# Ideal site for buccal shelf bone mini-screw placement: a retrospective study on CBCT

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## Abstract

**Objective: The aim was to determine the suitable sites of the mandibular buccal shelf (MBS) for the insertion of orthodontic mini-screws evaluating correlations between divergence and bone component and between divergence and inferior alveolar nerve (I.A.N.).**
**Materials and Methods: The sample consisted of 93 Cone Beam Computed Tomography (CBCT). Hard tissues's study has analysed buccal total thickness, apico-coronal total bone depth and cortical coronal bone depth. The I.A.N.'s study analyzed height and buccal thickness and distance between I.A.N. and mini-screw.**
**Results: Cortical depth at 4 mm and 6 mm showed significant measurements. The total thickness analysis at 6 mm didn't found difference while at 4 mm was significant for normodivergent in R7D and R7M. The bone height from I.A.N was higher in hyperdivergent at R7D and R6D. The thickness of the bone was significant in hypodivergents at L7D and R7M. The distance between I.A.N. and miniscrew was significant in L7M.**
**Conclusions: The MBS offered adequate quantity and quality of bone for the insertion of mini-screws. The optimal site is the buccal bone at distal root of the second molar at 4 mm buccal to the cementoenamel junction (CEJ). The study showed no significant correlation between divergence and bone thickness. The bone height between the bone ridge and the roof of I.A.N. decreases progressively in the distal direction. Although hyperdivergent patients showed a greater height between the bone crest and I.A.N. in MBS, this variability isn't clinically significant.**

**Keywords: orthodontic anchorage procedures; mandibular buccal shelf; miniscrew; orthodontics; Cone-Beam computed tomography.**



## How to Cite

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## Introduction

Mini-screws or Temporary Anchorage Devices (TAD) are used in orthodontics to improve the efficiency of orthodontic treatments. Cope et al.[1] defines mini-screws as devices temporarily inserted in the bone that dissipate the reaction forces acting on the dental elements through the anchoring units. The factors that influence the positioning of the mini-screws are primary stability and distances from dental roots and major blood vessels[2].

TAD can be inserted into jaw and mandible[2, 4-6]. The insertion sites in the jaw are palate, interradicular zone, edentulous crest and infrazygomatic crest. The insertion sites in the mandibular are the buccal shelf, the retromolar trine, the interradicular zone and the edentulous crest[2].

The most common indication for treatment with mini-screws is molar protraction. The skeletal anchorage in the anterior palate is optimal for intrusion, distalization, closure of space, rapid maxillary expansion, canine disinclusion and final position of the incisor with respect to the aesthetic of the facial profile[6]. The efficacy and accuracy of the combined use of mini-screws and clear aligners in cases of maxillary arch expansion have been confirmed by literature[7]. Today, the use of mini-screws to promote canine disinclusion is added to conventional surgical methods and laser technology[8-10]. There are also cases of gummy smile where the intrusion of the central incisors was solved by inserting mini-screws for orthodontic purposes[11].

Although lower molar distalization can be achieved by using clear aligners, the insertion of mini-screws into the mandibular buccal shelf (MBS) is a good treatment alternative[12]. Cases of lower molar distalization treated by the combined use of transparent aligners and mini-screws are reported[13].

The MBS area is an extra-alveolar anchorage site with a high quality and quantity of bone that provides biomechanical benefits by reducing failure rate. MBS is defined as the buccal anatomical area between the roots of lower first and second molar and mesial oblique mandibular body line[14].

The mini-screws inserted in the MBS are self-tapping. The self-tapping mini-screws need a pilot hole to insert the device due to the high bone thickness of the MBS. For this reason, mini-screws with a length of 10 mm are often used in the MBS area. The insertion of the mini-screws in the MBS must be perpendicular to the bone and parallel to the axis of the second molar[15].

The aim of this cross-sectional retrospective study is to determine the most suitable sites of the MBS for the insertion of orthodontic mini-screws to promote skeletal anchorage. Hard tissue and distance from the implantation site to the inferior alveolar nerve (I.A.N.) measurements are performed on cone-beam computed tomographic (CBCT) of patients. Lateral cephalograms were extrapolated from the CBCT to perform a cephalogram analysis and divide the sample into three groups: hypodivergents, normodivergents and hyperdivergents. The measurements were used to evaluate the clinical correlations between divergence and bone component and clinical correlations between divergence and course of the I.A.N. to choose the best site for inserting the mini-screw.

## Material and methods

### *Study Design*

The sample of this cross-sectional retrospective study included CBCT records of 100 subjects (mean age 17.44 years) including 41 males (mean age 16.3) and 59 females (mean age 18.3). The study focused on the analysis of parameters derived from CBCT. All radiographic examinations were collected from the archives of the U.O.C. of Orthodontics and the U.O.C. of Pediatric Dentistry and Odontostomatology of the Department of Dentistry and Maxillofacial Sciences (“Sapienza” University of Rome).

CBCTs were chosen following the inclusion criteria: male or female patients aged > 12 years; presence of the second premolar, first and second molars; and provision of informed consent for access to the records of each patient.

The exclusion criteria were as follows: incomplete or erroneous CBCT images; extensive coronal restorations on the second premolars and the first and/or second molars; presence of periapical lesions (endodontic or periodontal in origin), osseous or odontogenic tumors, supernumerary teeth, and horizontal or vertical bone loss in the area of study; genetic syndromes or craniofacial dysmorphism; history of facial trauma; and previous orthognathic surgery treatment.

Images were saved in Digital Imaging and Communications in Medicine (DICOM) files, which were imported into “Radiant DICOM Viewer 64 bit” (https://www.radiantviewer.com) to obtain the primary reconstructed images (sagittal, coronal, and axial) and 3D reconstructions.

Using “Radiant DICOM Viewer 64 bit”, lateral cephalograms were extrapolated from the CBCT volumes. All lateral cephalograms were used for automatic cephalometric analysis using “WebCeph” (https://webceph.com/it/).

Automatic cephalometric analysis divided the sample into three groups according to vertical facial patterns determined by Frankfort Mandibular Plane Angle: the angle between Frankfort horizontal (Porion to Orbitale) and the Mandibular Plane (Menton to Gonion).

