AJO-DO

Bone and cortical bone characteristics of mandibular retromolar trigone and anterior ramus region for miniscrew insertion in adults

Riccardo Nucera, Angela Mirea Bellocchio, Giacomo Oteri, Athena Janan Farah, Leonardi Rosalia, Cordasco Giancarlo, and Marco Portelli
Messina, Italy

Introduction: The aim of this study was to evaluate bone depth, cortical bone thickness, and vestibulolingual bone dimension of the mandibular retromolar trigone and anterior ramus region to evaluate what are its most suitable sites for miniscrew insertion in adults. **Methods:** The sample included cone-beam computerized tomography (CBCT) records of 60 adult subjects retrospectively evaluated. All CBCT examinations were performed with the use of an i-CAT CBCT scanner (Imaging Sciences International). Each exam was converted into DICOM format and processed with the use of Osirix Medical Imaging software. On reproducible sagittal scan views, bone depth and cortical bone thickness were evaluated on specific lines parallel and at a 45° angle to the occlusal plane, and at 3 mm and at 6 mm distance from it. Vestibulolingual bone dimension was computed in 4 different cross-section scans and at 3 different levels of depth (0, 6, and 11 mm). **Results:** All of the considered insertion sites showed on average more than 10 mm of bone depth. Inferential statistics showed significantly ($P < 0.05$) greater bone depth (+3 mm) in cross-sectional scans parallel to the occlusal plane compared with those at a 45° angle to it. Cortical bone thickness showed average values from 3 mm to 5 mm. Vestibulolingual bone dimension showed a significant ($P < 0.05$) reduction (−10 mm) in the posterior region of retromolar region. No significant differences were found between subjects with and without third molars. **Conclusions:** The retromolar trigone and anterior ramus region showed enough bone quantity and adequate bone quality for safe miniscrew insertion in adults. (Am J Orthod Dentofacial Orthop 2019;155:330-8)

Since the introduction of orthodontic miniscrews, their use reached a widespread popularity. Miniscrews can improve orthodontic mechanics in providing skeletal anchorage.[1-3] Literature has shown that miniscrews have low failure rates[4,5] and good patient acceptance.[6] Primary stability is a key factor to obtain a long term successful placement.[7] Anatomic characteristics of the insertion site play an important role, affecting the failure rate of miniscrews. Literature has also shown that the anatomic characteristics affecting a successful miniscrew placement are bone characteristics (amount of bone, cortical bone thickness, bone density),[8-10] soft tissue characteristics (periodontal soft tissue thickness and mobility),[11] and the proximity of specific anatomic structures (roots, nerves, vessels, sinus, nasal cavities, frenum).[12]

Different anatomic sites have been proposed for miniscrew insertion: palatal bone,[7,13] maxillary alveolar process,[7,14] mandibular buccal shelf,[8,15] infrazygomatic crest,[9] maxillary, and mandibular buccoalveolar cortical plate.[10]

The mandibular retromolar trigone and the anterior ramus region (MRTARR) has been proposed for suitable extra-alveolar miniscrew insertion sites.[16] The MRTARR is located bilaterally in the anterior part of the mandibular ramus and distally to the mandibular molars.

To date, no quantitative and qualitative assessment of the skeletal characteristics of the MRTARR has been performed for miniscrew insertion. The aim of the

Department of Biomedical and Dental Sciences and Morphofunctional Imaging, Section of Orthodontics, School of Dentistry, University of Messina, Messina, Italy.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Address correspondence to: Riccardo Nucera, c/o AOU Policlinico "G. Martino," UOC di Odontoiatria e Odontostomatologia, Via Consolare Valeria 1, 98125 Messina, Italy; e-mail, riccardo.nucera@gmail.com.
Submitted, January 2018; revised and accepted, April 2018.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2018.04.025

Table I. Sample characteristics and comparison

Group	Male/female, n	Age, y	ANB° All subjects	ANB° Class I subjects	ANB° Class II subjects	ANB° Class III subjects
Sample 1*	15/15	33.4 ± 8.6	30 (2.7 ± 2.8)	18 (1.8 ± 2.0)	9 (5.9 ± 1.2)	3 (−2.0 ± 1.9)
Sample 2†	15/15	31.7 ± 9.1	30 (3.2 ± 3.1)	16 (2.0 ± 1.2)	11 (6.5 ± 1.4)	3 (−2.3 ± 0.9)
Total	30/30	32.6 ± 8.8	60 (3.0 ± 2.9)	34 (1.9 ± 1.2)	20 (6.2 ± 1.3)	6 (−2.2 ± 1.3)
Sample 1 vs sample 2		NS ($P = 0.63$)	NS ($P = 0.46$)	NS ($P = 0.67$)	NS ($P = 0.34$)	NS ($P = 0.86$)

Values are presented as mean ± SD. *NS*, Nonsignificant difference (unpaired *t* test).
*Sample with third molars; †Sample without third molars.

present study was to evaluate bone depth, cortical bone thickness, and vestibulolingual bone dimension of the MRTARR to evaluate what are its most suitable sites for miniscrew insertion in adult subjects.

