equality of means				
	t	*P*	Mean difference	95% Confidence interval of the difference	
				Lower	Upper
6Ms	-2.203	0.045	-0.11917	-0.23526	-0.00307
6Md	0.176	0.862	0.01167	-0.12587	0.14920
6D	1.693	0.110	0.22917	-0.05826	0.51659
67 IR	0.704	0.493	0.09833	-0.20006	0.39673
7Ms	0.461	0.651	0.06000	-0.21369	0.33369
7Md	1.312	0.207	0.14500	-0.08820	0.37820
7D	1.450	0.164	0.16833	-0.07531	0.41198

Table 3: Comparison of the cortical bone thickness at a 30-degree angle of insertion between the horizontal (H) and vertical (V) growth patterns at 3 mm

	t-test for equality of means				
	t	*P*	Mean difference	95% Confidence interval of the difference	
				Lower	Upper
6Ms	-0.641	0.529	-0.06583	-0.28037	0.14870
6Md	0.276	0.786	0.02917	-0.19160	0.24993
6D	0.742	0.468	0.08500	-0.15704	0.32704
67 IR	-0.372	0.714	-0.04417	-0.29072	0.20238
7Ms	-0.968	0.343	-0.10083	-0.31676	0.11509
7Md	1.457	0.159	0.17000	-0.07195	0.41195
7D	2.149	0.043	0.32167	0.01123	0.63211

Table 4: Comparison of the cortical bone thickness at a 30-degree angle of insertion between the horizontal (H) and vertical (V) growth patterns at 5 mm

	t-test for equality of means				
	t	*P*	Mean difference	95% Confidence interval of the difference	
				Lower	Upper
6Ms	-0.201	0.842	-0.02083	-0.23534	0.19367
6Md	1.338	0.195	0.16917	-0.09313	0.43147
6D	2.392	0.026	0.44667	0.05947	0.83386
67 IR	3.152	0.005	0.46167	0.15790	0.76544
7Ms	2.915	0.008	0.39500	0.11400	0.67600
7Md	2.302	0.031	0.32250	0.03193	0.61307
7D	2.420	0.024	0.26833	0.03838	0.49829

5 mm at 30 degrees between the groups ($P = 0.03$; Table 6).
- At 67 IR, the independent samples *t*-test showed a statistically significant difference with respect to 5 mm at 30 degrees between the groups ($P = 0.005$; Table 7).
- At 7 Md, the independent samples *t*-test showed a statistically significant difference with respect to 5 mm at 30 degrees between the groups ($P = 0.031$; Table 8).
- At 7D, the independent samples *t*-test showed a statistically significant difference with respect to 3 mm and 5 mm at 30 degrees between the groups ($P = 0.043$ and 0.024, respectively; Table 9).

Comparison of the angulation of buccal shelf between the prognathic and retrognathic mandibles

- In 6Ms, 6 Md, 6D, 67 IR, 7 Ms, 7 Md, and 7D, the mean values were higher in the prognathic mandible than in the retrognathic mandible. In 67 IR, there was a statistically significant difference between the prognathic and retrognathic mandibles ($P < 0.05$). In 6 Ms, 6 Md, 6D, 7 Ms, 7 Md, and 7D, there were no statistically significant differences between the two groups ($P > 0.05$; Table 10).

Comparison of cortical bone thickness between the prognathic and retrognathic mandibles

- There was no statistically significant difference in the cortical bone thickness between the prognathic and retrognathic mandibles.

Comparison of the angulation of buccal shelf between the horizontal and vertical groups and safe depth values between the prognathic and retrognathic mandibles

- There was no statistically significant difference in the angulation of the buccal shelf between the horizontal and vertical groups and the safe depth values between the prognathic and retrognathic mandibles.

Comparison of buccal shelf area between the prognathic and retrognathic mandibles and horizontal and vertical groups

- There was no statistically significant difference in the buccal shelf area between the prognathic and retrognathic mandibles and between the horizontal and vertical groups.

Discussion

Anchorage preparation is a crucial step in orthodontic treatment. The success of orthodontic treatment relies on the anchorage protocol planned for a particular case.[8] Choosing the best location for a mini-implant is also important for patient safety and mini-implant retention. To achieve appropriate primary stability for mini-implant success, the placement site should have a cortical bone thickness >1.0 mm. The thickness of the cortical bone varies significantly throughout the maxilla and mandible. In general, the bone density in the mandible is higher than that in the maxilla.[9]

The mandibular buccal shelf (MBS) is an extra-alveolar anchorage site that has gained popularity because of its high quality and quantity of bone, biomechanical

Table 5: Comparison of the safe depth values of the mesial side of the first molar between the horizontal and vertical groups