Group 1 (hypodivergent type) consisted of 31 patients.
Group 2 (normodivergent type) consisted of 31 patients.
Group 3 (hyperdivergent type) consisted of 31 patients.

## Measurement method and study parameters

Before measuring for quantities and qualitative evaluation of hard tissue and distance from the implantation site to the I.A.N. for each CBCT were reoriented the three traditional scanning planes (sagittal, axial and coronal) (Figure 1). The axial scanning plane was oriented through the points of forcation of the first and second molar. At the level of this reoriented axial plane, two points were used to orient the sagittal plan and then identify the mesio-distal direction of the mandibular alveolar process. These points were identified at the centre of the dento-alveolar process at

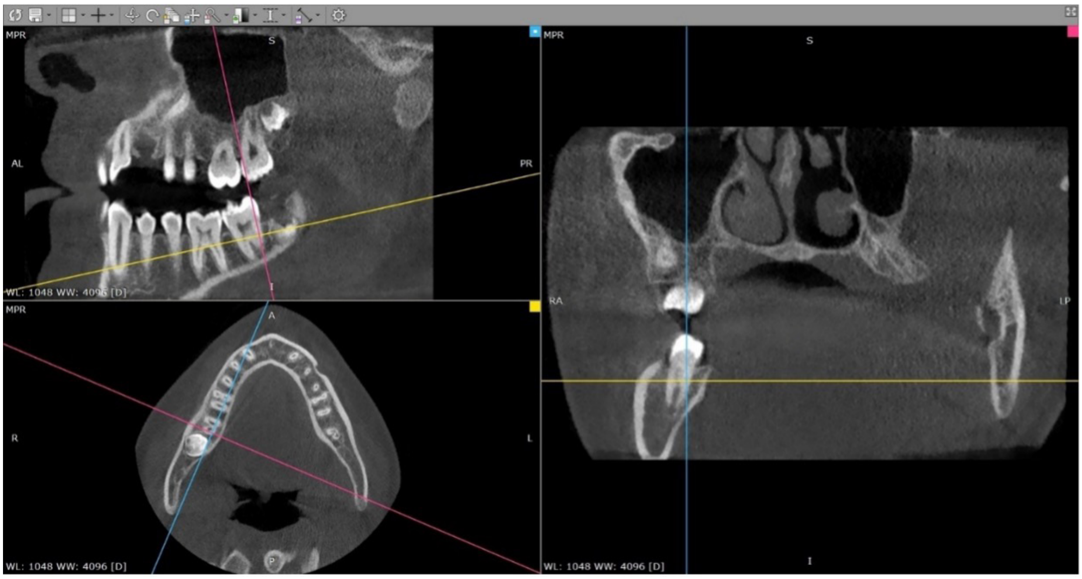

**Figure 1.** Reoriented reference scan lines (sagittal: blue line; axial: yellow line; and coronal: red line)

the mesial root of the first molar and at the distal root of the second molar. Finally, the coronal scanning plane was oriented to adapt to the direction of two thirds of the long coronal axes of the sites of the analyzed teeth. For each hemi-arch, four regions were selected for analysis: the distal root of the second molar (7D); the mesial root of the second molar (7M); the distal root of the first molar (6D) and the mesial root of the first molar (6M).

The individual measurements were made by selecting the measuring site (7D, 7M, 6D, 6M) and then identifying the vestibular cementoenamel junction (CEJ) in each scan view root section.

The parameters for the study of hard tissues for each site included:

1. Buccal total bone thickness
2. Apico-coronal total bone depth (cortical and medullary bone)
3. Cortical coronal bone depth

The buccal total bone thickness was evaluated in the bucco-lingual direction by the CEJ tracing a line perpendicular to the imaginary line passing through the CEJ itself. At this level, two horizontal lines were located apically at 6 mm (TotThick-at-6) and 11 mm (TotTick-at-11) from the CEJ (Figure 2 A,B).

The total bone depth was evaluated by tracing an imaginary vertical line perpendicular to the line passing through the CEJ. This parameter is measured at 4 mm (TotDepth-at-4) and 6 mm (TotaDepth-at-6) respectively by the CEJ (Figure 2 C,D). Cortical bone depth was measured as total bone depth, but only the coronal cortical portion was considered. This parameter is measured at 4 mm (CortDepth-at-4) and 6 mm (CortDepth-at-6) respectively by the CEJ (Figure 2 E,F).

The parameters analyzed for the I.A.N. study were:

a. Bone height from the I.A.N.
b. Bucco-lingual thickness from the I.A.N.
c. Distance between the insertion depth of the mini-screw and I.A.N.

The first measurements were carried out with the software “Radiant DICOM Viewer 64-bit”. The CBCTs files of each group were processed with the software “Radiant DICOM 64-bit Viewer”. Identified the CEJ and the position of the I.A.N. in the lower alveolar canal (I.A.C.) were measured on each CBCT at sites 7D, 7M, 6D and 6M: bone height and bucco-lingual thickness from the I.A.N.

The bone height from the I.A.N. represented the shortest linear distance between the most coronal point of the I.A.N. and the imaginary horizontal line passing through the CEJ (Figure 2 G).

The bucco-lingual thickness was estimated as the lineal distance between the most buccal portion of the I.A.N. at the end of the cortical (Figure 2 H).

The distance between the insertion depth of the mini-screw and I.A.N. was carried out using: “Invesalius 3.1” (https://invesalius.github.io) and “BlueSkyPlan Ver 4.11” (https://www.blueskyplan.com). The software “Invesalius 3.1” used the DICOM files of each sample group to get the STL files. The software “BlueSkyPlan Ver 4.11” simulated the removal of mini-screws in the MBS using the files DICOM and STL. The procedure consisted in aligning the DICOM and STL files and then selecting the area of interest and the I.A.N. choosing from the software library the TAD devices (Leone Tad-Leone s.p.a Sleeve). At this point it is possible to make measurements between the apex of the inserted mini-screw and the I.A.N. (Figure 3).

