Original Article

Optimal sites for orthodontic mini-implant placement assessed by cone beam computed tomography

Mona Mohamed Salah Fayed[a]; Pawel Pazera[b]; Christos Katsaros[c]

ABSTRACT

Objectives: To determine (1) the optimal sites for mini-implant placement in the maxilla and the mandible based on dimensional mapping of the interradicular spaces and cortical bone thickness and (2) The effect of age and sex on the studied anatomic measurements.

Material and Methods: The cone beam computed tomography images of 100 patients (46 males, 54 females) divided into two age groups (13–18 years), and (19–27 years) were used. The following interradicular measurements were performed: (1) Buccolingual bone thickness; (2) Mesiodistal spaces both buccally and palatally/lingually; and (3) Buccal and palatal/lingual cortical thicknesses.

Results: In the maxilla, the highest buccolingual thickness existed between first and second molars; the highest mesiodistal buccal/palatal distances were between the second premolar and the first molar. The highest buccal cortical thickness was between the first and second premolars. The highest palatal cortical thickness was between central and lateral incisors. In the mandible, the highest buccolingual and buccal cortical thicknesses were between the first and second molars. The highest mesiodistal buccal distance was between the second premolar and the first molar. The highest mesiodistal lingual distance was between the first and second premolars. The highest lingual cortical thickness was between the canine and the first premolar. The males and the older age group had significantly higher buccolingual, buccal, and palatal cortical thicknesses at specific sites and levels in the maxilla and the mandible.

Conclusions: A clinical guideline for optimal sites for mini-implant placement is suggested. Sex and age affected the anatomic measurements in certain areas in the maxilla and the mandible. (*Angle Orthod.* 2010;80:939–951.)

KEY WORDS: Optimal sites; Mini-implants; Interradicular dimensions; Cortical thickness; CBCT

INTRODUCTION

Mini-implants have become a very popular type of orthodontic skeletal anchorage, which is reflected in the escalating number of studies addressing this subject. However, there is still no consensus in these studies about the factors that influence the success of mini-implants. A recent systematic review could not prove an association between the type of mini-implant, patient characteristics, placement site, surgical technique, and orthodontic and implant maintenance factors and the success rates of mini-implants.[1]

The present study focused on only one of these factors: implant placement site. The most common implant sites appear to be the palate, the palatal aspect of the maxillary alveolar process, the retromolar area in the mandible, and the buccal cortical plate in both the maxilla and the mandible.[2–7] Among the important factors that should be considered when choosing mini-implant placement sites are soft-tissue anatomy, interradicular distance, sinus morphology, nerve location, buccolingual bone depth, and buccal and lingual cortical thicknesses.

Several studies provide measurements of the interradicular spaces at the posterior maxilla and

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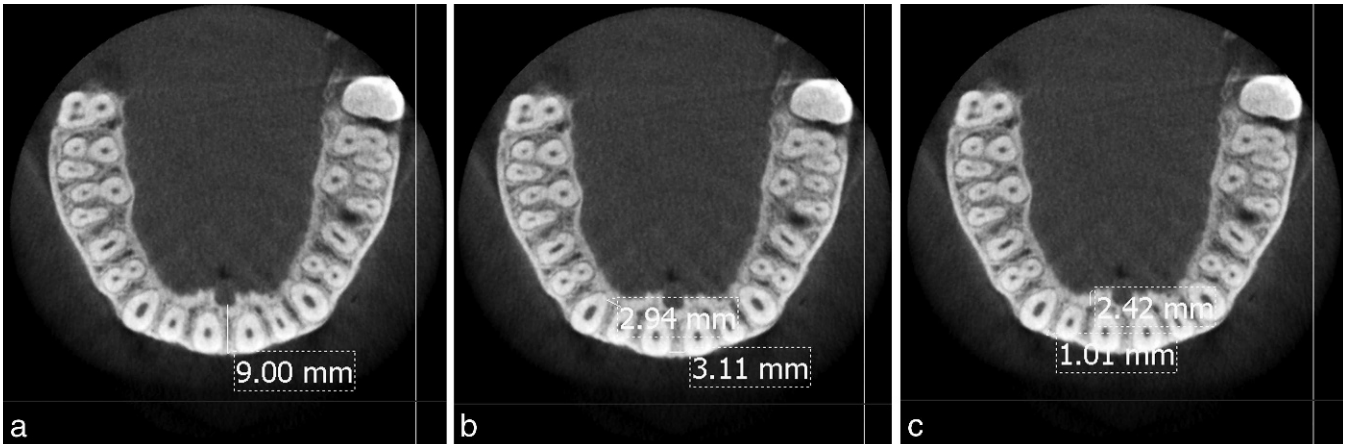

Figure 1. Maxillary anterior region. (A) Measurement of the buccolingual thickness. (B) Measurement of the mesiodistal buccal and palatal distances. (C) Measurement of the buccal and palatal cortical thicknesses.

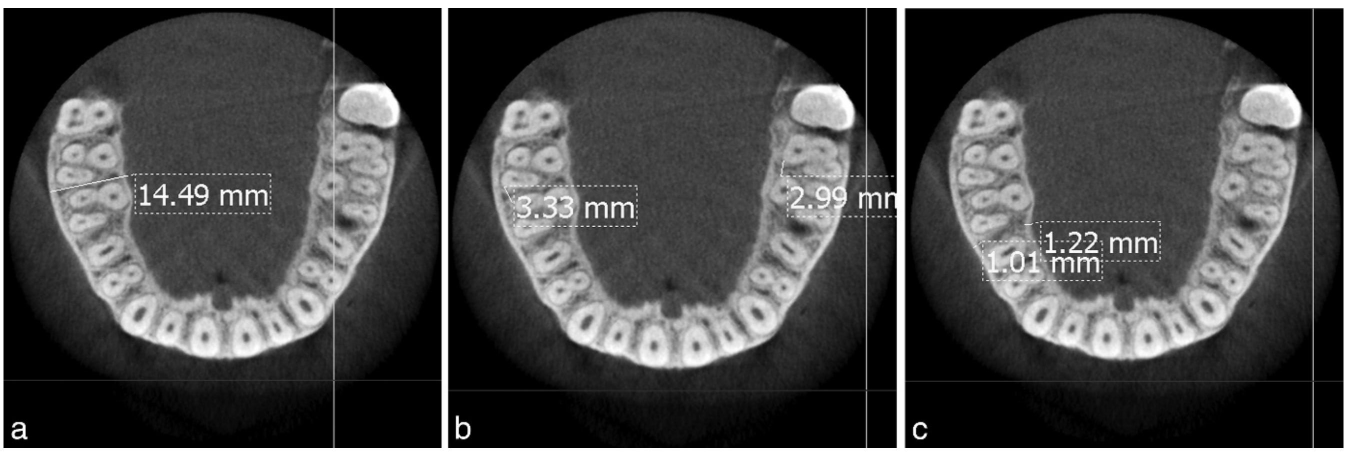

Figure 2. Maxillary posterior region. (A) Measurement of the buccolingual thickness. (B) Measurement of the mesiodistal buccal and palatal distances. (C) Measurement of the buccal and palatal cortical thicknesses.