Degrees	Depth	Groups	*n*	Minimum	Maximum	Mean	S.D.	Mean diff	*P*
90 degree	3 mm	Horizontal	12	1.56	2.12	1.85	0.21	-0.09	0.35
		Vertical	12	1.59	2.35	1.94	0.27		
	5 mm	Horizontal	12	1.87	2.28	2.12	0.17	-0.03	0.72
		Vertical	12	1.77	2.53	2.15	0.27		
	7 mm	Horizontal	12	2.53	2.74	2.62	0.06	-0.11	0.038*
		Vertical	12	2.50	2.95	2.74	0.18		
30 degree	3 mm	Horizontal	12	6.76	7.33	7.05	0.20	-0.06	0.52
		Vertical	12	6.72	7.48	7.11	0.29		
	5 mm	Horizontal	12	19.97	20.54	20.31	0.19	-0.02	0.84
		Vertical	12	19.92	20.86	20.33	0.30		
	7 mm	Horizontal	12	20.76	21.04	20.90	0.09	-0.06	0.30
		Vertical	12	20.68	21.33	20.96	0.17		

Table 6: Comparison of the safe depth values of the distal side of the first molar between the horizontal and vertical groups

Degrees	Depth	Groups	*n*	Minimum	Maximum	Mean	S.D.	Mean diff	*P*
90 degrees	3 mm	Horizontal	12	2.07	2.59	2.36	0.18	0.057	0.56
		Vertical	12	1.94	2.80	2.31	0.29		
	5 mm	Horizontal	12	2.34	3.42	2.88	0.41	0.29	0.07
		Vertical	12	2.10	3.13	2.59	0.35		
	7 mm	Horizontal	12	3.20	4.42	3.60	0.42	0.22	0.10
		Vertical	12	3.08	3.88	3.37	0.20		
30 degrees	3 mm	Horizontal	12	7.29	7.77	7.56	0.19	0.057	0.59
		Vertical	12	6.99	8.06	7.51	0.32		
	5 mm	Horizontal	12	20.59	21.91	21.21	0.53	0.43	0.03*
		Vertical	12	20.28	21.48	20.78	0.38		
	7 mm	Horizontal	12	21.42	22.65	21.83	0.44	0.23	0.12
		Vertical	12	21.22	22.05	21.60	0.24		

Table 7: Comparison of the interproximal values of the first and second molars between the horizontal and vertical groups

Degrees	Depth	Groups	*n*	Minimum	Maximum	Mean	S.D.	Mean diff	*P*
90 degrees	3 mm	Horizontal	12	2.56	3.05	2.78	0.16	-0.06	0.55
		Vertical	12	2.35	3.15	2.84	0.31		
	5 mm	Horizontal	12	3.07	3.73	3.40	0.24	0.30	0.035*
		Vertical	12	2.53	3.85	3.09	0.41		
	7 mm	Horizontal	12	3.67	4.97	4.14	0.45	0.09	0.48
		Vertical	12	3.79	4.44	4.04	0.19		
30 degrees	3 mm	Horizontal	12	7.77	8.33	8.01	0.22	-0.044	0.71
		Vertical	12	7.53	8.48	8.06	0.35		
	5 mm	Horizontal	12	21.32	22.48	21.77	0.39	0.46	0.005*
		Vertical	12	20.88	21.98	21.31	0.33		
	7 mm	Horizontal	12	21.90	23.27	22.40	0.46	0.09	0.52

benefits, and low failure rates. MBS implants do not obstruct the ideal path of tooth movement; therefore, there is no need to alter the mini-implant position during treatment.[10] Apart from the roots of the molar teeth, the inferior alveolar canal is the only anatomically sensitive structure that is close to this region. Despite these benefits, little information is available regarding the optimal location for MBS mini-implant placement.

In this study, we attempted to assess and compare the MBS anatomy affecting the length and angulation of bone screw insertion in the horizontal and vertical growth patterns (horizontal and vertical groups) and prognathic and retrognathic mandibles (prognathic and retrognathic groups) using CBCT. In our study, the cortical bone thickness, angulation, safe depth, and buccal shelf area were measured only on the right side of the mandible in all groups. The study results showed

Table 8: Comparison of the safe depth values of the middle portion of the second molar between the horizontal and vertical groups