Measurements were made for each CBCT in the MBS area, both left and right.

All measurements were made by the same experienced operator and repeated twice at thirty days.

## *Statistical analysis*

A descriptive and inferential statistical analysis of the data obtained for each site (6M, 6D, 7M, 7D) was carried out. The data analysis was conducted with the statistical software SPSS version 25.0. The statistical technique of univariate variance analysis (Anova One Way) followed by post-hoc comparisons (Bonferroni)


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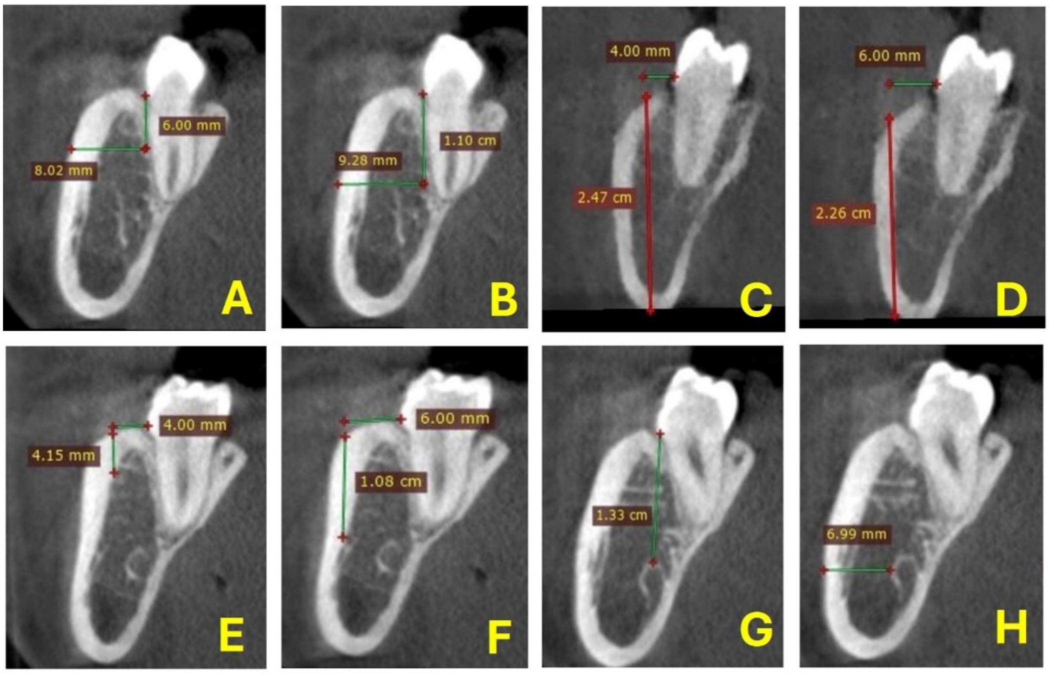


**Figure 2.** A: Buccal total bone thickness at 6 mm (TotThick-at-6); B: Buccal total bone thickness at 11 mm (TotThick-at-11); C: Apico-coronal total bone depth at 4 mm (TotDepth-at-4); D: Apico-coronal total bone depth at 6 mm (TotDepth-at-6); E: Cortical bone depth at 4 mm (CortDepth-at-4); F: Cortical bone depth at 6 mm (CortDepth-at-6); G: Bone height from the I.A.N.; H: Bucco-lingual thickness from the I.A.N.


**Figure 3.** The insertion depth of the miniscrew and the relationship to the digitally traced I.A.N.

was used to compare the mean scores of the three groups of patients (hypodivergent, normodivergent and hyperdivergent ) compared to a series of dependent variables consisting of hard tissue measurements (buccal-lingual thickness, cortical thickness and total thickness) and the positioning of the lower alveolar nerve (height, thickness and distance from the positioning of the mini-screw). All measurements were taken on the right and left sides of the shelf. The results were considered significant at a p-value < .05.

## Results

To clearly illustrate the results, it was decided to present the hard tissue results separately from those of the course of the I.A.N.

*Analysis of hard tissues*

The analysis of cortical thickness parameters at 6 and 11 mm, cortical thickness at 4 and 6 mm and total bone thickness at 4 and 6 mm are reported.

*Analysis of the buccal total bone thickness*

The results obtained for TotThick-at-6 and TotThick-at-11 measurements showed no significant differences between the three groups. The mean scores of the bucco-lingual thickness appear similar for the hyperdivergent, normodivergent and hypodivergent subjects (Table 1).

### *Analysis of total thickness*

In the analysis of the TotDepth-at-4, significant differences were observed between the groups with reference to measurements TotDepth-at-4-R7D ($F_{(2.90)}$= 4.21; p = .018) and TotDepth-at-4-R7M ($F_{(2,90)}$= 3.09; *p* = .050). Post-hoc comparisons have shown that average scores of total thickness appear higher among normodivergents than those at low divergence in both TotDepth-at-4-R7D (p = .015) and TotDepth-at-4-R7M (p = .046).

Otherwise, in the TotDepth-at-6 there were no significant differences between the groups (Table 2).

