Anatomical Assessment of Mandibular Buccal Shelf for Miniscrew Insertion: A Comparison of Sex and Facial Type

Melvin D. Pederson, DDS

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A Comparison of Sex and Facial Type

Master of Science in Orthodontics Research Committee

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Jeffrey Nickel, DMD, MSc, PhD
Professor Provisional, Graduate Program Director
Department of Orthodontics

____
Joseph Safirstein, DDS
Associate Professor
Department of Orthodontics

____
Saulo Sousa Melo, DDS, MS, PhD
Associate Professor of Oral and Maxillofacial
Radiology, Director of Oral Radiology

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Abstract

Objective: The methods used for insertion of miniscrews to aid in orthodontic mechanics depends on cortical bone morphology. The aim of this study was to test whether sex and/or facial type (dolichofacial, mesofacial, and brachyfacial) affected mandibular buccal shelf morphology with respect to cortical bone width and thickness.

Materials and Methods: This retrospective study analyzed the cone beam computed tomographic (CBCT) images of 70 individuals (37 males, 33 females). The analysis focused on i) mandibular buccal shelf width at 4mm and 8mm from the CEJ, and ii) cortical bone thickness parallel to the long axis of the distal root of the first molar and the mesial and distal root of the second molar. Frankfort-Mandibular Plane Angle was used to assign females and males to brachyfacial (MPA $<18.8°$), mesofacial (MPA $18.8°$-$25.1°$), and dolichofacial (MPA $>25.1°$) groups. Independent variables were i) sex (F,M), ii) facial type (D,M,B), iii) location (6D,7M,7D), and iv) distance from the CEJ (4 mm, 8 mm). Analysis of variance was used to test for independent variable effects the two dependent variables of i) buccal shelf width, and ii) cortical bone thickness.

Results: Neither sex or facial type was significant with respect to mandibular buccal shelf morphology. For women and men of all facial types and locations, bone width increased with distance from CEJ (all $p<0.05$). Similarly, both women and men of all facial types showed significantly increased bone width with progression distally from the first to the second molar (all $p<0.05$). All bone thickness measurements exceeded 2 mm.

Conclusions: The variables of sex and facial phenotype did not have a significant effect on the dependent variables of buccal shelf bone width or thickness. Given that all thickness measurements exceeded 2 mm, a pilot hole is a requirement for miniscrew insertion into the mandibular buccal shelf.

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Introduction

Obtaining and controlling anchorage in orthodontic treatment is a principle concern for orthodontists. Although anchorage has been defined in several ways, a commonly accepted definition is "resistance to unwanted tooth movement" [1,2]. The most basic form of orthodontic anchorage is the pitting of the dental units that are desired to move against dental anchorage units of greater total root surface area, this may be further aided via the use of ankylosed teeth as points of anchorage when they are present. Adjunctive techniques have been introduced that offer a means of gaining greater anchorage than is available through differential root surface area by displacing the force of orthodontic tooth movement onto the skeleton through the application of headgear and/or tooth-borne appliances such as transpalatal arches, the lingual holding arch, and the Nance button. Though these innovations offer improvements to orthodontic anchorage, they are not able to provide absolute anchorage. Absolute anchorage is defined as the lack of movement of the anchorage unit teeth as a consequence of the reaction forces applied to move teeth[3] . Absolute or near-absolute anchorage may be obtained by utilizing ankylosed teeth, osseointegrative implants, bone plates, or miniscrews as anchorage units. Having the advantages of a less invasive technique of placement and removal, lower cost, while providing the same rigid anchorage[4]; miniscrews have become a powerful adjunctive tool of obtaining anchorage in the modern orthodontic practice.

Miniscrews are typically made from titanium alloys, are biocompatible, and non-osseointegrative[3]. There is some ambiguity as to what their exact dimensions are within the literature, but in general their diameters have been described as being between 1.2mm and

2.3mm, and their lengths as being between 4mm and 20mm [3]. They can be manufactured with a wide variety of head and thread designs and with self-tapping and self-drilling features. Some of the possible sites of placement of miniscrews include the alveolar processes, the paramedian portion of the hard palate, the retromolar pad, and the mandibular buccal shelf[5]. They may be utilized as direct anchorage when they directly receive the reactive forces of tooth movement or as indirect anchorage when they are tied to the anchor teeth via bars or wires[3].