Degrees	Depth	Groups	*n*	Minimum	Maximum	Mean	S.D.	Mean diff	*P*
90 degrees	3 mm	Horizontal	12	3.05	4.05	3.47	0.30	0.02	0.87
		Vertical	12	3.02	3.96	3.45	0.29		
	5 mm	Horizontal	12	3.63	4.74	4.08	0.38	0.27	0.065
		Vertical	12	3.32	4.47	3.80	0.31		
	7 mm	Horizontal	12	4.33	5.37	4.75	0.34	0.14	0.20
		Vertical	12	4.15	4.85	4.61	0.18		
30 degrees	3 mm	Horizontal	12	8.43	9.36	8.82	0.29	0.17	0.15
		Vertical	12	8.13	9.06	8.65	0.28		
	5 mm	Horizontal	12	21.78	22.84	22.31	0.36	0.32	0.031*
		Vertical	12	21.51	22.71	21.99	0.32		
	7 mm	Horizontal	12	22.47	23.75	23.02	0.41	0.21	0.12
		Vertical	12	22.34	23.04	22.81	0.19		

Table 9: Comparison of the safe depth values of the distal side of the second molar between the horizontal and vertical groups

Degrees	Depth	Groups	*n*	Minimum	Maximum	Mean	S.D.	Mean diff	*P*
90 degrees	3 mm	Horizontal	12	3.36	4.43	3.89	0.29	0.15	0.26
		Vertical	12	3.14	4.35	3.73	0.38		
	5 mm	Horizontal	12	3.86	4.83	4.37	0.37	0.21	0.12
		Vertical	12	3.55	4.75	4.16	0.29		
	7 mm	Horizontal	12	4.57	5.66	5.06	0.34	0.16	0.16
		Vertical	12	4.40	5.17	4.90	0.21		
30 degrees	3 mm	Horizontal	12	8.57	9.86	9.18	0.40	0.32	0.043*
		Vertical	12	8.33	9.23	8.86	0.34		
	5 mm	Horizontal	12	22.06	22.92	22.60	0.30	0.26	0.024*
		Vertical	12	21.82	22.90	22.33	0.24		
	7 mm	Horizontal	12	20.02	23.95	23.08	1.04	-0.11	0.71
		Vertical	12	22.36	23.79	23.20	0.39		

Table 10: Comparison of the angulation of buccal shelf between prognathic (P) and retrognathic (R) mandibles

	t-test for equality of means				
	t	*P*	Mean difference	95% Confidence interval of the difference	
				Lower	Upper
6Ms	0.967	0.344	1.34000	-1.53375	4.21375
6Md	0.276	0.785	0.48833	-3.17467	4.15134
6D	0.049	0.961	0.08000	-3.30812	3.46812
67IR	2.700	0.013	5.45083	1.26439	9.63727
7Ms	0.851	0.404	2.18667	-3.14135	7.51469
7Md	1.001	0.327	1.89500	-2.02931	5.81931
7D	0.876	0.391	1.44083	-1.97068	4.85235

that cortical bone thickness increased as we moved distally, irrespective of the group. This is similar to the findings from studies conducted by Rajesh,[10] Chang *et al.*,[11] Tsunori *et al.*,[12] Patla *et al.*,[13] Vargas *et al.*,[14] and Sreenivasagan *et al.*[15]

In this study, the cortical bone thickness was higher in most sections in patients with a horizontal growth pattern than in those with a vertical growth pattern, which is similar to the results of studies conducted by Gandhi *et al.* and Vargas *et al.*[2,14] There was no statistically significant difference between the prognathic and retrognathic groups. In our study, the most suitable site for mini-screw placement in the buccal shelf area was 5–7 mm below the alveolar crest distal to the second molar, which is in accordance with studies conducted by Chang *et al.* and Sreenivasagan *et al.*[11,15]

In our study, the results for safe depth showed that bone screw insertion at all three locations for 90-degree angulation and 3 mm for 30-degree angulation was not favorable, as it had higher root proximity. However, at 5 and 7 mm for 30-degree angulation, it did not have proximity to the root from the outer cortical bone, which is similar to the findings of Chang *et al.* and Sreenivasagan *et al.*[11,15] The present study noted that the bone screw must always be inserted perpendicular to the bone surface to prevent injury due to slippage. Additionally, inserting the bone screw at 90 degrees reminds us that we cannot use this angulation and indicates how far we can move perpendicularly before changing the angulation. Thus, damage to the root can be prevented, and chipping or flaking of the cortical bone can be avoided.