MATERIAL AND METHODS

The sample of this retrospective study included cone-beam computerized tomographic (CBCT) scans preselected from the digital archive of a private practice of the subjects who fulfilled the following selection criteria: Caucasian, age 20-45 years, absence of metallic restorations in the first and second permanent mandibular premolars and molars, missing teeth except for third molars, genetic syndromes, craniofacial dysmorphisms, and previous orthognathic surgery treatment. The CBCT exams were performed from June 2012 to September 2016. After a preliminary evaluation, 125 patients fulfilled the selection criteria: 65 (28 men and 37 women) with both third mandibular molars and 60 (29 men and 31 women) without third mandibular molars. The patients were divided into 4 groups according to sex and the presence or absence of the third mandibular molars.

The patients included in each of the 4 groups were ordered chronologically from youngest to oldest and each assigned a number in consecutive order.

A random sequence generator (www.randomizer.org) was used to generate 4 lists of randomized numbers of 28, 37, 29, and 31 numbers, the first 15 numbers of each random list were selected, and the corresponding CBCT examinations were included in the study. According to this methodology, a balanced block randomization based on patients' sex and presence or absence of third mandibular molar, was applied to select the included CBCT exams. The above-mentioned selection procedure was used to create 2 groups of 30 subjects with equal number of male and female subjects: one group including subjects with the third molar and another group including subjects without the third molar. The size of the 2 samples was set after performing a power analysis calculation. The details of the power calculation are reported in the statistical analysis section.

The 2 new groups of patients were ordered and numbered from 1 to 30 according to their sex and subsequently according to their age. The right mandible molars of patients that were assigned the even numbers and the left mandible molars of patients, which were assigned the odd numbers, were then evaluated. The sagittal intermaxillary relationship characteristics of the patients enrolled in the 2 samples were then evaluated for ANB angle. Table I reports the mean and standard deviation of age and skeletal characteristics of the subjects included in this study.

The protocol of this study was approved by the Human Research Ethical Committee (103/16). All CBCT examinations were performed with the use of an i-CAT CBCT scanner (Imaging Sciences International, Hatfield, Pa). All of the patients signed informed consent forms before undergoing the CBCT examination. The following acquisition parameters were set: 120 kV, 5 mA, voxel size 0.337 mm, field of view 13.4 cm, exposure time 4-6 seconds. Each examination was saved in the digital imaging and communications in medicine (DICOM) format. DICOM files were processed with the use of the Osirix Medical Imaging software (Pixmeo, Geneva, Switzerland).

The following procedure was used to obtain proper view sections of the MRTARR for quantitative and qualitative bone characteristics evaluation. Three reference lines were preliminarily considered as shown by the software interface corresponding to the 3 conventional scan planes (sagittal: yellow line; axial: violet line; coronal: blue line; Fig 1); These view scan planes were reoriented according to the following 3-step procedure to obtain reproducible outcome measurements:

1. The sagittal view scan was oriented to divide the first and second molars into 2 as symmetric as possible parts (Fig 1, *A* and *B*). 2. The violet line representing the axial view scan was oriented to pass through the most inferior point of the first and second molar fossa (ie, the violet line was oriented parallel to the posterior