The method in which a miniscrew is placed has considerable influence in the success or failure of the miniscrew. Miniscrews may be placed by first elevating a flap prior to insertion, or through a flapless procedure where they are inserted through the gingiva. Studies have shown that the flapless procedure results in less pain and swelling while providing comparable levels of success therefore resulting in greater patient acceptance[4,6]. Miniscrews may be placed with (self-tapping) or without the drilling of a pilot hole (self-drilling) prior to insertion[7]. Typically, if the miniscrew is self-drilling a pilot hole is unnecessary, but with cortical bone thicknesses greater than 2mm a pilot hole may be required to avoid over-torqueing[7]. Insertion torques between 5 N-cm and 10 N-cm have been shown to provide improved success rates when compared to miniscrews with insertion torques outside of that range[8]. A study by Motoyoshi et al, reported findings where miniscrews placed with less than 5 N-cm of torque had a 72.7% success rate, those placed with more than 10 N-cm had a 60.9% success rate, while those placed within the range of 5-10 N-cm had a success rate of 96.2%. It is believed that miniscrews placed with torques below the 5 N-cm may lack the mechanical retention necessary to remain stable under load, while miniscrews placed with torques above 10 N-cm will have adequate initial stability but then may lose stability due to osteonecrosis secondary to ischemia related to the increased outward pressure imparted on the bone by the miniscrew[8,9]. A study from 2006 reported that the only sites where miniscrews could be inserted with insertion torques within the 5-10 N-cm range were sites where the cortical bone thickness was between 0.5mm and 1mm, they then discussed that when an insertion site with dense and thick cortical bone is selected insertion torque can be controlled by creating a pilot hole[10]. It is recommended that a pilot hole is made 0.3mm smaller in diameter than the diameter of the miniscrew and no greater than 2-3mm in depth to prevent insufficient torque[3], other sources recommend that the diameter of the pilot hole be 85% of the diameter of the miniscrew[11]. If the miniscrew is not the self-drilling type, it is recommended that the pilot hole be made to the full depth of insertion[10].

Insertion site selection dictates several of the clinical factors which impact the likelihood of inflammation around the site of the miniscrew. The likelihood of failure with miniscrew insertion is closely associated to the presence of inflammation at and around the miniscrew, therefore clinical factors contributing to inflammation can be said to contribute to miniscrew failure. For example, miniscrews placed in mobile mucosa are associated with increased levels of inflammation and a 30% increase in the rate of failure[11] when compared to miniscrews placed in attached gingiva. When compared to miniscrews placed in attached gingiva which have been shown to have an approximately 90% success rate[12], those placed in mobile mucosa have a lower rate of success. Further contributing to inflammation, the site selected can influence the ability of the patient to keep the miniscrew clean, poor oral hygiene at the site is associated with increased levels of inflammation and reduced success rates. Studies have even shown higher failure rates on the right side of the jaw in some patients[13,14], this finding correlates to the individual patients' dominant right hand being less effective at cleansing the implant site on the patients' right side. Depending on the site selected, it is possible for masticatory forces to be applied to the miniscrew. The application of masticatory force to the miniscrew can result in minor trauma creating micro-fracturing of the cortical bone surrounding the insertion site resulting in inflammation all the way to gross trauma of the bone and miniscrew itself[6].

Cone beam computed tomography as an addition to orthodontic diagnosis has provided the orthodontist with a powerful tool in the treatment planning of complicated cases and those which would utilize miniscrews. CBCT allows the provider to select an insertion site that will provide adequate cortical bone thickness and density while avoiding anatomical structures, with the added benefit of allowing visualization and planning of the projected path of insertion in three-dimensional space[15]. Prior knowledge of the characteristics of bone thickness and density allows the provider to select their insertion protocol for the highest chance of success. Visualization of tooth root position within the bone via CBCT imaging, prior to miniscrew insertion, is valuable in avoiding the intraoperative complication of root contact. In a study by Min et al., from 2012 they found that of 172 studied miniscrew insertions, proximity to roots had the highest correlation with failure, and if the miniscrew contacted a root the chance of failure was 68.8% [16]. Using CBCT, Vargas et al showed that patients with shorter facial types tended to have thicker bone in the mandibular buccal shelf than their counterparts with longer facial types, also concluding that the best site for mandibular buccal shelf miniscrew insertion was buccal to the distobuccal cusp of the second molar[17]. From CBCT data, not only can the appropriate insertion site be selected, but the insertion path can also be determined, and a template can be constructed to aid the insertion process if desired.