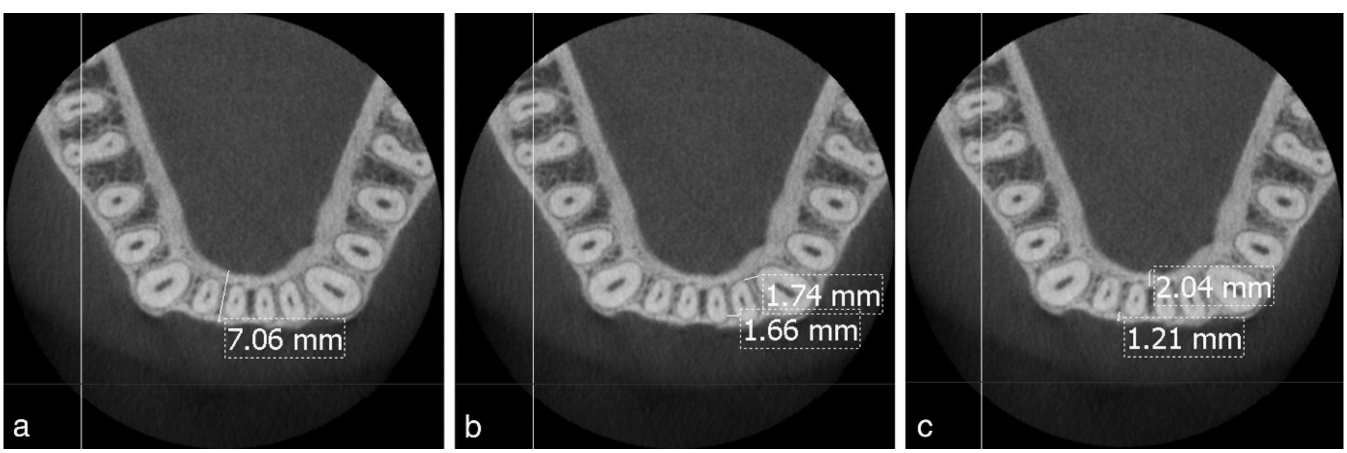

Figure 3. Mandibular anterior region. (A) Measurement of the buccolingual thickness. (B) Measurement of the mesiodistal buccal and lingual distances. (C) Measurement of the buccal and lingual cortical thicknesses.

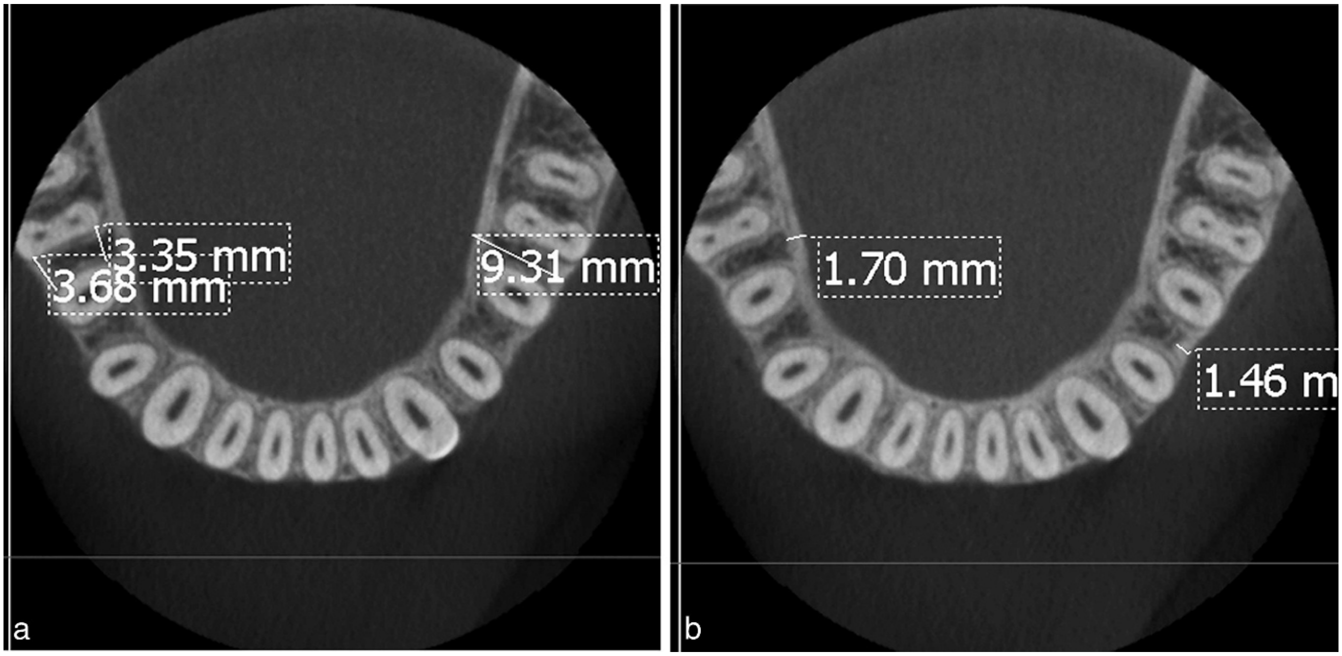

Figure 4. Mandibular posterior region. (A) Measurement of the buccolingual thickness and the mesiodistal buccal and lingual distances. (B) Measurement of the buccal and lingual cortical thicknesses.

mandible. It was reported that the volume of bone in the maxillary interradicular space between the second premolar and the first molar provides the optimal anatomic site for miniscrews in the maxilla.[8–10] Poggio et al.[11] ranked the safest sites available in interradicular spaces in the posterior maxilla and reported that the safest was between the first molar and the second premolar 2–8 mm from the alveolar crest; for the posterior mandible it was between the first and second molars. Hardly any data are available concerning the interradicular spaces of the anterior maxillary and mandibular areas in spite of the fact that mini-implants can also be useful in the anterior region as anchorage for mesial movement of the posterior dentition or correction of the anterior vertical occlusion.[4,6]

A limited number of studies have investigated cortical bone thickness in the maxilla and the mandible. Most of these studies have been carried out on a small sample or were limited to the posterior part of the jaws. The buccal cortical bone thickness seems to be greater in

Table 1A. Means and Standard Deviations of Measurements of the Right Side of the Maxilla[a]