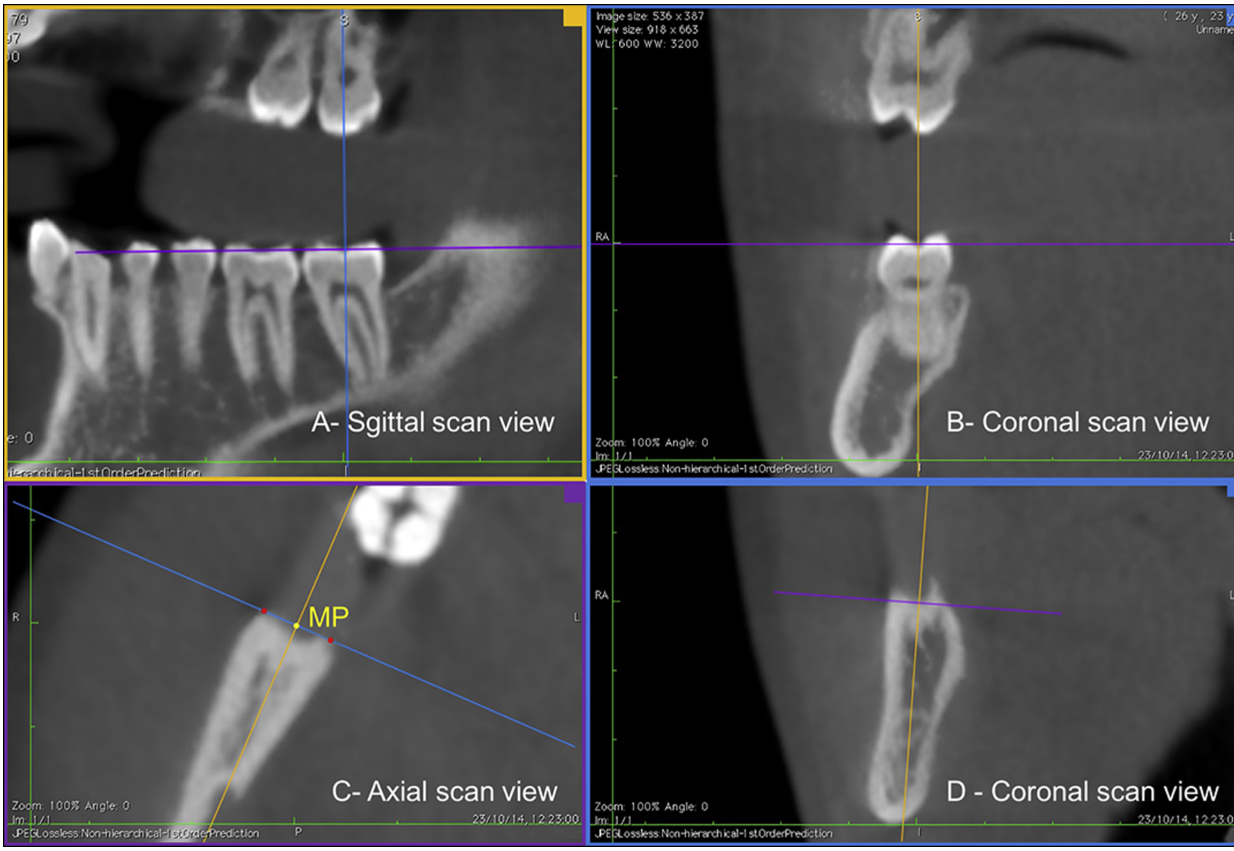

Fig 1. Identification procedure applied to select the sagittal scan used to measure bone depth and cortical bone thickness. **A,** The violet line representing the axial view scan was oriented to pass through the most inferior point of the first and second molar fossa. **B,** The yellow line representing the sagittal view scan was oriented to divide the first and second molars into 2 symmetric parts. **C,** The reference scan system was shifted on the middle point (MP) of the anterior retromolar cortical bone, and subsequently the orientation of the sagittal scan was adjusted to pass through the geometric center of the mandibular canal in the **(C)** axial scan and **(D)** coronal scan.

occlusal plane; Fig 1, *A*). 3. In the axial view (Fig 1, *C*), 2 points on the mandibular ramus were identified: the most anterior point of the vestibular cortical bone and the most anterior point of the lingual cortical bone. In the axial scan, the middle point (MP) between these 2 points was identified and the intersection between the coronal reference scan (blue line) and the sagittal reference scan (yellow line) was shifted on the MP (Fig 1, *C*); subsequently the orientation of the sagittal scan was adjusted to pass through the geometric center of the mandibular canal in the axial scan (Fig 1, *C*) and the coronal scan (Fig 1, *D*).

This selection procedure was able to identify the sagittal scan clearly showing the distance between the anterior cortical bone of the retromolar area and the mandibular alveolar canal (Fig 2); this sagittal scan was used to measure 8 outcomes: 4 outcomes evaluated bone depth (represented as yellow segments in Fig 2) and 4 outcomes evaluated cortical bone thickness (not represented in Fig 2).

Two parallel lines at 3 mm and 6 mm coronal to the occlusal plane were considered (red lines in Fig 2). On each of these lines, 2 linear outcomes were considered: The first outcome evaluated bone depth from the anterior cortical bone of the ramus to the cortical bone of mandibular canal; the second outcome evaluated cortical bone thickness of the anterior ramus. As a consequence, on the 2 lines parallel to the occlusal plane the following 4 outcomes were considered: BD-3mm-0° (ie, bone depth on the reference line at 3 mm); BD-6mm-0° (bone depth on the reference line at 6 mm); CBT-3mm-0° (cortical bone thickness on the reference line at 3 mm); and CBT-6mm-0° (cortical bone thickness on the reference line at 6 mm).

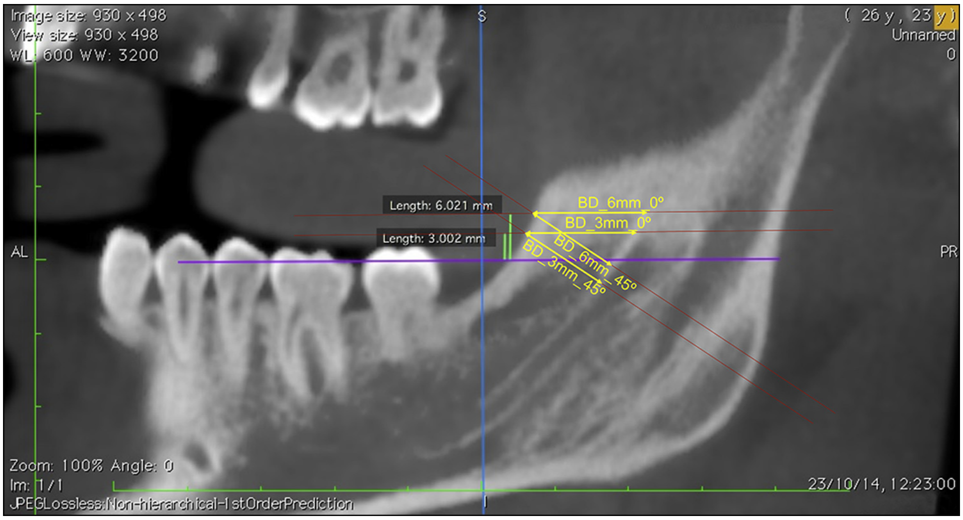

Fig 2. Sagittal scan used to measure bone depth and cortical bone thickness, showing the distance between the anterior cortical bone of the retromolar area and the mandibular alveolar canal. Four lines were considered (*red lines*): 2 lines parallel and 2 lines at a 45° of angulation, 3 mm and 6 mm coronal, to the occlusal plane. On each of these 4 lines, 2 linear outcomes were considered: bone depth from the anterior cortical bone of the ramus to the cortical bone of mandibular canal (*yellow segments*) and cortical bone thickness of the anterior ramus (not represented in the figure).