To date, studies that have investigated the mandibular buccal shelf as a site for miniscrew insertion have focused primarily on race/ethnicity as a factor in bone quantity and quality. Though that data is valuable in describing the mandibular buccal shelf in those racial or ethnic groups, many orthodontic providers practice in regions where patient demographics are less homogenous than the populations represented in the available literature, their practices consisting patients of many different racial and ethnic backgrounds. Factors such as sex and facial type, across racial and ethnic groups, may be relevant with respect to quantity and quality of mandibular buccal shelf bone that is available for placement of temporary anchorage devices. This project tested the working hypothesis that both sex and facial type (dolichofacial, mesofacial, and brachyfacial) affect both the quantity and the quality of the cortical bone of the mandibular buccal shelf. The outcomes of this project may have clinical implication for the use of miniscrews within the mandibular buccal shelf.

Materials and Methods

Description of sample

The study is retrospective, utilizing de-identified case records of individuals who participated in an earlier study. According to institutional review board oversight, all individuals consented to allow their records to be utilized for research. Patients were of 18 years or older and had cone beam computed tomography (CBCT) imaging of the maxilla and mandible. Exclusion criteria from participation included evidence of craniofacial deformity or previous mandibular osteotomies. Data collection was comprised of CBCT image files, age at time of imaging, and sex. All CBCT files were de-identified and assigned a case number. Using Dolphin imaging software, the de-identified files were processed to produce a software generated lateral cephalogram from which a cephalometric analysis was performed. The analysis included the Mandibular Plane to Frankfort Horizontal angle (MPA) to determine facial types of brachyfacial, mesofacial, and dolichofacial. All cephalometric images were traced by the same individual. Subjects were divided into three groups based on MPA. The brachyfacial group had MPA of <18.8°. Mesofacial subjects had MPA which ranged from 18.8° to 25.1°. The Dolichofacial group had MPA >25.1°.

Landmarks and measurements

The cephalometric landmarks of importance to this study are porion, orbitale, gonion, and menton. The intersection of the lines formed by the two sets of points porion and orbitale (FH), and gonion and menton (MP) form the mandibular plane to Frankfort horizontal angle (°)(MP-FH).

The measurements of importance to this study include cortical bone thickness and buccal shelf bone width. These measurements were assessed at 3 sites on each side of the mandible: (i) buccal to the distobuccal cusp of the mandibular first molar, (ii) buccal to the mesiobuccal, and (iii) distobuccal cusps of the mandibular second molar. Cortical thickness of buccal shelf bone was defined as the dimension of the cortical bone measured from the midpoint of the osseous ledge buccal to the mandibular first and second molars, parallel to the contour of the buccal root surfaces of the first or second molar. Buccal shelf bone width was defined as the total amount of bone available in the buccolingual direction from the most buccal point of the alveolar bone to the root of the mandibular molars at 4 and 8mm from the CEJ, parallel to the occlusal plane. Intra-rater reliability of the bone width and cortical bone thickness measurements was performed by orienting and measuring a randomly selected file ten times by the primary investigator.

The de-identified CBCT images were uploaded into the Invivo6 imaging software by Anatomage (™Anatomage U.S., Santa Clara, CA) and oriented prior to measurement. Orientation of the CBCT file images for measurement was performed by following a protocol described by Vargas, et al which allows for reliable and repeatable assessment of the mandibular buccal shelf at the three sites of measurement described earlier[17]. First, the sagittal plane established by passing a line through the furcations of the mandibular molars on the right side (**Figure 1**). Then, the coronal plane was established by passing a line through the length of the distal root of the first molar when visualized in a sagittal section (**Figure 2**). This process was repeated for the measurements taken at the mesial and distal roots of the second molar. Next, the axial plane was established by passing a line through the length of the distal root of the first molar when visualized in a coronal section (Figure 3). This process was repeated for each measurement site. From these oriented files, the measurements of cortical bone thickness and buccal shelf width were taken at the distobuccal cusp of the first molar, and the mesiobuccal cusp and the distobuccal cusp of the second molar. Buccal shelf bone with was measured to the nearest tenth of a millimeter at the most buccal point of the alveolar bone to the root, at both 4mm and 8mm from CEJ, parallel to the occlusal plane. Cortical bone thickness measurements were made to the nearest tenth of a millimeter from the midpoint of the osseus ledge, buccal to the first and second molar , parallel to the contours of the buccal of the root surface.