		Right Side											
		7-6		6-5		5-4		4-3		3-2		2-1	
Cut Level	Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-mm cut	BL	12.70	1.26	11.38	1.53	9.77	1.35	8.93	1.40	8.20	1.49	8.32	1.56
	MD-B	2.85	0.90	3.64	0.95	3.32	0.67	3.18	1.34	3.06	0.81	2.52	0.75
	MD-P	3.80	0.94	5.32	1.14	3.52	0.72	2.55	1.23	3.19	0.86	2.28	0.60
	BC	1.28	0.43	1.12	0.27	1.15	0.22	1.10	0.30	1.01	0.26	0.97	0.25
	PC	1.39	0.30	1.36	0.33	1.58	0.41	1.68	0.50	1.77	0.52	1.64	0.58
4-mm cut	BL	13.33	1.34	12.12	1.77	10.07	1.64	9.43	1.46	8.70	1.51	9.08	1.68
	MD-B	2.55	0.92	3.86	1.40	3.44	0.75	3.27	1.37	3.69	1.00	2.91	0.86
	MD-P	3.75	0.92	5.90	1.48	3.43	0.86	2.62	1.30	3.40	1.01	2.46	0.77
	BC	1.19	0.37	1.18	0.30	1.18	0.33	1.15	0.37	1.05	0.29	1.05	0.30
	PC	1.30	0.37	1.54	0.39	1.64	0.49	1.78	0.54	1.68	0.53	1.75	0.54
6-mm cut	BL	14.21	1.62	12.66	2.11	10.48	1.98	9.79	1.69	9.22	1.77	9.58	2.16
	MD-B	2.16	0.86	4.06	1.59	3.51	0.90	3.35	1.44	3.96	1.20	3.03	0.96
	MD-P	3.84	1.20	6.75	1.55	3.71	1.04	2.78	1.45	3.68	1.07	2.77	0.90
	BC	1.20	0.47	1.12	0.30	1.10	0.31	1.18	0.34	1.09	0.32	1.09	0.29
	PC	1.41	0.43	1.63	0.44	1.69	0.50	1.72	0.56	1.75	0.59	1.85	0.64

[a] SD indicates standard deviation; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-P, mesiodistal distance from the palatal side; BC, buccal cortical thickness; and PC, palatal cortical thickness.

Table 1B. Means and Standard Deviations of Measurements of the Left side of the Maxilla[a]

		Left Side													
		1-1		1-2		2-3		3-4		4-5		5-6		6-7	
Cut Level	Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-mm cut	BL	7.16	1.68	7.89	1.69	7.68	1.36	8.95	1.28	9.67	1.64	11.30	1.40	13.05	1.43
	MD-B	3.23	0.94	2.69	0.76	3.07	0.99	3.13	0.98	2.95	0.66	3.57	0.95	2.75	0.93
	MD-P	3.77	1.11	2.26	0.80	3.24	1.00	2.74	0.95	3.60	1.02	4.72	1.41	3.98	0.93
	BC	1.00	0.31	1.01	0.26	1.06	0.27	1.21	0.31	1.28	0.34	1.28	0.26	1.35	0.35
	PC	1.39	0.43	1.54	0.51	1.55	0.46	1.57	0.50	1.48	0.44	1.39	0.34	1.40	0.38
4-mm cut	BL	7.82	2.25	8.61	1.69	8.40	1.45	9.37	1.46	10.14	1.60	11.89	1.42	13.76	1.48
	MD-B	3.77	1.04	2.95	0.70	3.49	1.20	3.24	0.96	3.39	0.74	3.66	1.05	2.51	1.16
	MD-P	4.00	1.28	2.52	0.90	3.50	1.14	2.91	1.03	3.75	0.88	5.55	1.58	4.18	1.00
	BC	1.06	0.29	1.05	0.28	1.14	0.30	1.19	0.31	1.28	0.34	1.27	0.27	1.37	0.31
	PC	1.49	0.49	1.64	0.50	1.66	0.46	1.75	0.50	1.55	0.45	1.39	0.35	1.42	0.27
6-mm cut	BL	9.35	3.11	9.14	1.94	8.80	1.80	9.59	1.71	10.31	1.67	12.56	1.63	14.21	1.48
	MD-B	4.27	1.23	3.17	0.93	3.84	1.36	3.37	1.05	3.25	0.82	3.84	1.40	2.35	1.20
	MD-P	4.49	1.15	2.75	1.12	3.73	1.28	3.30	1.23	3.97	0.99	6.19	1.78	4.37	1.15
	BC	1.14	0.31	1.14	0.29	1.24	0.30	1.24	0.32	1.26	0.35	1.31	0.31	1.33	0.32
	PC	1.75	0.61	1.78	0.53	1.74	0.47	1.78	0.46	1.66	0.51	1.49	0.40	1.43	0.22

[a] SD indicates standard deviation; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-P, mesiodistal distance from the palatal side; BC, buccal cortical thickness; and PC, palatal cortical thickness.

the mandible than in the maxilla.[12–16] Baumgaertel and Hans[15] studied 30 dry skulls and found that the thickness of the buccal cortical bone increases with increasing distance from the alveolar crest in the mandible and in the maxillary anterior area.

The influence of age and sex in success of mini-implants remains controversial. It seems that cortical bone is thinner in females mesial to the maxillary first molar[16] However, several articles reported no association between sex and implant success.[1] Motoyoshi et al.[17] showed less implant success in adolescents when the implants were loaded early, whereas the success rates were similar to that in adults after a 3-month latent period.

The purpose of the present investigation was to determine the optimal sites of mini-implant placement in the anterior and posterior maxilla and mandible based on mapping of the dimensions of the interradicular spaces and cortical bone thickness using cone beam computed tomography (CBCT). In addition, we wanted to elucidate the effect of age and sex on the studied anatomic measurements.

MATERIALS AND METHODS

The sample consisted of three-dimensional (3D) images of 100 patients (46 males and 54 females; mean age, 20 years) in whom there were 66 maxillae

Table 2A. Means and Standard Deviations of Measurements of the Right Side of the Mandible[a]

		Right Side											
		7-6		6-5		5-4		4-3		3-2		2-1	
Cut Level	Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-mm cut	BL	12.69	1.50	10.02	1.21	8.61	1.37	8.11	1.29	7.60	1.24	6.85	1.00
	MD-B	4.24	2.88	4.00	1.03	3.87	1.03	3.01	0.91	2.61	0.59	2.12	0.68
	MD-L	4.72	2.57	3.74	1.01	4.16	1.22	3.00	1.16	2.47	0.72	2.05	0.60
	BC	2.30	0.75	1.56	0.63	1.25	0.41	1.18	0.33	1.05	0.27	1.10	0.30
	LC	2.07	0.43	1.96	0.73	2.13	0.75	2.39	0.66	2.10	0.59	1.63	0.54
4-mm cut	BL	13.44	1.87	10.89	1.26	9.38	1.40	8.89	1.43	7.85	1.26	7.01	1.06
	MD-B	3.59	1.77	4.15	1.38	4.35	1.34	3.20	1.03	2.94	0.90	2.23	0.61
	MD-L	4.40	1.94	3.70	1.07	4.76	1.15	3.20	1.35	2.59	0.83	1.93	0.60
	BC	2.66	0.69	1.74	0.63	1.45	0.40	1.20	0.27	1.17	0.28	1.16	0.26
	LC	2.12	0.43	2.26	0.55	2.50	0.61	2.61	0.65	2.29	0.56	1.89	0.47
6-mm cut	BL	13.79	2.03	11.62	1.15	9.95	1.60	9.17	1.44	7.83	1.36	7.14	1.27
	MD-B	3.96	1.93	4.36	1.46	4.80	1.42	3.32	1.05	3.28	0.88	2.37	0.73
	MD-L	4.74	2.44	4.03	1.42	5.31	1.32	3.47	1.40	2.78	1.13	1.89	0.62
	BC	3.00	0.56	2.00	0.71	1.71	0.42	1.42	0.59	1.22	0.23	1.19	0.37
	LC	2.21	0.49	2.40	0.47	2.44	0.55	2.50	0.57	2.29	0.48	2.12	0.59

[a] SD indicates standard deviation; BL, buccolingual thickness; MD-B, mediodistal distance from the Buccal side; MD-P, mesiodistal distance from the palatal side; BC, Buccal cortical thickness; PC, palatal cortical thickness.