Four additional outcomes (BD-3mm-45°, BD-6mm-45°, CBT-3mm-45°, and CBT-6mm-45°), presenting the same characteristics of the outcomes mentioned above but taken on 2 lines oriented with a 45° inclination to the occlusal plane (Fig 2), were considered. These additional outcomes shared with the complementary outcomes the most mesial point taken on the most external part of the cortical bone of the mandibular ramus.

To have additional information of the anatomic characteristics of the mandibular ramus, in terms of vestibulolingual dimensions, 4 cross-sectional scan views were considered. These scan views were perpendicular to the sagittal scan view used to measure bone depth and cortical bone thickness (Fig 2), and they passed through the 4 red lines represented on Figure 2.

On each cross-section scan view 3 linear outcomes were measured: the vestibulolingual bone dimension of the most anterior portion of the ramus (VLBD-0 mm) and the vestibulolingual bone dimension of the ramus at 6 mm (VLBD-6 mm) and at 11 mm (VLBD-11 mm) of depth from anterior ramus bone surface (Fig 3). To measure these outcomes, a line was drawn to best fit the vestibular cortical bone of the ramus and 3 segments were traced perpendicular to this line and originating from the most anterior point of the lingual cortical bone (0 mm) and 6 mm and 11 mm from the most anterior point of the lingual cortical bone. According to this procedure, 3 outcomes were considered for each of the 4 scan views used to evaluate the vestibulolingual bone dimension of the mandibular ramus. In total, 12 measurements were used to achieve a comprehensive evaluation of vestibulolingual mandibular ramus extension. All measurements were taken by the same expert operator.

Statistical analysis

A preliminary analysis was run on 10 subjects to obtain data for power analysis evaluation. The values of the average bone depth on reference lines 3 mm from the occlusal plane and measured on 2 reference lines parallel and 45° to the occlusal plane were used to perform the power analysis calculation along with the corresponding standard deviations. The data used to perform the analysis were: average DB-3mm-0° = 13.95; average DB-3mm-45° = 12.12; $\sigma = 2.5$. The results of the power analysis indicated that to reach 80% power, 30 subjects per sample were necessary to perform the study.

Two samples of 30 subjects were enrolled: 1 sample included subjects with the third molar and 1 sample included subjects without the third molar. The data obtained from the 2 samples were compared to evaluate if the presence of the third molar could affect the skeletal characteristics of the MRTARR.

Descriptive statistics were performed for both considered samples, reporting mean, standard deviation, maximum, and minimum values for each considered insertion site and for all considered view scan sections.

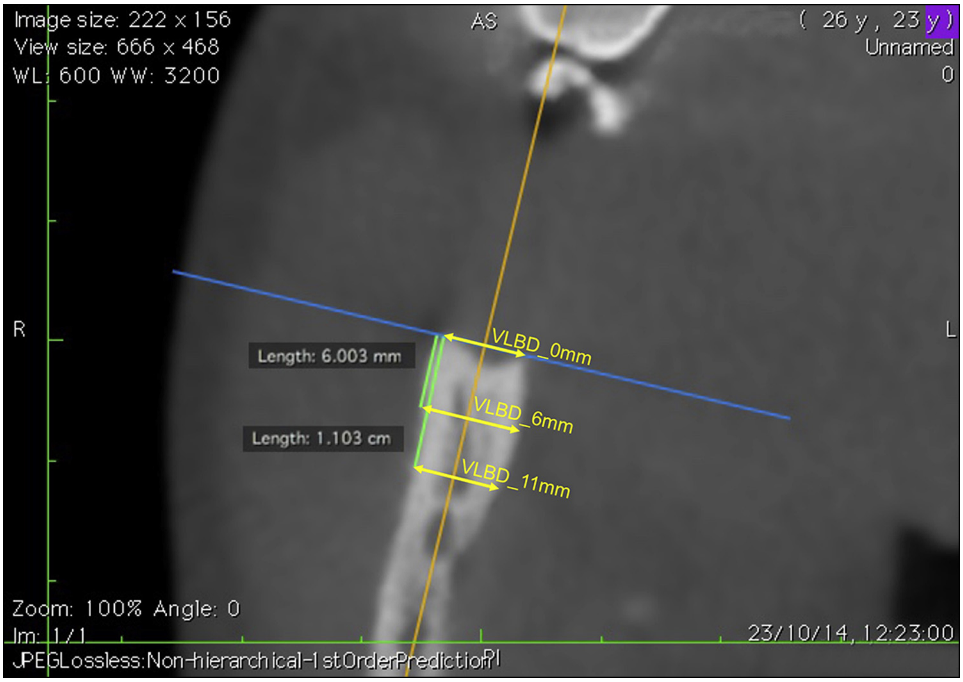

Fig 3. On each cross-section scan view 3 vestibulolingual linear outcomes were measured: the vestibulolingual bone dimension of the most anterior portion of the ramus (VLBD-0 mm) and the vestibulolingual bone dimension of the ramus at 6 mm (VLBD-6 mm) and 11 mm (VLBD-11 mm) depth from anterior ramus bone surface.