From the three-dimensional image file, a derived lateral cephalogram was created using the Dolphin imaging software (Dolphin, Registered TM) which was processed to provide the measurement of the MP-FH angle previously mentioned.

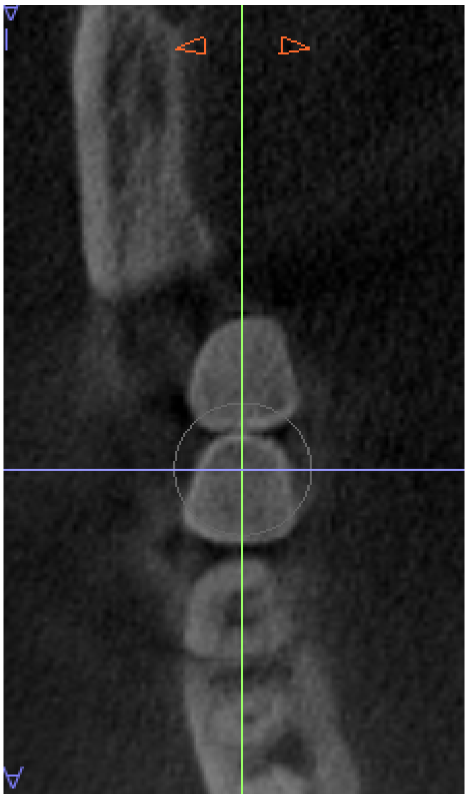

Figure 1 Axial View of mandibular buccal shelf.

Axial view of the right side of the mandible, with guidelines to orient the sagittal plane through the furcations of the first and second molars and to orient the coronal plane through the long axis of the distal root of the first molar.

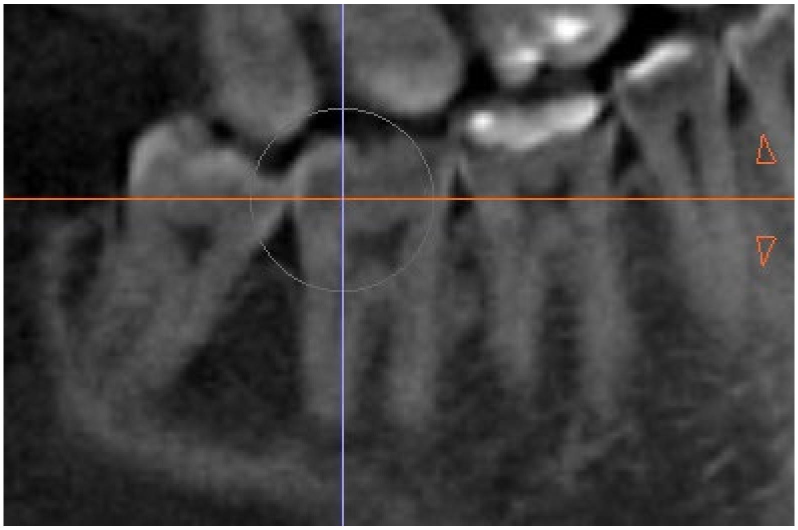

Figure 2 Sagittal View of mandible.

Sagittal view of the right side of the mandible, with guidelines to orient the coronal plane on the long axis of the distal root of the first molar.

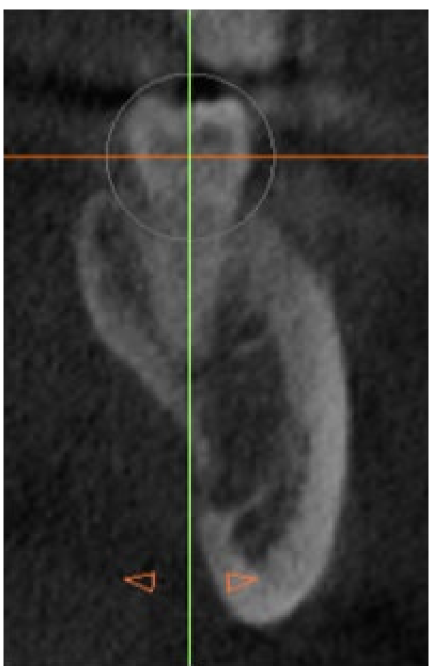

Figure 3 Coronal View of mandibular buccal shelf.