Table 2B. Means and Standard Deviations of Measurements of the Left Side of the Mandible[a]

		1-1		Left Side 1-2		2-3		3-4		4-5		5-6		6-7	
Cut Level	Site	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-mm cut	BL	6.34	1.13	7.01	1.10	7.45	1.15	8.25	1.24	8.55	1.53	10.13	1.56	11.96	1.49
	MD-B	2.20	0.54	2.21	0.54	3.00	0.99	3.09	1.18	3.97	1.03	4.56	1.38	4.18	3.67
	MD-L	2.20	0.83	2.15	0.55	2.54	0.95	3.11	0.88	4.90	1.10	4.16	1.44	4.88	2.20
	BC	1.11	0.26	1.21	0.28	1.22	0.29	1.20	0.26	1.41	0.29	1.70	0.41	2.38	2.20
	LC	1.75	0.35	1.61	0.37	1.92	0.59	2.16	0.60	2.15	0.70	1.92	0.54	2.07	1.76
4-mm cut	BL	6.73	1.17	7.06	1.21	7.71	1.21	8.90	1.31	9.23	1.47	10.73	1.45	12.77	1.66
	MD-B	2.29	0.69	2.15	0.60	3.31	1.36	3.22	0.97	4.59	1.31	5.00	1.51	4.29	3.88
	MD-L	2.24	0.79	2.12	0.63	2.79	1.11	3.23	0.92	5.57	1.16	4.70	1.67	4.76	2.60
	BC	1.09	0.28	1.15	0.31	1.23	0.25	1.35	0.27	1.61	0.36	1.78	0.38	2.61	2.49
	LC	2.09	0.48	1.96	0.46	2.28	0.50	2.62	0.45	2.38	0.58	2.11	0.38	2.35	1.80
6-mm cut	BL	7.29	1.35	7.14	1.39	7.75	1.43	9.13	1.33	9.70	1.44	11.33	1.50	13.26	1.66
	MD-B	2.31	0.75	2.31	0.64	3.89	1.33	3.12	1.03	5.22	1.25	5.61	2.00	5.28	3.46
	MD-L	2.19	0.90	1.98	0.63	3.12	1.51	3.31	1.06	5.85	1.16	5.23	2.20	5.43	2.04
	BC	1.10	0.32	1.12	0.22	1.24	0.19	1.39	0.35	1.72	0.30	2.08	0.32	3.05	2.22
	LC	2.19	0.50	2.13	0.50	2.36	0.53	2.56	0.46	2.46	0.43	2.33	0.38	2.53	1.53

[a] SD indicates standard deviation; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-L, mesiodistal distance from the lingual side; BC, buccal cortical thickness; and LC, lingual cortical thickness.

Table 3. Comparison Between Measurements of Males and Females in the Anterior Maxillary Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	Male	8.217	1.008						
		Female	7.451	1.532	0.766	0.331	0.105	1.426	2.317	.024*
	MD-B	Male	2.925	0.468						
		Female	2.934	0.545	−0.009	0.128	−0.265	0.246	−0.073	.942
	MD-P	Male	2.851	0.448						
		Female	3.120	0.677	−0.269	0.146	−0.561	0.023	−1.839	.071
	BC	Male	1.023	0.223						
		Female	1.015	0.204	0.008	0.054	−0.100	0.117	0.152	.880
	PC	Male	1.615	0.404						
		Female	1.514	0.408	0.101	0.104	−0.106	0.309	0.976	.333
4-mm cut	BL	Male	9.002	1.090						
		Female	8.086	1.584	0.916	0.346	0.224	1.607	2.647	.010*
	MD-B	Male	3.367	0.475						
		Female	3.440	0.671	−0.073	0.148	−0.368	0.222	−0.495	.622
	MD-P	Male	3.115	0.476						
		Female	3.314	0.871	−0.199	0.180	−0.559	0.162	−1.102	.275
	BC	Male	1.106	0.240						
		Female	1.031	0.209	0.075	0.056	−0.037	0.186	1.341	.185
	PC	Male	1.727	0.397						
		Female	1.570	0.389	0.157	0.098	−0.038	0.353	1.605	.113
6-mm cut	BL	Male	9.534	1.440						
		Female	8.902	2.009	0.633	0.457	−0.282	1.547	1.383	.172
	MD-B	Male	3.665	0.531						
		Female	3.658	0.699	0.007	0.162	−0.317	0.330	0.041	.967
	MD-P	Male	3.369	0.471						
		Female	3.547	0.729	−0.178	0.162	−0.501	0.146	−1.099	.276
	BC	Male	1.179	0.243						
		Female	1.097	0.214	0.082	0.058	−0.034	0.199	1.414	.163
	PC	Male	1.846	0.490						
		Female	1.713	0.422	0.134	0.117	−0.100	0.367	1.143	.258

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-P, mesiodistal distance from the palatal side; BC, buccal cortical thickness; and PC, palatal cortical thickness.

* $P < .05$, significant.