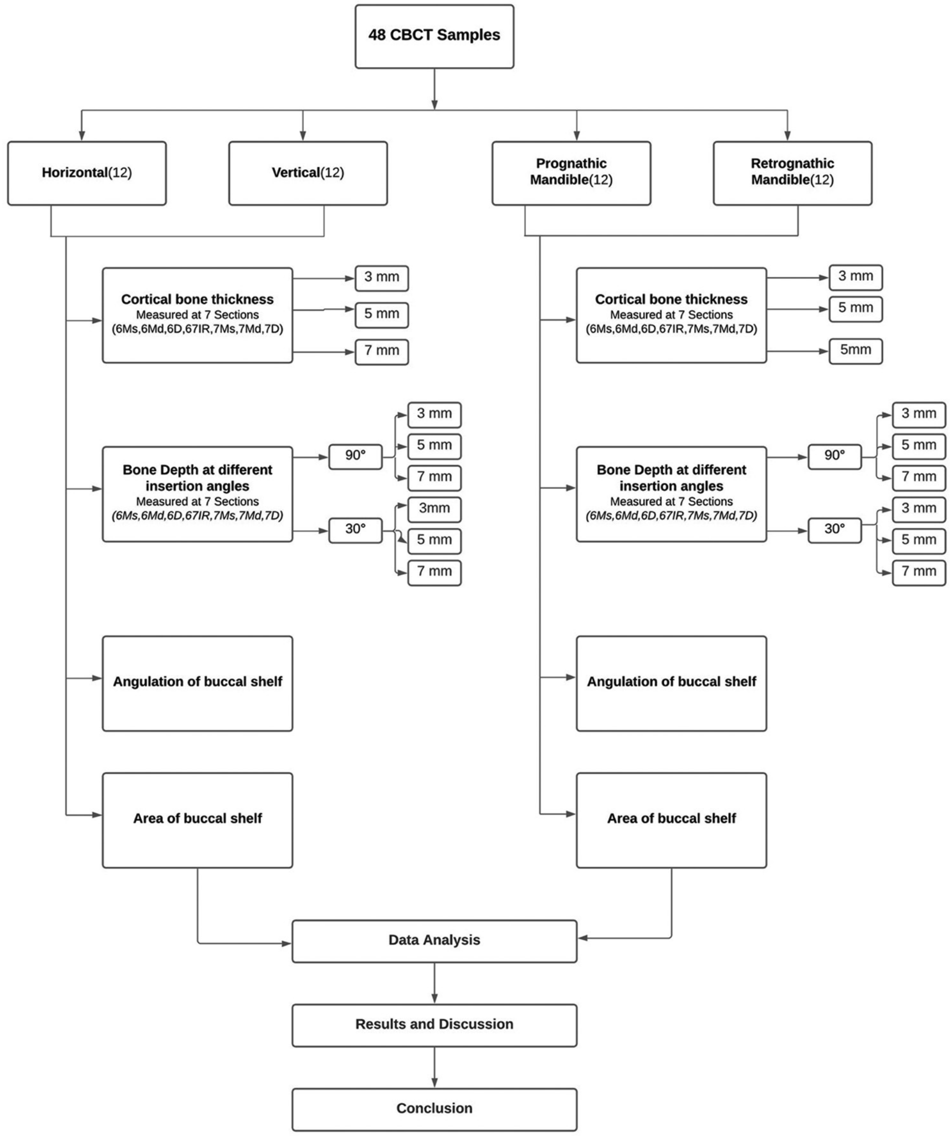

Figure 7: Diagrammatic representation of the study design

On evaluating the angulation of the buccal shelf, the prognathic group had a greater angulation than the retrognathic group in 67 IR. The mean angulation of MBS in 67 IR in the prognathic group was 26.1 degrees in our study. No significant differences were observed between the horizontal and vertical groups. Chang *et al*., in their study, found that the angulation of the buccal shelf increased progressively from mesial to the first molar to distal to the second molar, which was not seen in the current study.[11] This demographic variation of the angulation of the buccal shelf makes buccal shelf implant placement in the Indian population difficult.

In this study, the extent of the buccal shelf area was also evaluated and compared. The widest area in the axial plane extended from the mesial surface of the mandibular first molar to the external oblique ridge. The results showed no statistically significant difference in the buccal shelf area in the horizontal and vertical groups and the prognathic and retrognathic groups, which was similar to the findings reported by Gandhi *et al*.[2]

Although our study provides valuable evidence to the literature, it does have certain limitations. Considering the varying effects of age on cortical bone thickness, our study results may not be applicable to older or younger age groups, as our samples were in the age group of 18–30 years. Furthermore, a study with a larger sample size would aid in extrapolating the results to a larger population.

Conclusions

The results showed that the cortical bone thickness increased as we moved distally from the first to the second molar distal roots in all four groups. Thus, the preferred site for buccal shelf implant placement is distal to the mandibular second molar. The maximum amount of cortical bone was observed distal to the second molar, 7 mm vertically from the alveolar crest, when the buccal shelf implant was placed at 30-degree angulation to the long axis of the tooth. The angulation of the buccal shelf in the prognathic group was greater than that in the retrognathic group in 67 IR. This demographic variation in the angulation of buccal shelves makes buccal shelf implant placement in the Indian population difficult.

Ethics statement

The Institutional Ethics Committee has cleared this study with the ethical clearance number: **Cert No: ABSM/EC 38/2019**

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Conflicts of interest

There are no conflicts of interest.

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