Coronal view of the left side of the mandible, with guide lines orienting the sagittal plane

through the long axis of the
distal root of the first molar.

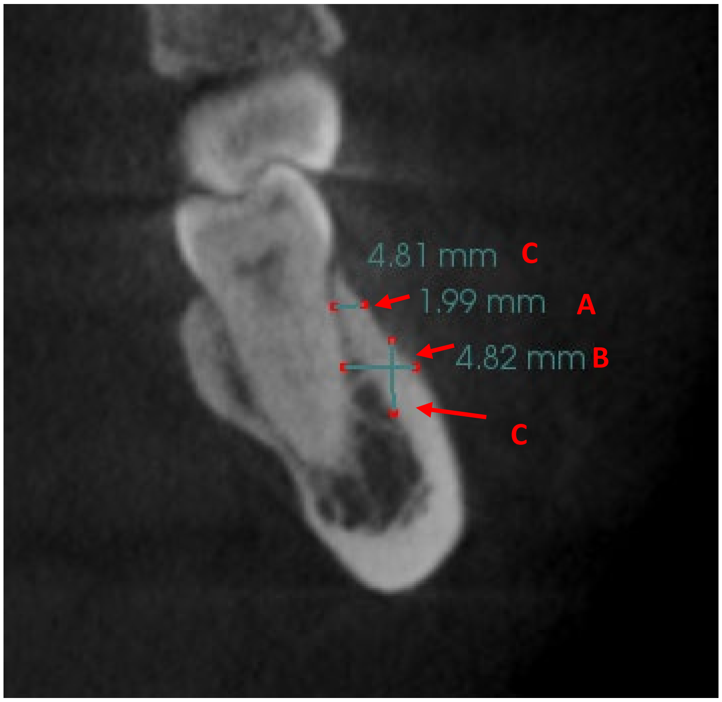

Figure 4 Mandibular buccal shelf measurement protocol example.

Coronal view of the left side of the mandible, with measurements of buccal shelf bone width at 4mm (A) and 8mm from CEJ and cortical bone thickness measured in parallel to the root long axis (C).

Study Design and Statistical Analysis

Descriptive statistics of means and standard deviations of the cortical bone thickness and buccal shelf width at each of the sites of measurements were calculated for each of the three facial types as well for the two sexes. An analysis of variance test was performed to compare within group for sex differences and between groups for phenotype effects for the same sex. Cases were divided into three groups, dolichofacial (#males, #females), mesofacial (#males, #females), and brachyfacial (#males, #females). Each group was also subdivided into three subgroupings based on the location of measurement, distobuccal cusp of the first molar, mesiobuccal cusp of the second molar, and distobuccal cusp of the second molar. For analysis of the buccal shelf width, each subgrouping was then further divided into two further subgroups, 4mm and 8mm from the cementoenamel junction. Analysis of variance was used to test for independent variable effects on two dependent variables of (i) buccal shelf width, and (ii) cortical bone thickness. The independent variables were sex (Female, Male), facial type (Brachyfacial, Mesofacial, Dolichofacial), location (6D, 7M, 7D), and distance from the CEJ (4mm, 8mm). Significant differences were defined as having a p-value <0.05 and a β value of $\geq$ 0.08.

Table 1. Study Design

Study design required 10 subjects for each grouping of sex and facial type for a total of 60 subjects, allowing for 10 data entries for each sub-grouping of sex, facial type, and distance from CEJ.

Diagnostic Group	Sex/CEJ distance	Site #1	Site #2	Site #3
Dolichofacial	Female 4 mm	N=10	N=10	N=10
	Female 8 mm	N=10	N=10	N=10
	Male 4 mm	N=10	N=10	N=10
	Male 8 mm	N=10	N=10	N=10
Mesofacial	Female 4 mm	N=10	N=10	N=10
	Female 8 mm	N=10	N=10	N=10
	Male 4 mm	N=10	N=10	N=10
	Male 8 mm	N=10	N=10	N=10
Brachyfacial	Female 4 mm	N=10	N=10	N=10
	Female 8 mm	N=10	N=10	N=10