Table 4. Comparison Between Measurements of Males and Females in the Posterior Maxillary Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	Male	10.496	1.088						
		Female	9.950	1.359	0.546	0.309	−0.072	1.163	1.766	.082
	MD-B	Male	3.231	0.650						
		Female	3.268	0.617	−0.036	0.157	−0.351	0.278	−0.231	.818
	MD-P	Male	3.540	0.968						
		Female	3.564	0.747	−0.023	0.213	−0.449	0.402	−0.109	.914
	BC	Male	1.204	0.224						
		Female	1.166	0.255	0.038	0.062	−0.086	0.163	0.616	.540
	PC	Male	1.435	0.299						
		Female	1.501	0.403	−0.066	0.093	−0.252	0.119	−0.716	.477
4-mm cut	BL	Male	11.191	1.195						
		Female	10.333	1.436	0.858	0.331	0.196	1.519	2.591	.012*
	MD-B	Male	3.269	0.723						
		Female	3.413	0.569	−0.144	0.160	−0.464	0.176	−0.900	.372
	MD-P	Male	3.758	0.960						
		Female	3.830	0.892	−0.072	0.230	−0.532	0.387	−0.315	.754
	BC	Male	1.256	0.223						
		Female	1.135	0.243	0.121	0.058	0.005	0.237	2.080	.042*
	PC	Male	1.567	0.355						
		Female	1.532	0.382	0.035	0.093	−0.149	0.220	0.384	.703
6-mm cut	BL	Male	11.615	1.443						
		Female	10.713	1.718	0.902	0.408	0.085	1.719	2.209	.031*
	MD-B	Male	3.308	0.749						
		Female	3.452	0.708	−0.145	0.186	−0.516	0.226	−0.780	.439
	MD-P	Male	4.139	1.048						
		Female	4.242	0.914	−0.103	0.249	−0.601	0.396	−0.413	.681
	BC	Male	1.270	0.283						
		Female	1.135	0.228	0.135	0.065	0.005	0.265	2.085	.041*
	PC	Male	1.673	0.367						
		Female	1.579	0.371	0.095	0.094	−0.094	0.283	1.004	.320

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-P, mesiodistal distance from the palatal side; BC, buccal cortical thickness; and PC, palatal cortical thickness.

* $P < .05$, significant.

and 34 mandibles divided into two age groups (13–18 years and 18–27 years) selected from an already available larger sample of images at the Radiology Unit, Clinic of Oral Surgery and Stomatology, University of Bern, Switzerland. Patient data were treated according to the recommendations of the declaration of Helsinki. Images were taken with the 3D Accuitomo (J Morita Manufacturing Corp, Kyoto, Japan). Of the 920 images screened, 780 were rejected according to the following exclusion criteria:

—Overlapping of crowns or roots of adjacent teeth
—Periodontal disease (determined from radiographic signs of alveolar bone resorption)
—Severe ectopic eruption (ie, buccally blocked out canines)
—Missing teeth (excluding third molars)
—Mixed dentition (in the first age group) or incomplete crown eruption
—Blurred or unclear images

The 3D images were generated by the 3DX Accuitomo XYZ Tomograph and I-Dexil software (Morita, Tokyo, Japan). Orthogonal tomographic images were constructed using the I-Dexil. After 2 months of training and trial measurements with 15 cases, the investigator made all the measurements. Four weeks later, the same investigator remeasured 10 randomly selected cases to test for intraobserver reliability.

To minimize measurement errors produced from nonstandardized head postures, all images were oriented using a standardized protocol in which the palatal plane was aligned parallel to the horizontal axis supplied by the software, and the nasal septum was aligned parallel to the vertical axis. The slicing angle would be adjusted accordingly.

Measurements

For each interradicular space in the maxilla and the mandible, from the second molar on one side to the

Table 5. Comparison Between Measurements of Males and Females in the Anterior Mandibular Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	Male	7.331	0.914						
		Female	6.751	1.065	0.581	0.343	−0.117	1.278	1.695	.100
	MD-B	Male	2.502	0.474						
		Female	2.309	0.371	0.193	0.145	−0.102	0.489	1.333	.192
	MD-L	Male	2.320	0.423						
		Female	2.232	0.318	0.088	0.128	−0.172	0.348	0.691	.494
	BC	Male	1.113	0.242						
		Female	1.140	0.196	−0.027	0.075	−0.180	0.126	−0.362	.720
	LC	Male	1.656	0.412						
		Female	1.815	0.417	−0.160	0.142	−0.450	0.130	−1.121	.270
4-mm cut	BL	Male	7.602	0.901						
		Female	6.982	1.161	0.620	0.368	−0.130	1.370	1.686	.102
	MD-B	Male	2.670	0.460						
		Female	2.492	0.425	0.178	0.154	−0.137	0.492	1.152	.258
	MD-L	Male	2.342	0.466						
		Female	2.340	0.388	0.002	0.149	−0.301	0.305	0.014	.989
	BC	Male	1.227	0.225						
		Female	1.090	0.171	0.137	0.069	−0.003	0.278	1.992	.055
	LC	Male	2.022	0.424						
		Female	2.117	0.361	−0.095	0.137	−0.374	0.184	−0.696	.492
6-mm cut	BL	Male	7.689	1.188						
		Female	7.106	1.376	0.583	0.478	−0.397	1.563	1.219	.233
	MD-B	Male	2.955	0.561						
		Female	2.711	0.487	0.244	0.192	−0.149	0.637	1.272	.214
	MD-L	Male	2.463	0.575						
		Female	2.307	0.347	0.156	0.169	−0.190	0.502	0.922	.364
	BC	Male	1.194	0.199						
		Female	1.161	0.166	0.033	0.067	−0.103	0.170	0.497	.623
	LC	Male	2.064	0.442						
		Female	2.354	0.413	−0.290	0.157	−0.611	0.031	−1.850	.075

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-L, mesiodistal distance from the lingual side; BC, buccal cortical thickness; and LC, lingual cortical thickness.

second molar on the opposite side, the following measurements were done at three different depths from the cementoenamel junction, that is, at 2 mm, 4 mm, and 6 mm.

—*Mesiodistal distance*: These measurements were taken both buccally and palatally/lingually at the widest distance between each two adjacent teeth.
—*Buccolingual thickness*: The thickness was measured from the outermost point on the buccal side to the outermost point on the palatal/lingual side at the middle of the distance between each two adjacent teeth.
—*Cortical bone thickness*: Buccally and lingually/palatally, the distance between the internal and external aspects of the cortex in the middle of the interradicular distance between each two adjacent teeth was measured.

For each patient about 195 distances were measured. These distances were measured using the millimetric ruler provided by the I-Dexil (Figures 1 through 4).

Statistical Analysis

Descriptive analysis was used to obtain the mean and standard deviation (SD) of all the studied measurements. Student's *t*-test was used to determine the intraobserver reliability. To simplify the comparative analysis, the data were divided into two regions: anterior (from canine to canine) and posterior (from the first premolar to the second molar bilaterally). Student's *t*-test was used for comparisons between sexes and age groups; $P < .05$ was considered significant, and $P < .01$ was considered highly significant.

RESULTS

Intraobserver Reliability

There was no significant difference ($P > .05$) between the repeated measurements of the 10 patients.