**Table 1.** Results of measurements TotThick-at-6 and TotThick-at-11

| TotThick-at-6 | | N | Mean | SD | F | Sig. | TotThick-at-11 | | N | Mean | SD | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R7D | Hypodivergent | 31 | 6.26 | 1.47 | .59 | .555 | R7D | Hypodivergent | 31 | 6.46 | 1.70 | .85 | .433 |
| | Normodivergent | 31 | 6.53 | 1.46 | | | | Normodivergent | 31 | 6.70 | 1.63 | | |
| | Hyperdivergent | 31 | 6.07 | 2.06 | | | | Hyperdivergent | 31 | 7.19 | 3.11 | | |
| | Total | 93 | 6.29 | 1.68 | | | | Total | 93 | 6.79 | 2.25 | | |
| L7M | Hypodivergent | 31 | 5.51 | 1.27 | .418 | .660 | L7M | Hypodivergent | 31 | 5.92 | 2.30 | .94 | .395 |
| | Normodivergent | 31 | 5.40 | 1.43 | | | | Normodivergent | 31 | 6.00 | 1.53 | | |
| | Hyperdivergent | 31 | 5.19 | 1.48 | | | | Hyperdivergent | 31 | 6.66 | 2.99 | | |
| | Total | 93 | 5.37 | 1.39 | | | | Total | 93 | 6.20 | 2.35 | | |
| R6D | Hypodivergent | 31 | 4.42 | 1.57 | .72 | .489 | R6D | Hypodivergent | 31 | 5.35 | 1.21 | .22 | .805 |
| | Normodivergent | 31 | 4.29 | 1.98 | | | | Normodivergent | 31 | 5.29 | 1.77 | | |
| | Hyperdivergent | 31 | 3.92 | 1.38 | | | | Hyperdivergent | 31 | 5.60 | 2.70 | | |
| | Total | 93 | 4.21 | 1.66 | | | | Total | 93 | 5.41 | 1.97 | | |
| L6M | Hypodivergent | 31 | 3.56 | 1.57 | 1.37 | .261 | L6M | Hypodivergent | 31 | 4.42 | 2.32 | .38 | .684 |
| | Normodivergent | 31 | 3.21 | 1.41 | | | | Normodivergent | 31 | 4.24 | 1.47 | | |
| | Hyperdivergent | 31 | 3.06 | .73 | | | | Hyperdivergent | 31 | 4.02 | 1.36 | | |
| | Total | 93 | 3.29 | 1.29 | | | | Total | 93 | 4.23 | 1.76 | | |
| R7D | Hypodivergent | 31 | 6.31 | 1.52 | .31 | .737 | R7D | Hypodivergent | 31 | 6.55 | 2.25 | 1.79 | .172 |
| | Normodivergent | 31 | 5.83 | 1.30 | | | | Normodivergent | 31 | 5.93 | 1.41 | | |
| | Hyperdivergent | 31 | 6.12 | 2.00 | | | | Hyperdivergent | 31 | 7.06 | 3.08 | | |
| | Total | 93 | 6.10 | 1.62 | | | | Total | 93 | 6.51 | 2.37 | | |
| L7M | Hypodivergent | 31 | 5.61 | 1.66 | .98 | .379 | L7M | Hypodivergent | 31 | 6.04 | 2.63 | 1.32 | .272 |
| | Normodivergent | 31 | 5.25 | 1.65 | | | | Normodivergent | 31 | 5.62 | 1.62 | | |
| | Hyperdivergent | 31 | 4.97 | 1.31 | | | | Hyperdivergent | 31 | 6.59 | 2.69 | | |
| | Total | 93 | 5.29 | 1.55 | | | | Total | 93 | 6.08 | 2.38 | | |
| R6D | Hypodivergent | 31 | 3.86 | .89 | .09 | .912 | R6D | Hypodivergent | 31 | 4.96 | 2.76 | .17 | .84 |
| | Normodivergent | 31 | 3.81 | 1.33 | | | | Normodivergent | 31 | 4.83 | 1.72 | | |
| | Hyperdivergent | 31 | 3.92 | 1.08 | | | | Hyperdivergent | 31 | 5.19 | 2.59 | | |
| | Total | 93 | 3.86 | 1.10 | | | | Total | 93 | 4.99 | 2.38 | | |
| L6M | Hypodivergent | 31 | 3.38 | 1.39 | 1.85 | .163 | L6M | Hypodivergent | 31 | 4.71 | 2.90 | 2.09 | .129 |
| | Normodivergent | 31 | 3.15 | 1.15 | | | | Normodivergent | 31 | 3.93 | 1.29 | | |
| | Hyperdivergent | 31 | 2.87 | .83 | | | | Hyperdivergent | 31 | 3.70 | 1.46 | | |
| | Total | 93 | 3.15 | 1.16 | | | | Total | 93 | 4.12 | 2.05 | | |

### *Analysis of cortical coronal bone depth*

The results of the analysis of the variance of the CortDepth-at-4 allowed to observe statistically significant differences between the average scores of the groups in reference to the measurements CortDepth-at-4-L7M ($F_{(2,90)}$= 4.03; *p* = .022) and CortDepth-at-4-L6D ($F_{(2,90)}$= 3.65; *p* = .030).

The post-hoc comparisons allowed these results to deepen these results showing how in CortDepth-at-4-L7M the hyperdivergent subjects are characterized by a thickness of the cortical bone greater than that of the normodivergent group (p = .029). Similarly,



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**Table 2.** Results of measurements TotDepth-at-4 and TotDepth-at-6