	Male 4 mm	N=10	N=10	N=10
	Male 8 mm	N=10	N=10	N=10

Results

1.0 Description of sample

Of the 89 CBCT image files available in the JGB study group, a total of 70 image files representing 37 males and 33 females, met the inclusion criteria. Reasons for exclusion were related to limited field of view of the image file or first or second molars were excluded from the images. Included image files were divided into three diagnostic facial type groups, brachyfacial (14 males, 5 females), mesofacial (11 males, 12 females), and dolichofacial (12 males, 16 females). Mean Frankfort mandibular plane angle of brachyfacial individuals as a group was 14.8° ± 2.4°, males had a mean FMA of 14.5° ± 2.7°, and females had a mean FMA of 15.7° ± 0.9°. Mean FMA of mesofacial individuals as a group was 21.8° ± 1.9°, males had a mean FMA of 22° ± 1.9°, and females had a mean FMA of 21.6° ± 1.8°. Mean FMA of dolichofacial individuals as a group was 29.5° ± 3.3°, males had a mean FMA of 29.4° ± 3.5°, and females had a mean FMA of 29.6° ± 3°. Estimated standard error of repeated measurements of bone width at 4 and 8 mm from the CEJ were ±0.06 mm, indicating confidence in measurement accuracy to 0.2 mm.

2.0 Location differences in bone width in women

Within diagnostic groups, statistical analysis found site differences in women depending on depth.

There was a general trend at 4 and 8 mm from the CEJ for increasing bone width with progression from 6D to 7D.

At 4 mm from the CEJ, the thinnest bone amongst all facial groups was located at 6D, where widths were consistently under 2 mm. Location differences in bone width were significantly different in mesofacial and dolichofacial women. Mesofacial women had significantly thicker bone width at 7D ($p < 0.05$: 4.9mm ± 2.9mm: Figure 5). Dolichofacial women had significantly different bone width (all $p<0.05$) for all 3 locations. The thinnest bone width was found at 6D (1.4mm ± 0.7mm), followed by 7M (2.9mm ± 1.6mm). The thickest bone was at 7D (4.9mm ± 2.1mm).

Progressing to 8 mm from the CEJ (Figure 6), thinnest bone widths amongst all facial groups was at location 6D, and were consistently less than 4 mm. Location differences in bone width were significantly different for all three facial type groups. Brachyfacial women had significantly different bone widths at sites 6D and 7D. The thinnest bone width was found at 6D ($p < 0.05$: 3.2mm ± 1.1mm). The thickest bone width was found at 7D ($p < 0.05$: 6.7mm ± 1.7mm). Mesofacial women had significantly thinner bone at site 6D ($p < 0.05$: 3mm ± 1.8mm). Dolichofacial women had significantly different bone width (all $p<0.05$) for all 3 locations. Thinnest bone width was found at 6D (2.8mm ± 1.6mm), followed by 7M (4.5mm ± 1.7mm). Again, the thickest bone was at 7D (6.6mm ± 1.3mm).