Table 6. Comparison Between Measurements of Males and Females in the Posterior Mandibular Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	Male	9.745	0.803						
		Female	8.927	1.093	0.818	0.333	0.141	1.495	2.460	.019*
	MD-B	Male	3.641	0.540						
		Female	3.910	0.995	−0.269	0.280	−0.838	0.301	−0.962	.343
	MD-L	Male	3.849	0.560						
		Female	4.093	0.970	−0.244	0.276	−0.807	0.319	−0.883	.384
	BC	Male	1.475	0.408						
		Female	1.467	0.339	0.008	0.128	−0.253	0.269	0.063	.950
	LC	Male	1.986	0.540						
		Female	2.238	0.544	−0.251	0.186	−0.631	0.128	−1.349	.187
4-mm cut	BL	Male	10.440	0.741						
		Female	9.848	1.284	0.592	0.375	−0.173	1.357	1.578	.125
	MD-B	Male	3.922	0.544						
		Female	4.036	0.963	−0.114	0.280	−0.685	0.458	−0.406	.688
	MD-L	Male	4.183	0.538						
		Female	4.178	0.770	0.005	0.236	−0.477	0.486	0.020	.984
	BC	Male	1.614	0.389						
		Female	1.648	0.366	−0.034	0.132	−0.302	0.235	−0.255	.801
	LC	Male	2.311	0.429						
		Female	2.469	0.437	−0.158	0.152	−0.467	0.151	−1.041	.306
6-mm cut	BL	Male	10.956	0.777						
		Female	10.167	1.381	0.789	0.428	−0.087	1.665	1.844	.076
	MD-B	Male	4.260	0.812						
		Female	4.219	1.191	0.041	0.385	−0.747	0.830	0.108	.915
	MD-L	Male	4.571	0.666						
		Female	4.366	1.263	0.205	0.387	−0.587	0.997	0.529	.601
	BC	Male	1.755	0.427						
		Female	1.887	0.452	−0.132	0.162	−0.465	0.201	−0.812	.424
	LC	Male	2.395	0.379						
		Female	2.455	0.282	−0.060	0.121	−0.307	0.187	−0.500	.621

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-L, mesiodistal distance from the lingual side; BC, buccal cortical thickness; and LC, lingual cortical thickness.

* $P < .05$, significant.

Interradicular Dimensions Measured

Interradicular dimensions are reported in Tables 1 and 2: (all expressed in millimeters at the 2-mm, 4-mm, and 6-mm levels from CEJ). Generally, all the dimensions measured increased upon moving apically and posteriorly except for the mesiodistal distances between the first and second molars.

In the Anterior Maxilla

The highest buccolingual thickness was found between the right central and lateral incisor at the 6-mm level (9.6 ± 2.16), which decreased the more cervical the measurements were taken. The lowest buccolingual thickness was between the central incisors at the 2-mm and 4-mm level. The highest mesiodistal distance from the buccal side between the central incisors at the 6-mm level was 4.27 ± 1.23, and the lowest was between the left central and lateral incisor. The highest mesiodistal distance from the palatal side and buccal cortical thickness was between the lateral incisor and canine at the 6-mm level (3.73 ± 1.28), and (1.24 ± 0.53), respectively. The greatest palatal cortical thickness was at the 6-mm level between the central and lateral incisor (1.85 ± 0.64) and the lateral incisor and canine (1.75 ± 0.59) and was greater in the anterior region than in the posterior region.

In the Posterior Maxilla

The highest buccolingual thickness was found at the 6-mm level between the first and second molars (14.21 ± 1.48). The highest mesiodistal distances, both buccally and palatally, were found between the second premolar and the first molar (4.05 ± 1.6 and 6.75 ± 1.55, respectively). A certain pattern was found in the thickness of the buccal cortex: at the 2-mm level, the thickness was 1.35 ± 0.35 between first and second molars, but it increased to 1.36 ± 0.31 at 4 mm and then decreased to 1.32 ± 0.3214 at 6 mm. The highest palatal cortical bone thickness was found between the

Table 7. Comparison Between Measurements of the Two Age Groups (13–18 Years and 19–27 Years) in the Anterior Maxillary Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	13–18 y	7.669	1.409						
		19–27 y	7.905	1.343	−0.236	0.341	−0.918	0.446	−0.691	.492
	MD-B	13–18 y	2.867	0.471						
		19–27 y	2.988	0.541	−0.120	0.126	−0.373	0.132	−0.953	.344
	MD-P	13–18 y	2.924	0.656						
		19–27 y	3.069	0.538	−0.145	0.148	−0.441	0.151	−0.979	.331
	BC	13–18 y	0.970	0.215						
		19–27 y	1.062	0.201	−0.092	0.053	−0.198	0.014	−1.737	.087
	PC	13–18 y	1.422	0.355						
		19–27 y	1.680	0.415	−0.258	0.099	−0.456	−0.060	−2.611	.011*
4-mm cut	BL	13–18 y	8.405	1.417						
		19–27 y	8.577	1.496	−0.172	0.362	−0.896	0.552	−0.475	.636
	MD-B	13–18 y	3.326	0.617						
		19–27 y	3.482	0.561	−0.155	0.146	−0.447	0.136	−1.064	.291
	MD-P	13–18 y	3.225	0.828						
		19–27 y	3.225	0.627	0.000	0.181	−0.362	0.362	0.000	1.000
	BC	13–18 y	1.028	0.251						
		19–27 y	1.098	0.196	−0.070	0.056	−0.181	0.041	−1.266	.210
	PC	13–18 y	1.548	0.398						
		19–27 y	1.723	0.383	−0.175	0.097	−0.369	0.018	−1.808	.075
6-mm cut	BL	13–18 y	9.119	1.590						
		19–27 y	9.228	1.986	−0.109	0.461	−1.031	0.814	−0.236	.814
	MD-B	13–18 y	3.561	0.636						
		19–27 y	3.749	0.614	−0.188	0.159	−0.506	0.129	−1.186	.240
	MD-P	13–18 y	3.459	0.613						
		19–27 y	3.479	0.657	−0.021	0.162	−0.345	0.304	−0.128	.899
	BC	13–18 y	1.059	0.218						
		19–27 y	1.198	0.222	−0.140	0.056	−0.252	−0.028	−2.497	.015*
	PC	13–18 y	1.630	0.410						
		19–27 y	1.900	0.460	−0.270	0.112	−0.494	−0.046	−2.408	.019*

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-P, mesiodistal distance from the palatal side; BC, buccal cortical thickness; and PC, palatal cortical thickness.

* $P < .05$, significant.

canine and the first premolar at the 6-mm level (1.78 ± 0.46).

In the Anterior Mandible

The highest buccolingual thickness, mesiodistal distances labially and lingually, and cortical thicknesses both labially and lingually were found between the lateral incisor and canine at the 6-mm level (7.83 ± 1.36, 3.89 ± 1.33, 3.12 ± 1.51, 1.24 ± 0.19, and 2.36 ± 0.53, respectively). The lowest measured dimensions were found between the central incisors.

In the Posterior Mandible

The highest buccolingual thickness and buccal cortical thickness were between the first and second molars (13.79 ± 2.03, 3.05 ± 2.22, respectively). The highest mesiodistal distance from the buccal side was found between the second premolar and the first molar (5.61 ± 1.99), and the highest mesiodistal distance from the lingual side was between the first and second premolars (5.85 ± 1.16). The thickest lingual cortex was found between the canine and the first premolar (2.56 ± 0.46).

Comparison Between Sexes

Comparison between sexes was significant at $P < .05$ (Tables 3 through 6).