Preliminary data analysis was performed with the use of Shapiro-Wilk test for normal distribution evaluation and Levene test for equality of variance appraisal. When data showed normal distribution, the following parametric tests were used: unpaired *t* test, analysis of variance, and Tukey post- hoc test. In case data showed nonnormal distribution, the following nonparametric tests were used: Mann-Whitney *U* test, Kruskal-Wallis test, and Dunn-Bonferroni post hoc test. Inferential statistics was performed applying multiple comparisons and post hoc tests among different evaluated sites of the following bone characteristics: bone depth, cortical bone thickness, and vestibulolingual bone dimension.

Moreover, multiple comparisons and post hoc tests were used to evaluate VLBD at different bone depths (0, 6, and 11 mm). Finally, samples with and without third molars were compared to detect significant differences.

To estimate intra-examiner reliability, view sections selection and outcome measurements were repeated for 10 randomly selected patients 1 week apart. In addition, 10 patients were randomly selected and evaluated by a different operator to evaluate interexaminer reliability. For both inter- and intra-examiner reliability the methodologic error was estimated with the use of paired *t* tests and intraclass correlation coefficient (ICC). No significant differences (P <0.05) were detected between the 2 readings; all measurements were reliable, with the ICC varying from 0.72 to 0.87 for the intra-examiner reliability and from 0.63 to 0.75 for the inter-examiner reliability.

The measurement error was calculated with the use of the Bland-Altman method. Applying this method, we calculated the mean difference between the 2 readings, its standard deviation, and the corresponding 95% confidence interval (CI). Results showed a mean difference of 0.6 $\pm$ 0.19 mm (95% CI 0.22-0.98) for the intra-examiner reliability and a mean difference of 0.7 $\pm$ 0.12 mm (95% CI 0.48-0.92) for the interexaminer reliability.

SPSS software (version 17.0; IBM Corp, Armonk, NY) was used for all statistical analyses except for the Bland-Altman CI calculations, which were performed with the use of Medcalc software (version 18.2.1; Mariakerke, Belgium). The significance levels for all tests were set at P <0.05.

RESULTS

Total bone depth, cortical bone thickness, and vestibulolingual bone dimensions at 0, 6, and 11 mm

Table II. Descriptive statistics of evaluated outcomes of with third molar sample

	BD-3 mm-0°				*BD-6 mm-0°*				*CBT-3 mm-45°*				*CBT-6 mm-45°*			
Outcome	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*
BD	14.58	2.59	7.92	18.71	14.93	2.77	8.62	20.07	11.39	2.28	5.43	16.45	11.78	2.31	5.95	15.78
CBT	4.61	1.53	1.22	6.75	5.33	2.01	1.85	8.84	3.64	0.86	0.23	3.77	4.41	1.03	1.57	5.33
VLBD at 0 mm	20.76	3.79	12.50	25.68	18.79	3.12	9.30	22.40	23.02	3.72	14.28	29.60	21.98	3.74	13.36	31.76
VLBD at 6 mm	9.93	1.80	5.56	12.62	8.87	1.91	4.22	9.00	10.57	1.58	6.24	12.50	9.84	1.90	5.62	13.50
VLBD at 11 mm	8.89	1.44	4.50	12.62	7.85	1.32	3.90	9.00	8.93	1.61	6.24	11.14	8.38	1.60	3.96	11.12

BD, Bone depth; *CBT*, cortical bone thickness; *VLBD*, vestibulolingual bone dimension of mandibular ramus at 0, 6, and 11 mm of bone depth.

Table III. Descriptive statistics of evaluated outcomes of without 3rd molar sample

	BD-3 mm-0°				*BD-6 mm-0°*				*CBT-3 mm-45°*				*CBT-6 mm-45°*			
Outcome	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*
BD	13.17	2.63	6.13	18.71	13.22	4.01	5.99	25.08	10.46	2.59	4.93	15.21	10.71	2.46	5.64	15.06
CBT	3.27	1.28	1.49	5.95	4.18	1.64	1.16	7.46	3.30	1.25	1.15	6.34	3.49	1.51	1.17	8.35
VLBD at 0 mm	19.48	3.59	12.76	27.56	17.55	3.42	12.88	26.68	21.03	3.88	13.16	28.82	20.87	3.89	13.92	28.28
VLBD at 6 mm	8.19	1.57	4.86	10.96	7.45	1.74	4.40	11.92	9.22	1.89	5.84	13.78	8.82	1.76	4.60	12.14
VLBD at 11 mm	7.39	1.48	4.14	10.96	6.69	1.40	4.12	10.64	7.81	1.45	4.68	11.06	7.53	1.27	5.48	10.78

BD, Bone depth; *CBT*, cortical bone thickness; *VLBD*, vestibulolingual bone dimension of mandibular ramus at 0, 6, and 11 mm of bone depth.

depth are reported in Tables II and III, along with the corresponding descriptive statistics. In particular, Table II reports the data derived from the subjects with third molars and Table III reports the data derived from the subjects without third molars. Tables IV-VI report inferential statistics. Specifically, Table IV reports multiple comparisons and post hoc tests of different insertion sites for the following outcomes: bone depth, cortical bone thickness, and vestibulolingual bone dimensions at 0 mm of depth, Table V reports multiple comparisons and post hoc tests of vestibulolingual bone dimension at different bone depths (0, 6, and 11 mm), and Table VI reports the significant differences between the two samples (ie, subjects with and without third molars).