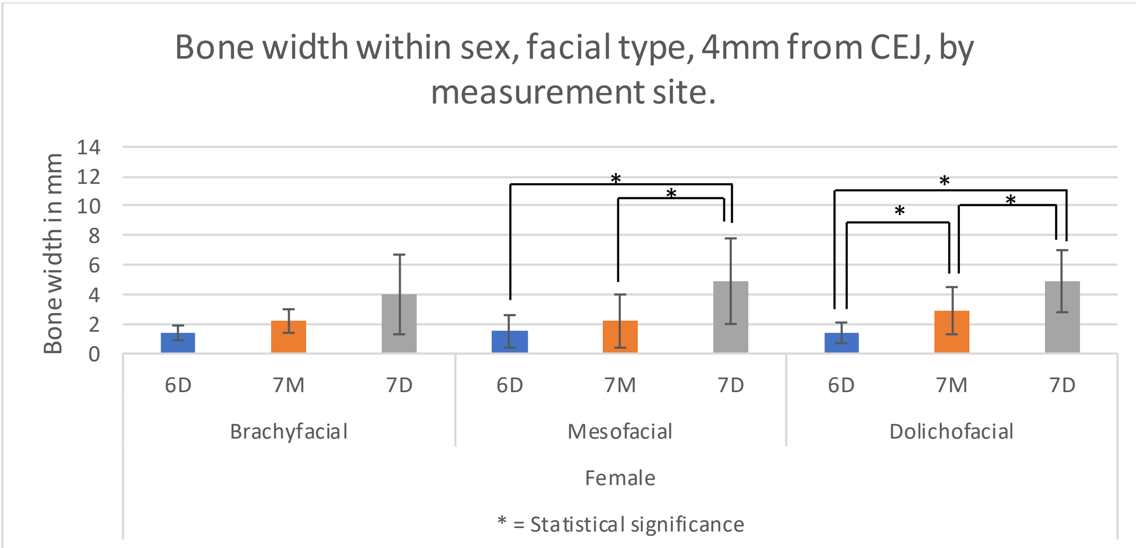

Figure 5 Female bone width at 4mm from CEJ by facial type and measurement site.

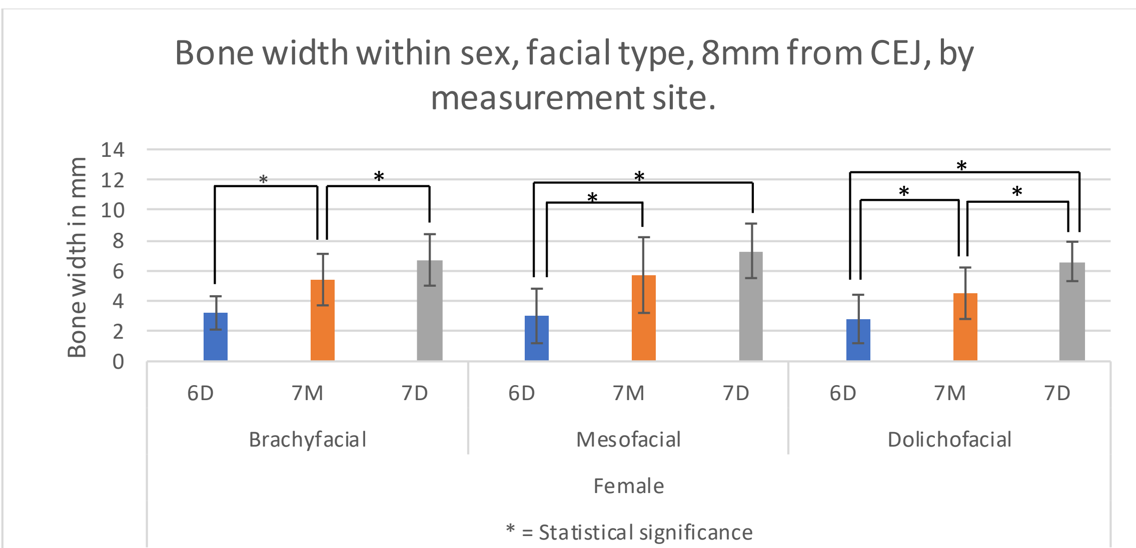

Figure 6 Female bone width at 8mm from CEJ by facial type and measurement site.

3.0 <u>Location differences in bone width in men</u>

Statistical analyses found site differences in bone width depending on depth and tooth site.

As noted in females, again there was a general trend at 4 and 8 mm from the CEJ for increasing bone width with progression from 6D to 7D.

At 4 mm from the CEJ, the thinnest bone amongst all facial groups was located at 6D, where widths were consistently under 2 mm. Location differences in bone width were significantly thicker at site 7D in all three facial types of men ($p< 0.05$ in all). Brachyfacial men had significantly thicker bone width at 7D (4.8mm ± 2.5mm: Figure 7), as did mesofacial men (3.3mm ± 2.1mm: Figure 7), and dolichofacial men (4.8mm ± 2.5mm: Figure 7).

Progressing to 8 mm from the CEJ (Figure 8), thinnest bone widths amongst all facial groups was at location 6D, and were consistently less than 4 mm. Location differences in bone width were significantly different for all three facial type groups. Brachyfacial men had significantly thicker bone at site 7D ($p< 0.05$: 7.5mm ± 4.8mm). Mesofacial men had significantly different bone width in all three sites ($p< 0.05$ in all), with the thinnest bone at site 6D (2mm ± 1.2mm), followed by 7M (4.5mm ± 2mm). Thickest bone was found at site 7D (6.3mm ± 1.9mm). Dolichofacial men had significantly thinner bone at site 6D ($p < 0.05$: 2.8mm ± 1.9mm).