In the Maxilla

Anteriorly, males had significantly higher buccolingual thickness at the 2-mm and 4-mm level from the CEJ. Posteriorly, males had a significantly higher buccolingual and buccal cortical thickness at the 4-mm and 6-mm level from the CEJ.

In the Mandible

Anteriorly, there was no significant difference between sexes. Posteriorly, males had a significantly

Table 8. Comparison Between Measurements of the Two Age Groups (13–18 Years and 19–27 Years) in the Posterior Maxillary Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	13–18 y	10.325	1.302						
		19–27 y	10.090	1.233	0.235	0.314	−0.393	0.863	0.748	.457
	MD-B	13–18 y	3.203	0.466						
		19–27 y	3.294	0.750	−0.090	0.157	−0.404	0.223	−0.577	.566
	MD-P	13–18 y	3.331	0.742						
		19–27 y	3.756	0.899	−0.425	0.206	−0.836	−0.014	−2.068	.043*
	BC	13–18 y	1.125	0.239						
		19–27 y	1.236	0.232	−0.111	0.061	−0.233	0.011	−1.819	.074
	PC	13–18 y	1.389	0.275						
		19–27 y	1.531	0.399	−0.142	0.092	−0.326	0.042	−1.546	.128
4-mm cut	BL	13–18 y	10.879	1.480						
		19–27 y	10.593	1.307	0.286	0.346	−0.405	0.977	0.827	.411
	MD-B	13–18 y	3.372	0.494						
		19–27 y	3.323	0.761	0.049	0.161	−0.272	0.371	0.307	.760
	MD-P	13–18 y	3.674	0.852						
		19–27 y	3.909	0.973	−0.235	0.228	−0.690	0.220	−1.033	.306
	BC	13–18 y	1.109	0.229						
		19–27 y	1.265	0.228	−0.156	0.057	−0.269	−0.042	−2.746	.008**
	PC	13–18 y	1.398	0.318						
		19–27 y	1.681	0.360	−0.283	0.085	−0.454	−0.112	−3.316	.002**
6-mm cut	BL	13–18 y	11.409	1.852						
		19–27 y	10.867	1.431	0.542	0.418	−0.293	1.378	1.299	.199
	MD-B	13–18 y	3.475	0.475						
		19–27 y	3.309	0.889	0.166	0.185	−0.203	0.536	0.899	.372
	MD-P	13–18 y	4.099	0.855						
		19–27 y	4.281	1.066	−0.182	0.248	−0.678	0.313	−0.736	.465
	BC	13–18 y	1.091	0.221						
		19–27 y	1.288	0.261	−0.198	0.062	−0.321	−0.074	−3.189	.002**
	PC	13–18 y	1.509	0.354						
		19–27 y	1.721	0.358	−0.212	0.091	−0.393	−0.031	−2.338	.023*

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-P, mesiodistal distance from the palatal side; BC, buccal cortical thickness; and PC, palatal cortical thickness.

* $P < .05$, significant.

** $P < .01$, highly significant.

higher buccolingual thickness than females at the 2-mm level from CEJ.

Comparison Between Age Groups

Comparison between the two age groups (13–18 years) and (19–27 years) for all the measurements was significant at $P < .05$ and highly significant at $P < .001$ (Tables 7 through 10).

In the Maxilla

Anteriorly, the group aged 19–27 years had a significantly thicker palatal cortex at the 2-mm level from the CEJ and higher buccal and palatal cortical thicknesses at 6 mm. Posteriorly, the group aged 19–27 years had a significantly higher mesiodistal palatal distance at the 2-mm level at the CEJ and a thicker buccal and palatal cortex with a highly significant difference at the 4-mm and 6-mm level from the CEJ.

In the Mandible

Anteriorly, there was no significant difference between the two groups. Posteriorly, the group aged 19–27 years had a significantly thicker lingual cortex at the 2-mm level from the CEJ.

DISCUSSION

Many factors could affect the success rates and effectiveness of mini-implants used for establishing skeletal orthodontic anchorage. Some of these factors are implant related (type, diameter, and length of the implant), patient related (sex, age, physical status), surgical related (direction of mini-implant placement and placement torque), orthodontic related (magnitude and timing of force), location related (peri-implant bone quantity, cortical bone thickness, keratinized versus oral mucosa), and implant-maintenance related.[1] The exact role of these factors, however, is not fully understood.[1] The present study investigated the

Table 9. Comparison Between Measurements of the Two Age Groups (13–18 Years and 19–27 Years) in the Anterior Mandibular Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	13–18 y	7.069	0.801						
		19–27 y	6.967	1.282	0.101	0.359	−0.630	0.833	0.282	.780
	MD-B	13–18 y	2.358	0.489						
		19–27 y	2.452	0.343	−0.094	0.149	−0.397	0.209	−0.631	.533
	MD-P	13–18 y	2.265	0.394						
		19–27 y	2.283	0.346	−0.018	0.129	−0.281	0.245	−0.138	.891
	BC	13–18 y	1.182	0.240						
		19–27 y	1.058	0.162	0.123	0.072	−0.024	0.271	1.701	.099
	LC	13–18 y	1.778	0.423						
		19–27 y	1.692	0.417	0.085	0.145	−0.210	0.381	0.588	.561
4-mm cut	BL	13–18 y	7.431	0.828						
		19–27 y	7.065	1.327	0.366	0.378	−0.406	1.138	0.967	.341
	MD-B	13–18 y	2.491	0.497						
		19–27 y	2.671	0.360	−0.180	0.154	−0.495	0.134	−1.171	.250
	MD-P	13–18 y	2.316	0.426						
		19–27 y	2.371	0.423	−0.055	0.148	−0.357	0.248	−0.369	.714
	BC	13–18 y	1.213	0.170						
		19–27 y	1.079	0.227	0.134	0.069	−0.007	0.275	1.935	.062
	LC	13–18 y	2.141	0.419						
		19–27 y	1.992	0.342	0.149	0.135	−0.127	0.425	1.103	.279
6-mm cut	BL	13–18 y	7.620	1.032						
		19–27 y	7.017	1.581	0.603	0.478	−0.375	1.581	1.263	.217
	MD-B	13–18 y	2.670	0.554						
		19–27 y	3.009	0.433	−0.339	0.186	−0.721	0.042	−1.821	.079
	MD-P	13–18 y	2.344	0.546						
		19–27 y	2.415	0.327	−0.071	0.171	−0.422	0.280	−0.415	.682
	BC	13–18 y	1.162	0.171						
		19–27 y	1.193	0.194	−0.031	0.067	−0.167	0.106	−0.460	.649
	LC	13–18 y	2.189	0.477						
		19–27 y	2.280	0.406	−0.091	0.165	−0.430	0.247	−0.554	.584

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-L, mesiodistal distance from the lingual side; BC, buccal cortical thickness; and LC, lingual cortical thickness.

anatomic data gathered from 100 CBCT images to determine the optimal sites for mini-implant placement by studying two elements that are related to the mini-implant location factor: interradicular bone dimensions and cortical bone thickness. Three-dimensional measurements of the interradicular spaces at 3 vertical levels (2 mm, 4 mm, and 6 mm) from the CEJ were performed. Intraobserver reliability was established for the measurement method of this study. The availability of a relatively large number of CBCT images for this study allowed the researchers to overcome the shortcoming of limited sample size in several previous studies.[11,12,18]

Most studies on this topic have aimed to determine the safest sites for mini-screw placement by focusing on the posterior region of the jaws.[8–11] The fact, however, that mini-implants are often useful in the anterior region for space closure[4] or correction of overbite problems[6] necessitated the evaluation of the anterior region as well. To fulfill this objective in the present study, data on interradicular distances and cortical bone thicknesses were provided for all the teeth, both anteriorly and posteriorly, to provide the clinician with a comprehensive anatomic map of the maxilla and the mandible.