DISCUSSION

To the best of our knowledge, this is the first study in the literature that investigates the anatomic skeletal characteristics of the MRTARR for miniscrew insertion.

Orthodontic literature has shown that the MRTARR can be successfully used as a miniscrew insertion site for different clinical applications. Different authors showed that the MRTARR can be successfully used to distalize the entire mandibular dentition in case of class III camouflage treatment.[16-18] Moreover, the MRTARR can be used to improve biomechanics in mesially impacted mandibular molars treatment[19] and in mandibular molars uprighting.[20]

The MRTARR, as an extra-alveolar insertion site, offers clinical advantages compared with the dentoalveolar interradicular insertion site. The absence of screw-roots impaction risk during insertion potentially improves the success rate of miniscrew insertion, considering that screw-roots impaction is one of the most frequent causes of miniscrew failure.[9]

The present study was designed to provide clinicians with useful information for miniscrew insertion in the MRTARR, and for this purpose we chose to design our analysis of the insertion site starting from the occlusal mandibular plane to provide an easy reference to the clinicians. From the occlusal plane, we moved 3 mm and 6 mm coronally and we evaluated bone depth (considered as the distance between the surface cortical bone of the trigone and the external cortical bone of the alveolar nerve canal) on parallel and 45° cross-sectional scans compared with the occlusal plane. All of the considered insertion sites showed on average more than 10 mm of bone depth. As a consequence, the MRTARR can be defined as a safe zone for miniscrew insertion. Descriptive statistics in some cases also showed minimum values close to 5 mm of bone depth, but with the abundance of gingiva it is unlikely that the miniscrew could be completely inserted in the MRTARR; in addition, bone depth did not consider the cortical thickness of the mandibular alveolar canal, therefore the use of 6-mm-length miniscrews can be considered to be a safe procedure for all of the evaluated sites. Cross-sectional scans parallel to the occlusal plane showed significantly greater bone depth (+3mm on

Table IV. Multiple comparisons and post hoc tests among different sites of the following outcomes: bone depth (BD), cortical bone thickness (CBT), and vestibulolingual bone dimension (VLBD) of the anterior mandibular ramus at 0 mm of bone depth

	With 3rd molar			*Without 3rd molar*		
Outcome	*BD*	*CBT*	*VLBD*	*BD*	*CBT*	*VLBD*
Levene test significance	*P* = 0.687 (NS)	*P* <0.001	*P* = 0.759 (NS)	*P* = 0.062 (NS)	*P* = 0.402 (NS)	*P* = 0.479 (NS)
Multiple comparison tests significance	*P* <0.001*	*P* = 0.02†	*P* <0.001*	*P* <0.001*	*P* = 0.07* (NS)	*P* <0.001*
Post hoc comparisons						
3mm-0° vs 6mm-0°	*P* = 0.941‡ (NS)	*P* = 1.0§ (NS)	*P* = 0.133‡ (NS)	*P* = 1.0‡ (NS)	(NS)	*P* = 0.137‡ (NS)
3mm-45° vs 6mm-45°	*P* = 0.923‡ (NS)	*P* = 0.109§ (NS)	*P* = 0.656‡ (NS)	*P* = 0.987‡ (NS)	(NS)	*P* = 0.998‡ (NS)
3mm-0° vs 3mm-45°	*P* <0.05‡	*P* = 0.097§ (NS)	*P* = 0.064‡ (NS)	*P* <0.05‡	(NS)	*P* = 0.386‡ (NS)
6mm-0° vs 6mm-45°	*P* <0.05‡	*P* = 1.0§ (NS)	*P* <0.05‡	*P* <0.05‡	(NS)	*P* <0.05‡

*Analysis of variance; †Kruskal-Wallis test; ‡Tukey test; §Dunn-Bonferroni test.

Table V. Multiple comparisons and post hoc tests of vestibulolingual bone dimension at different bone depth (0, 6 and 11 mm)

	Vestibulolingual bone dimension without 3rd molar				*Vestibulolabial bone dimension with 3rd molar*			
Outcome	*0°-3 mm*	*0°-6 mm*	*45°-3 mm*	*45°-6 mm*	*0°-3 mm*	*0°-6 mm*	*45°-3 mm*	*45°-6 mm*
Levene test	*P* <0.001	*P* <0.001	*P* <0.001	*P* <0.001	*P* <0.001	*P* <0.001	*P* <0.001	*P* <0.001
Multiple comparison tests significance	*P* <0.001*	*P* <0.001*	*P* <0.001*	*P* <0.001*	*P* <0.001*	*P* <0.001*	*P* <0.001*	*P* <0.001*
Post hoc comparisons								
0 mm vs 6 mm	*P* = 0.451† (NS)	*P* = 0.345† (NS)	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†
0 mm vs 11 mm	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* <0.05†
6 mm vs 11 mm	*P* <0.05†	*P* <0.05†	*P* <0.05†	*P* = 0.114† (NS)	*P* = 0.561† (NS)	*P* = 0.345† (NS)	*P* = 0.114† (NS)	*P* = 0.114† (NS)

*Kruskal-Wallis test; †Dunn-Bonferroni test.