| TotThick-at-6 | | N | Mean | SD | F | Sig. | TotThick-at-11 | | N | Mean | SD | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R7D | Hypodivergent | 31 | 16.24 | 7.46 | 4.21 | **.018** | R7D | Hypodivergent | 31 | 14.37 | 7.75 | 2.32 | .104 |
| | Normodivergent | 31 | 20.09 | 3.00 | | | | Normodivergent | 31 | 17.35 | 5.70 | | |
| | Hyperdivergent | 31 | 18.68 | 4.36 | | | | Hyperdivergent | 31 | 13.75 | 7.51 | | |
| | Total | 93 | 18.34 | 5.46 | | | | Total | 93 | 15.16 | 7.15 | | |
| L7M | Hypodivergent | 31 | 15.74 | 5.78 | 3.09 | .050 | L7M | Hypodivergent | 31 | 9.61 | 8.27 | 1.19 | .308 |
| | Normodivergent | 31 | 18.56 | 3.19 | | | | Normodivergent | 31 | 12.82 | 8.29 | | |
| | Hyperdivergent | 31 | 17.42 | 4.14 | | | | Hyperdivergent | 31 | 11.11 | 7.98 | | |
| | Total | 93 | 17.24 | 4.60 | | | | Total | 93 | 11.178 | 8.19 | | |
| R6D | Hypodivergent | 31 | 14.19 | 6.32 | .08 | .452 | R6D | Hypodivergent | 31 | 8.44 | 7.79 | .65 | .527 |
| | Normodivergent | 31 | 16.08 | 6.49 | | | | Normodivergent | 31 | 8.96 | 8.11 | | |
| | Hyperdivergent | 31 | 15.59 | 5.45 | | | | Hyperdivergent | 31 | 6.73 | 8.39 | | |
| | Total | 93 | 15.29 | 6.09 | | | | Total | 93 | 8.04 | 8.07 | | |
| L6M | Hypodivergent | 31 | 11.89 | 7.22 | .13 | .883 | L6M | Hypodivergent | 31 | 5.79 | 7.28 | 2.75 | .069 |
| | Normodivergent | 31 | 12.71 | 7.49 | | | | Normodivergent | 31 | 3.98 | 6.99 | | |
| | Hyperdivergent | 31 | 12.69 | 7.33 | | | | Hyperdivergent | 31 | 1.96 | 4.75 | | |
| | Total | 93 | 12.42 | 7.28 | | | | Total | 93 | 3.91 | 6.56 | | |
| R7D | Hypodivergent | 31 | 17.59 | 7.52 | .88 | .419 | R7D | Hypodivergent | 31 | 13.22 | 9.11 | .26 | .769 |
| | Normodivergent | 31 | 19.46 | 3.90 | | | | Normodivergent | 31 | 14.75 | 7.40 | | |
| | Hyperdivergent | 31 | 18.63 | 4.64 | | | | Hyperdivergent | 30 | 13.84 | 8.49 | | |
| | Total | 93 | 18.56 | 5.57 | | | | Total | 92 | 13.94 | 8.29 | | |
| L7M | Hypodivergent | 31 | 15.17 | 7.39 | 1.76 | .178 | L7M | Hypodivergent | 31 | 9.54 | 9.26 | .83 | .440 |
| | Normodivergent | 31 | 17.45 | 5.77 | | | | Normodivergent | 31 | 12.33 | 8.33 | | |
| | Hyperdivergent | 31 | 17.75 | 4.21 | | | | Hyperdivergent | 31 | 10.97 | 7.93 | | |
| | Total | 93 | 16.79 | 5.92 | | | | Total | 93 | 10.95 | 8.52 | | |
| R6D | Hypodivergent | 31 | 13.58 | 7.92 | 1.31 | .276 | R6D | Hypodivergent | 31 | 7.24 | 8.35 | .97 | .384 |
| | Normodivergent | 31 | 14.01 | 7.95 | | | | Normodivergent | 31 | 7.85 | 8.56 | | |
| | Hyperdivergent | 31 | 16.28 | 4.92 | | | | Hyperdivergent | 31 | 5.13 | 7.30 | | |
| | Total | 93 | 14.63 | 7.09 | | | | Total | 93 | 6.74 | 8.08 | | |
| L6M | Hypodivergent | 31 | 9.76 | 8.46 | .67 | .512 | L6M | Hypodivergent | 31 | 4.06 | 6.56 | .49 | .614 |
| | Normodivergent | 31 | 11.33 | 8.25 | | | | Normodivergent | 31 | 4.32 | 7.02 | | |
| | Hyperdivergent | 31 | 8.93 | 8.09 | | | | Hyperdivergent | 31 | 2.79 | 5.89 | | |
| | Total | 93 | 10.01 | 8.24 | | | | Total | 93 | 3.72 | 6.47 | | |

hyperdivergent subjects show a greater thickness of the cortical bone in CortDepth-at-4-L6D than those of the normodivergent group (p = .025).
The results of the analysis of CortDepth-at-6 show statistically significant differences between the mean scores between groups for measurements: CortDepth-at-6-R6D ($F_{(2,90)}$= 4.58; *p* = .013) and CortDepth-at-6-L6M ($F_{(2,90)}$= 5.87; *p* = .004).
Post-hoc comparisons showed that hypodivergent patients are characterized by a greater cortical thickness at 6 mm in CortDepth-at-6-R6D compared to normodivergent (p = .038) and hyperdivergent (p = .025) patients.