In this study the CEJ was selected as the starting point for the measurements, unlike other studies[11,19] that used the alveolar crest, which could be affected by different periodontal problems. As it is advisable to place the mini-implants in areas of attached gingival,[20] the maximum level of measurement in this study was selected to be 6 mm from CEJ. Lim et al.[21] excluded levels higher than 6 mm in their study on interradicular soft tissue for the same reason.

The results of this study showed a consistent increase in the buccolingual thickness and the mesiodistal distances both buccally and palatally/lingually in most of the studied sites in the maxilla and the mandible when moving apically and posteriorly. One exception was the mesiodistal buccal distance between the maxillary first and second molars. The means of the different measurements in

Table 10. Comparison Between Measurements of the Two Age Groups (13–18 Years and 19–27 Years) in the Posterior Mandibular Region (Student's *t*-test)[a]

Cut Level	Measurement Site	Group	Mean	SD	Mean Difference	Standard Error Difference	Lower CI	Upper CI	*t*	*P* value
2-mm cut	BL	13–18 y	9.461	0.641						
		19–27 y	9.122	1.396	0.339	0.360	−0.393	1.071	0.943	.353
	MD-B	13–18 y	3.919	0.883						
		19–27 y	3.612	0.706	0.307	0.280	−0.263	0.877	1.097	.281
	MD-L	13–18 y	4.036	0.933						
		19–27 y	3.905	0.620	0.131	0.280	−0.439	0.702	0.469	.642
	BC	13–18 y	1.466	0.397						
		19–27 y	1.477	0.339	−0.011	0.129	−0.273	0.251	−0.085	.932
	LC	13–18 y	1.914	0.481						
		19–27 y	2.379	0.531	−0.465	0.174	−0.820	−0.111	−2.675	.012*
4-mm cut	BL	13–18 y	10.417	0.557						
		19–27 y	9.757	1.457	0.660	0.371	−0.098	1.417	1.776	.086
	MD-B	13–18 y	3.967	0.844						
		19–27 y	4.005	0.750	−0.039	0.281	−0.611	0.534	−0.138	.891
	MD-L	13–18 y	4.189	0.689						
		19–27 y	4.169	0.657	0.020	0.236	−0.461	0.502	0.086	.932
	BC	13–18 y	1.646	0.424						
		19–27 y	1.616	0.308	0.029	0.132	−0.239	0.298	0.221	.826
	LC	13–18 y	2.266	0.392						
		19–27 y	2.554	0.442	−0.288	0.145	−0.584	0.008	−1.984	.056
6-mm cut	BL	13–18 y	10.821	0.600						
		19–27 y	10.101	1.652	0.720	0.432	−0.165	1.606	1.667	.107
	MD-B	13–18 y	4.178	1.131						
		19–27 y	4.313	0.913	−0.135	0.384	−0.922	0.653	−0.351	.729
	MD-L	13–18 y	4.414	1.145						
		19–27 y	4.508	0.918	−0.094	0.388	−0.890	0.701	−0.243	.810
	BC	13–18 y	1.798	0.524						
		19–27 y	1.872	0.308	−0.074	0.164	−0.410	0.261	−0.452	.654
	LC	13–18 y	2.351	0.300						
		19–27 y	2.531	0.335	−0.179	0.116	−0.417	0.059	−1.541	.134

[a] SD indicates standard deviation; CI, confidence interval; BL, buccolingual thickness; MD-B, mesiodistal distance from the buccal side; MD-L, mesiodistal distance from the lingual side; BC, buccal cortical thickness; and LC, lingual cortical thickness.

* $P < .05$, significant.

this study were found to be in agreement with those obtained in other similar studies.[8,11,12,18]

Limited data are available in the literature describing the buccal cortical thickness. The results of this study showed that in the maxilla the buccal cortical thickness had a certain pattern: the thickness increased as the cuts moved apically from the CEJ to the 4-mm level, and then they decreased again at the 6-mm level. This is in agreement with the study by Baumgaertel and Hans[15] on dry skulls. In the mandible, the thickness increased gradually in the apical direction; the highest was between the first and second molar, and the lowest was between the central incisors. Monnert et al.[19] reported the lowest thickness between the lateral incisor and canine. Lingual and palatal cortical bone thicknesses showed a gradual increase as the cuts moved apically.

Based on the findings of the present study, the optimal site for mini-implant placement in the anterior maxilla is the interradicular space between the central and lateral incisors and between the lateral incisor and canine in the anterior mandible. These sites had the highest buccolingual and cortical thicknesses and mesiodistal distance. In the posterior region of the maxilla and the mandible the most suitable sites are between the second premolar and the first molar and between the first and second molars, which was also recommended in previous studies.[8,12,18]

In the present study, males had a significantly thicker buccolingual dimension and buccal cortical thickness than females in both the maxilla and the mandible. Kim et al.[22] found no statistical difference between sexes in the interradicular measurements of the posterior maxilla, probably because of the small sample size (35 patients). In the maxilla, the older age group (19–27 years) had a significantly higher buccal and palatal cortical thickness both anteriorly and posteriorly. In the mandible, the older age group had a significantly thicker lingual cortex. In the study by Swasty et al.,[13] the age group of 40–49 years had a significantly higher buccal cortical thickness in the mandible. In the present study more significant differences were found between the sexes and age groups in the maxilla than in the mandible, which could be due to the difference in sample size. Thus, it would be expected that mini-implants placed in males and in those older than 18 years to have higher success rates because of the higher interradicular dimensions and thicker cortical bone thickness, especially in the maxilla.

CONCLUSIONS

- The optimal site for mini-implant placement in the anterior region is between the central and lateral incisors in the maxilla and between the lateral incisor and the canine in the mandible at the 6-mm level from the CEJ. At the buccal aspect of the posterior region of both jaws, the optimal sites are between the second premolar and the first molar and between the first and second molars. Palatally, the optimal site is between the first and second premolars as it has the advantage of the highest cortical thickness. The more apical the site, the safer the placement.
- The males and the age group older than 18 years had a significantly higher buccolingual, palatal, and buccal cortical thickness at specific levels and sites in the maxilla and the mandible.

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