Table VI. Inferential statistics comparing the two considered sample subjects groups with and without third molars

	Insertion site			
Variable	*0°-3 mm*	*0°-6 mm*	*45°-3 mm*	*45°-6 mm*
BD	*P* = 0.352* (NS)	*P* = 0.292* (NS)	*P* = 0.501* (NS)	*P* = 0.358* (NS)
CBT	*P* = 0.647† (NS)	*P* = 0.647† (NS)	*P* = 0.505* (NS)	*P* = 0.069† (NS)
VLBD at 0 mm	*P* = 0.46* (NS)	*P* = 0.132† (NS)	*P* = 0.145† (NS)	*P* = 0.537* (NS)
VLBD at 6 mm	*P* <0.05*	*P* = 0.05* (NS)	*P* = 0.06* (NS)	*P* = 0.28* (NS)
VLBD at 11 mm	*P* <0.05*	*P* = 0.029†	*P* = 0.116* (NS)	*P* = 0.277† (NS)

*Unpaired *t* test (normal distribution); †Mann-Whitney *U* test (non-normal distribution).

average) compared to those 45° oriented. These findings suggest that miniscrew insertion with a screw that is parallel to the occlusal plane is potentially safer compared to a 45° insertion direction.

Descriptive statistics showed the average cortical bone thickness was 3-5 mm. Inferential statistics showed no significant differences of cortical bone thickness among the considered sites. Cortical bone thickness evaluation before miniscrew insertion could be a suitable parameter in considering predrilling during the miniscrew insertion procedure.[21] Literature has shown that the control of torque insertion is a fundamental aspect to reduce miniscrew failure.[22,23] In fact, an adequate insertion torque ensures primary screw stability and successful placement, whereas an excessive insertion torque can cause bone necrosis around the screw, potentially compromising long-term screw stability.[22]

Insertion torque is affected by the cortical bone thickness of the insertion site,[23,24] and according to some authors,[21,25,26] if the screw insertion in a specific site requires high insertion torque owing to the presence of abundant cortical bone thickness, an adequate procedure to reduce insertion torque is predrilling of the insertion site.

Evidence suggests that when cortical bone thickness is greater than 2 mm, predrilling is always recommended to control insertion torque.[21] As a consequence, considering that the MRTARR showed on average cortical bone thickness of 3-5 mm, predrilling could be a procedure to avoid excessive insertion torque and improve miniscrew long-term stability.

To properly insert miniscrews in the MRTARR, understanding of the anatomic bone characteristics of the insertion site is essential. During insertion, a wrong mediolateral inclination could cause cortical screw impaction or perforation (vestibular or lingual). As a consequence, we decided to also evaluate the VLBD of MRTARR at different bone depths (0, 6, and 11 mm). Descriptive statistics indicated that VLBD of the MRTARR offers, in its most anterior part, safe bone extension (17-21 mm). However, VLBD decreases significantly at 6 mm of depth (for almost all of the considered sites); at that level we measured average values of bone depth of 7-8 mm. VLBD remains stable at 11 mm of depth compared with 6 mm of depth. At 11 mm we found nonsignificant results or statistically significant but not clinically significant results compared with 6 mm; in fact we measured average values of 6-8 mm of bone depth. Our data show that VLBD of the MRTARR decreases moving posteriorly, and this aspect could increase the risk of screw-cortical bone impaction. In this regard, the vestibular cortical bone of the MRTARR (which can be evaluated by means of palpation relatively in its anterior part) could be a suitable reference structure to place the miniscrew parallel to it at a proper distance to avoid cortical bone impaction during screw insertion.

It was supposed that the presence of the third molar could affect the anatomic characteristics of the MRTARR, and for this reason 2 different groups were enrolled and compared for all the considered outcomes. No significant difference was found between the 2 groups, with the exception of the parameter evaluating VLBD at 6 mm and 11 mm of bone depth in cross-sectional scans parallel to the occlusal plane. Subjects with the third molar showed greater average values of VLBD with +1.74mm of increment at 6mm and +1.16mm at 11mm compared to subjects without the third molar. These results indicate that subjects with third molars present a statistically significant wider posterior retromolar region. However, the difference between the 2 groups, even if statistically significant, could be clinically nonsignificant for miniscrew insertion.

To properly insert miniscrews for orthodontic purposes, soft tissue evaluation is mandatory, especially for the MRTARR, where free gingiva is abundant. Free gingiva is mobile, its mobility causes irritation, and its proliferation around the head of the screw potentially affects long-term miniscrew stability.[27] Because the purpose of the present study was not the evaluation of MRTARR periodontal soft tissue characteristics, we evaluated only bone characteristics of the MRTARR and this represents a limit of this investigation.

Moreover, this study considered only the Caucasian racial group and adult subjects; the bone characteristics of MRTARR could be different in other racial groups and in growing children. In the future, additional studies will be necessary for the evaluation of MRTARR characteristics in different racial groups and in growing children. However, the results of this study showed that specific sites of MRTARR present adequate skeletal characteristics, even considering possible racial variation.