**Table 3.** Results of measurements CortDepth-at-4 and CortDepth-at-6

| CortDepth-at-4 | | N | Mean | SD | F | Sig. | CortDepth-at-6 | | N | Mean | SD | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R7D | Hypodivergent | 31 | 4.43 | 2.13 | 2.19 | .117 | R7D | Hypodivergent | 31 | 5.91 | 5.98 | .68 | .508 |
| | Normodivergent | 31 | 4.33 | 1.05 | | | | Normodivergent | 31 | 4.99 | 1.64 | | |
| | Hyperdivergent | 31 | 5.15 | 1.69 | | | | Hyperdivergent | 31 | 4.82 | 2.99 | | |
| | Total | 93 | 4.64 | 1.71 | | | | Total | 93 | 5.24 | 3.96 | | |
| L7M | Hypodivergent | 31 | 4.78 | 2.07 | .08 | .922 | L7M | Hypodivergent | 31 | 6.11 | 6.61 | 2.01 | .140 |
| | Normodivergent | 31 | 4.87 | 1.06 | | | | Normodivergent | 31 | 4.42 | 3.10 | | |
| | Hyperdivergent | 31 | 4.94 | 1.38 | | | | Hyperdivergent | 31 | 3.93 | 2.67 | | |
| | Total | 93 | 4.86 | 1.55 | | | | Total | 93 | 4.82 | 4.54 | | |
| R6D | Hypodivergent | 31 | 4.77 | 1.99 | 1.81 | .169 | R6D | Hypodivergent | 31 | 5.37 | 6.12 | 4.58 | **.013** |
| | Normodivergent | 31 | 4.19 | 1.78 | | | | Normodivergent | 31 | 2.68 | 2.38 | | |
| | Hyperdivergent | 31 | 5.08 | 1.79 | | | | Hyperdivergent | 31 | 2.52 | 2.97 | | |
| | Total | 93 | 4.68 | 1.87 | | | | Total | 93 | 3.52 | 4.32 | | |
| L6M | Hypodivergent | 31 | 4.78 | 2.94 | 1.69 | .193 | L6M | Hypodivergent | 31 | 4.18 | 6.12 | 5.87 | **.004** |
| | Normodivergent | 31 | 3.64 | 2.24 | | | | Normodivergent | 31 | 1.06 | 1.88 | | |
| | Hyperdivergent | 31 | 4.14 | 2.04 | | | | Hyperdivergent | 31 | 1.23 | 2.83 | | |
| | Total | 93 | 4.18 | 2.47 | | | | Total | 93 | 2.15 | 4.25 | | |
| R7D | Hypodivergent | 31 | 4.15 | 1.37 | .78 | .462 | R7D | Hypodivergent | 31 | 5.73 | 5.64 | 2.33 | .103 |
| | Normodivergent | 31 | 4.39 | 1.25 | | | | Normodivergent | 31 | 4.05 | 2.13 | | |
| | Hyperdivergent | 31 | 4.57 | 1.41 | | | | Hyperdivergent | 31 | 3.81 | 2.69 | | |
| | Total | 93 | 4.37 | 1.34 | | | | Total | 93 | 4.53 | 3.87 | | |
| L7M | Hypodivergent | 31 | 4.26 | 1.90 | 4.00 | **.022** | L7M | Hypodivergent | 31 | 4.06 | 4.59 | .34 | .713 |
| | Normodivergent | 31 | 4.08 | 1.49 | | | | Normodivergent | 31 | 3.67 | 2.40 | | |
| | Hyperdivergent | 31 | 5.15 | 1.33 | | | | Hyperdivergent | 31 | 4.39 | 3.05 | | |
| | Total | 93 | 4.49 | 1.64 | | | | Total | 93 | 4.04 | 3.45 | | |
| R6D | Hypodivergent | 31 | 4.15 | 2.09 | 3.65 | **.030** | R6D | Hypodivergent | 31 | 3.78 | 5.35 | 1.76 | .178 |
| | Normodivergent | 31 | 3.49 | 2.00 | | | | Normodivergent | 31 | 2.38 | 2.61 | | |
| | Hyperdivergent | 31 | 4.79 | 1.49 | | | | Hyperdivergent | 31 | 2.09 | 2.77 | | |
| | Total | 93 | 4.15 | 1.94 | | | | Total | 93 | 2.75 | 3.82 | | |
| L6M | Hypodivergent | 31 | 3.89 | 2.95 | 1.31 | .275 | L6M | Hypodivergent | 31 | 2.65 | 4.75 | .81 | .447 |
| | Normodivergent | 31 | 3.33 | 2.64 | | | | Normodivergent | 31 | 2.65 | 4.68 | | |
| | Hyperdivergent | 31 | 2.78 | 2.53 | | | | Hyperdivergent | 31 | 1.45 | 3.26 | | |
| | Total | 93 | 3.33 | 2.72 | | | | Total | 93 | 2.25 | 4.28 | | |

Similarly, in CortDepth-at-6-L6M hypodivergent patients show a greater cortical thickness than in normodivergent (p = .009) and hyperdivergent (p = .015) people (Table 3).

## *Analysis of the course of the I.A.N.*

**Bone height analysis**

The bone height results showed statistically significant differences between groups compared to measurements: BoneHeight-R7D ($F_{(2,90)}$= 6.76; *p* = .002) and BoneHeight-R6D ($F_{(2,90)}$= 4.66; *p*= 012).

The post-hoc comparisons made it possible to deepen these findings. In particular, with regard to measure BoneHeight-R7D, it was found that the group made up of hyperdivergent subjects had on average higher scores


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**Table 4.** Results of measurements Bone Height from the I.A.N.

| **Bone Height from the I.A.N.** | | **N** | **Mean** | **SD** | **F** | **Sig.** |
|---|---|---|---|---|---|---|
| R7D | Hypodivergent | 31 | 15.24 | 2.52 | 6.77 | **.002** |
| | Normodivergent | 31 | 15.48 | 1.94 | | |
| | Hyperdivergent | 31 | 15.92 | 1.71 | | |
| | Total | 93 | 15.92 | 2.21 | | |
| L7M | Hypodivergent | 31 | 15.46 | 2.62 | .11 | .894 |
| | Normodivergent | 31 | 15.63 | 2.11 | | |
| | Hyperdivergent | 31 | 15.74 | 2.04 | | |
| | Total | 93 | 15.61 | 2.25 | | |
| R6D | Hypodivergent | 31 | 15.67 | 6.12 | 2.42 | .095 |
| | Normodivergent | 31 | 15.77 | 2.38 | | |
| | Hyperdivergent | 31 | 17.06 | 2.97 | | |
| | Total | 93 | 16.17 | 4.32 | | |
| L6M | Hypodivergent | 31 | 15.56 | 2.43 | 1.18 | .313 |
| | Normodivergent | 31 | 15.61 | 2.03 | | |
| | Hyperdivergent | 31 | 16.30 | 1.96 | | |
| | Total | 93 | 15.82 | 2.16 | | |
| R7D | Hypodivergent | 31 | 16.75 | 2.28 | 4.66 | **.012** |
| | Normodivergent | 31 | 17.07 | 2.33 | | |
| | Hyperdivergent | 31 | 18.32 | 1.74 | | |
| | Total | 93 | 17.38 | 2.22 | | |
| L7M | Hypodivergent | 31 | 17.02 | 2.46 | 1.16 | .318 |
| | Normodivergent | 31 | 16.58 | 2.63 | | |
| | Hyperdivergent | 31 | 17.51 | 2.13 | | |
| | Total | 93 | 17.04 | 2.42 | | |
| R6D | Hypodivergent | 31 | 17.05 | 2.47 | .36 | .701 |
| | Normodivergent | 31 | 17.58 | 3.87 | | |
| | Hyperdivergent | 31 | 17.73 | 3.57 | | |
| | Total | 93 | 17.45 | 3.33 | | |
| L6M | Hypodivergent | 31 | 17.27 | 2.60 | 3.08 | .051 |
| | Normodivergent | 31 | 17.24 | 2.20 | | |
| | Hyperdivergent | 31 | 18.53 | 2.18 | | |
| | Total | 93 | 17.68 | 2.39 | | |

than both the group of normodivergents and the group of hypodivergent subjects.