CONCLUSIONS

1. The MRTARR showed enough bone quantity and adequate bone quality for safe miniscrew insertion in adults.
2. Miniscrew insertion with a parallel orientation to the occlusal plane exhibited increased bone depth (+3 mm) compared with the 45° insertion orientation.
3. Vestibulolingual bone dimension showed a significant reduction (−10 mm) in the posterior regions of retromolar trigone.
4. Almost no differences were found between subjects with and without third molars.

REFERENCES

1. Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:e6-15.
2. Nienkemper M, Pauls A, Ludwig B, Wilmes B, Drescher D. Multifunctional use of palatal mini-implants. J Clin Orthod 2012;46:679-86.
3. Chandhoke TK, Nanda R, Uribe FA. Clinical applications of predictable force systems, part 2: miniscrew anchorage. J Clin Orthod 2015;49:229-39.
4. Papageorgiou SN, Zogakis IP, Papadopoulos MA. Failure rates and associated risk factors of orthodontic miniscrew implants: a meta-analysis. Am J Orthod Dentofacial Orthop 2012;142:577-95.
5. Papadopoulos MA, Papageorgiou SN, Zogakis IP. Clinical effectiveness of orthodontic miniscrew implants: a meta-analysis. J Dent Res 2011;90:969-76.
6. Zawawi KH. Acceptance of orthodontic miniscrews as temporary anchorage devices. Patient Prefer Adherence 2014;8:933-7.
7. Baumgaertel S. Cortical bone thickness and bone depth of the posterior palatal alveolar process for mini-implant insertion in adults. Am J Orthod Dentofacial Orthop 2011;140:806-11.
8. Nucera R, Lo Giudice A, Bellocchio AM, Spinuzza P, Caprioglio A, Perillo L, et al. Bone and cortical bone thickness of mandibular buccal shelf for mini-screw insertion in adults. Angle Orthod 2017;87:745-51.
9. Baumgaertel S, Hans MG. Assessment of infrazygomatic bone depth for mini-screw insertion. Clin Oral Implants Res 2009;20:638-42.

10. Baumgaertel S, Hans MG. Buccal cortical bone thickness for mini-implant placement. Am J Orthod Dentofacial Orthop 2009;136:230-5.
11. Baumgaertel S, Tran TT. Buccal mini-implant site selection: the mucosal fallacy and zones of opportunity. J Clin Orthod 2012;46:434-6.
12. 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;131:S68-73.
13. Gracco A, Lombardo L, Cozzani M, Siciliani G. Quantitative cone-beam computed tomography evaluation of palatal bone thickness for orthodontic miniscrew placement. Am J Orthod Dentofacial Orthop 2008;134:361-9.
14. Poggio PM, Incorvati C, Velo S, Carano A. "Safe zones": a guide for miniscrew positioning in the maxillary and mandibular arch. Angle Orthod 2006;76:191-7.
15. Chang C, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf mini-screws placed in movable mucosa or attached gingiva. Angle Orthod 2015;85:905-10.
16. Poletti L, Silvera AA, Ghislanzoni LT. Dentoalveolar class III treatment using retromolar miniscrew anchorage. Prog Orthod 2013;14:7.
17. Miguel JA, Zanardi G. Class III camouflage using skeletal anchorage and Pendex appliance. Prog Orthod 2011;12:73-83.
18. Anhoury PS. Retromolar miniscrew implants for Class III camouflage treatment. J Clin Orthod 2013;47:706-15.
19. Kim SJ, Kim JW, Choi TH, Lee KJ. Restoration of a vertical alveolar bone defect by orthodontic relocation of a mesially impacted mandibular first molar. Am J Orthod Dentofacial Orthop 2015;147:S122-32.
20. Musilli M, Marsico M, Romanucci A, Grampone F. Molar uprighting with mini screws: comparison among different systems and relative biomechanical analysis. Prog Orthod 2010;11:166-73.
21. Baumgaertel S. Predrilling of the implant site: Is it necessary for orthodontic mini-implants? Am J Orthod Dentofacial Orthop 2010;137:825-9.
22. Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N. Recommended placement torque when tightening an orthodontic mini-implant. Clin Oral Implants Res 2006;17:109-14.
23. Motoyoshi M, Yoshida T, Ono A, Shimizu N. Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implants. Int J Oral Maxillofac Implants 2007;22:779-84.
24. Marquezan M, Mattos CT, Sant'Anna EF, de Souza MM, Maia LC. Does cortical thickness influence the primary stability of miniscrews? A systematic review and meta-analysis. Angle Orthod 2014;84:1093-103.
25. Wilmes B, Drescher D. Impact of insertion depth and predrilling diameter on primary stability of orthodontic mini-implants. Angle Orthod 2009;79:609-14.
26. Heidemann W, Gerlach KL, Grobel KH, Kollner HG. Influence of different pilot hole sizes on torque measurements and pullout analysis of osteosynthesis screws. J Craniomaxillofac Surg 1998;26:50-5.
27. Ure DS, Oliver DR, Kim KB, Melo AC, Buschang PH. Stability changes of miniscrew implants over time. Angle Orthod 2011;81:994-1000.