With reference to BoneHeight-R6D, the results showed that the group of hyperdivergent patients obtained on average higher scores only compared to the hypodivergent. In this case, the normodivergent subjects do not differ significantly either from the hyperdivergent subjects or from the hypodivergent subjects, recording values equidistant from the other two groups (Table 4).

## *Analysis of the thickness of the bone.*

Analysis of bone thickness data showed statistically significant differences between the three groups in relation to measurements: Bone-Thick-L7D ($F_{(2,90)}$= 4.75; *p* = .011) and Bone-Thick-R7M ($F_{(2,90)}$= 3.93; *p* = .023). Post-hoc comparisons allowed to establish that hypodivergent subjects have significantly higher scores on these two measurements than those observed in the normodivergent patient group (but not compared to patients classified as hyperdivergent). (Table 5).

**Table 5.** Results of measurements of bucco-lingual thickness from the I.A.N.

| Bucco-lingual thickness from the I.A.N. | | N | Mean | SD | F | Sig. |
|---|---|---|---|---|---|---|
| R7D | Hypodivergent | 31 | 6.42 | 1.53 | 1.31 | .275 |
| | Normodivergent | 31 | 5.83 | .88 | | |
| | Hyperdivergent | 31 | 5.97 | 1.89 | | |
| | Total | 93 | 6.07 | 1.50 | | |
| L7M | Hypodivergent | 31 | 6.58 | 1.29 | 4.75 | **.011** |
| | Normodivergent | 31 | 5.51 | 1.31 | | |
| | Hyperdivergent | 31 | 6.39 | 1.76 | | |
| | Total | 93 | 6.16 | 1.53 | | |
| R6D | Hypodivergent | 31 | 6.61 | 1.80 | 3.93 | .023 |
| | Normodivergent | 31 | 5.48 | 1.27 | | |
| | Hyperdivergent | 31 | 5.88 | 1.74 | | |
| | Total | 93 | 5.99 | 1.67 | | |
| L6M | Hypodivergent | 31 | 6.35 | 1.60 | 1.66 | .196 |
| | Normodivergent | 31 | 5.82 | 1.54 | | |
| | Hyperdivergent | 31 | 6.50 | 1.52 | | |
| | Total | 93 | 6.22 | 1.57 | | |
| R7D | Hypodivergent | 31 | 6.39 | 2.26 | 3.00 | .055 |
| | Normodivergent | 31 | 5.28 | 1.43 | | |
| | Hyperdivergent | 31 | 5.70 | 1.64 | | |
| | Total | 93 | 5.79 | 1.85 | | |
| L7M | Hypodivergent | 31 | 6.07 | 1.63 | 1.91 | .154 |
| | Normodivergent | 31 | 5.29 | 1.55 | | |
| | Hyperdivergent | 31 | 5.63 | 1.57 | | |
| | Total | 93 | 5.66 | 1.61 | | |
| R6D | Hypodivergent | 31 | 5.33 | 2.13 | .00 | .996 |
| | Normodivergent | 31 | 5.35 | 1.79 | | |
| | Hyperdivergent | 31 | 5.31 | 1.41 | | |
| | Total | 93 | 5.33 | 1.78 | | |
| L6M | Hypodivergent | 31 | 5.19 | 1.82 | 1.75 | .180 |
| | Normodivergent | 31 | 4.97 | 1.66 | | |
| | Hyperdivergent | 31 | 4.48 | 1.01 | | |
| | Total | 93 | 4.88 | 1.55 | | |


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*Analysis distance between the insertion depth of the mini-screw and I.A.N.*

In the analysis of the distance between the N.A.I. and the mini-screw. a significant difference was observed between the groups with reference to the Dist-L7M ($F_{(2.90)}$= 7.28; $p$ = .001).

Post-hoc comparisons establish that this distance is significantly smaller among normodivergent than in hyperdivergent and hypodivergent patients (Table 6).

**Table 6.** Results of measurements of distance between the insertion depth of the mini-screw and I.A.N.

| Distance between the insertion depth of the mini-screw and I.A.N. | | N | Mean | SD | F | Sig. |
|---|---|---|---|---|---|---|
| R7D | Hypodivergent | 31 | 11.26 | 3.04 | 1.68 | .193 |
| | Normodivergent | 31 | 10.39 | 1.85 | | |
| | Hyperdivergent | 31 | 11.43 | 2.15 | | |
| | Total | 93 | 11.03 | 2.42 | | |
| L7M | Hypodivergent | 31 | 9.79 | 3.02 | 1.39 | .256 |
| | Normodivergent | 31 | 9.03 | 2.48 | | |
| | Hyperdivergent | 31 | 10.17 | 2.71 | | |
| | Total | 93 | 9.67 | 2.76 | | |
| R6D | Hypodivergent | 31 | 8.71 | 2.39 | 1.72 | .186 |
| | Normodivergent | 31 | 8.15 | 1.47 | | |
| | Hyperdivergent | 31 | 9.13 | 2.28 | | |
| | Total | 93 | 8.67 | 2.11 | | |
| L6M | Hypodivergent | 30 | 7.69 | 2.03 | 7.29 | **.001** |
| | Normodivergent | 31 | 5.98 | 2.58 | | |
| | Hyperdivergent | 31 | 8.52 | 2.24 | | |
| | Total | 92 | 7.39 | 2.85 | | |
| R7D | Hypodivergent | 31 | 11.17 | 3.50 | .111 | .895 |
| | Normodivergent | 31 | 10.89 | 2.23 | | |
| | Hyperdivergent | 31 | 10.85 | 2.88 | | |
| | Total | 93 | 10.97 | 2.89 | | |
| L7M | Hypodivergent | 31 | 10.22 | 3.12 | .42 | .662 |
| | Normodivergent | 31 | 10.04 | 1.66 | | |
| | Hyperdivergent | 31 | 9.63 | 2.83 | | |
| | Total | 93 | 9.96 | 2.56 | | |
| R6D | Hypodivergent | 31 | 8.80 | 2.94 | 1.46 | .237 |
| | Normodivergent | 31 | 8.27 | 2.17 | | |
| | Hyperdivergent | 31 | 9.32 | 2.04 | | |
| | Total | 93 | 8.79 | 2.43 | | |
| L6M | Hypodivergent | 31 | 7.04 | 3.37 | .44 | .645 |
| | Normodivergent | 31 | 6.15 | 3.11 | | |
| | Hyperdivergent | 31 | 6.50 | 4.63 | | |
| | Total | 93 | 6.57 | 3.74 | | |

## Discussion

Understanding the anatomical features of the MBS is crucial for the application of buccal shelf skeletal anchorage in clinical practice.

The anatomical insertion of certain places appears to present trustworthy models and reproducible; yet, local anatomy is typically subject to significant individual differences. With the use of technology, information on the anatomical conditions of bones can be obtained[16].

Nucera et al.'s[17] focused exclusively on the analysis of hard tissues using CBCT for the anatomical features of the buccal shelf area on the body mandibular. They found that this location was perfect for inserting mini-screws into the distal root of the second molar, 4 mm from the CEJ in the buccal direction.

Gandhi et al.[18] and Liu et al.[19] state that the MBS region is a perfect place to place mini-screws because it has a significant amount of bone thickness in the buccolingual direction that increases in the antero-posterior and corono-apical directions.

As supported by Nucera[17] et al and Chang[20] et al, the insertion of mini-screws in the MBS compared to interradicular insertion allows to obtain TAD with a parallel orientation to that of the long axes of molar roots reducing the risk of impact with the same roots or secondary complications in the active phase of treatment during antero-posterior dental movements.

These findings are consistent with the descriptive analysis of the bone tissue research parameters, which does not consider the sample's separation into three groups based on divergence. Based on a preliminary assessment, a minimum buccal elongation threshold value of 5 mm bucco-lingual thickness was considered for the safe insertion of the mini screw (root safety distance 1.7 mm, screw diameter 1.6 mm, buccal cortical bone safety distance 1.7 mm).

Gadhi[18] divided the sample according to the divergence into three groups, obtaining favorable results for the group of hypodiverging subjects. These results are also confirmed by Aleluia[21] and Arango[22] , who show the presence of a greater bone thickness in the MBS of hypodivergent subjects.

Analysis of data supported by literature shows an increase thickness in the antero-posterior direction and an increase in total bone depth in corono-apical direction. This study suggests that the sites with adequate bone depth are the mesial and distal roots of the second molar. Thickness is a key parameter in clinical practice for TAD insertion site selection. From the analysis of measurements, the correlation between the divergence and thickness of the MBS bone was not significant among the three groups. This result can be explained by the heterogeneity of the sample examined. Genetic variability influences morphology and facial divergence which may vary between ethnic groups due to the presence of genetic markers for sagittal and/or vertical alterations[23]. Storniolo-Souza[24] compared the parameters of the McNamara cephalometric analysis between Brazilian, Japanese and Japanese-Brazilian groups stating that different ethnic groups have different cephalometric models. Thus, individual characteristics should be respected to support diagnosis and to aid the treatment plan for different ethnic groups and their different miscegenation habits.

However, cortical thickness measured at 4 mm and 6 mm in sites 7D. 7M and 6D shows beneficial measures for orthodontic treatment with mini-screws in the MBS for hypodiverging subjects. This result identifies hypodiverging subjects as ideal patients for this orthodontic treatment due to the increase in bone thickness and primary stability. which allow immediate loading of TAD.

Therefore, to obtain suitable parameters for the positioning of mini-screws in the MBS is essential to make a preoperative CBCT for study bone availability and ideal location[25-27].

The analysis of the I.A.N. course confirms what is stated in the literature. Eto's studies[28] show that the height of the bone between the bone crest and the roof of the I.A.N. increases progressively in distal direction. This anatomical feature does not affect the positioning of the mini-screws, as the I.A.N. topographically leads in the medial direction inside the mandibular canal, minimizing the negative impact secondary to the reduction in height.

The analysis of bone height reveals significant information in the group of hyperdivergent that have values on average higher than those of normodivergers and hypodivergents. In the study of lingual thickness, the influence of divergence is statistically significant. favoring the group of hypodiverging people compared to other groups. These results are consistent with those obtained by Gandhi[17] and Oliveira[26] CBCT study that showing how the I.A.N. occurs closer to the root apices in patients with low and normodivergence than in hyperdiverging patients. However, the study remains incomplete in that it considers only the position of the nerve without any measurement of thickness.

The measurement of the distance between the top of the simulation mini-screw and the roof of the I.A.N. is similarly supported by literature[28-29].

The absence of soft tissue examination is a major limitation of this study. Therefore, it is recommended that this variable be studied in the future, contingent on the necessity for suitable therapy. The STL models on which the study was carried out are in fact digital models obtained only from CBCT and are therefore not indicative of the thickness of soft tissues that can influence the choice of the mini-screw. MBS provides an optimal surface for the insertion of mini-screws in terms of bone characteristics and in relation to the course of the I.A.N. The results obtained suggest that this form of skeletal anchorage can be the key to solving clinical problems, such as skeletal classes III and the molar line. The insertion of mini-screws into the MBS not only facilitates clinical activity, but reduces treatment time by increasing patient compliance during orthodontic treatment.

## Conclusion

Potential MBS insertion sites should be evaluated for each individual patient given the potential anatomical variations. The study confirmed that MBS has adequate bone quantity and quality for insertion of mini-screws


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with preference for the vestibular region of the distal root of the second molar, regardless of divergence.
The thickness and height of the bone gradually increase in the anteroposterior direction. The depth and thickness of the bone progressively increases from the first to the second mandibular molar.
The bone thickness and height considered in relation to I.A.N. increase and decrease respectively in the same direction in all age groups, in the three different groups of vertical facial patterns and in both sexes.
The bone characteristics of MBS do not have significant features between the right and left arcus.

## Author Contributions

H.M.: Conceptualization. Writing – Review; DS.A.A: Methodology. Writing – Review ; C.G.: Data curation. Writing – Preparation of the original draft; G.G.: Validation. supervision.

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## Conflicts of Interest

The authors declare no conflict of interest.

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