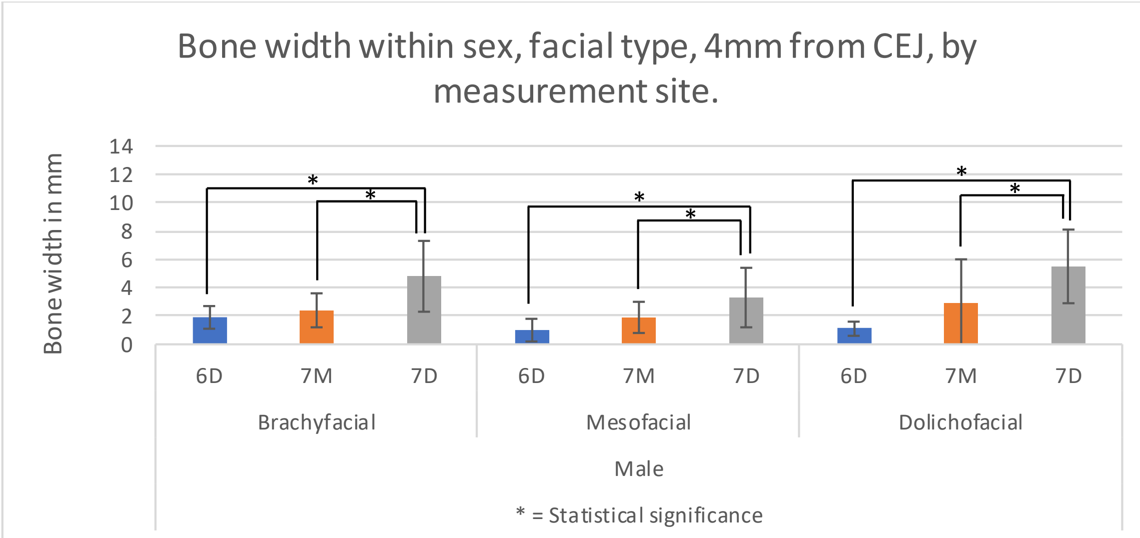

Figure 7 Male bone width at 4mm from CEJ by facial type and measurement site.

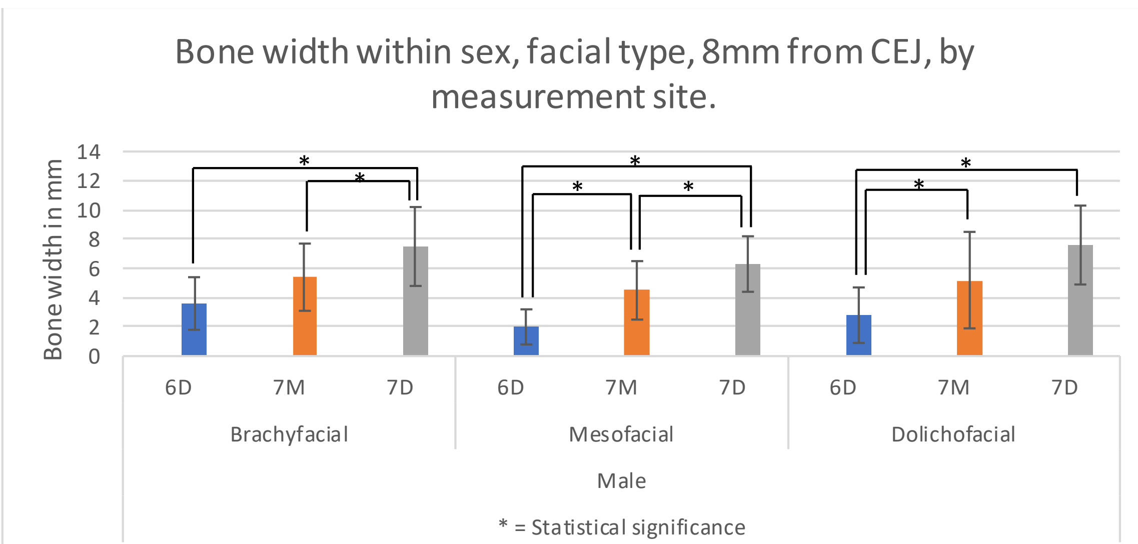

Figure 8 Male bone width at 8mm from CEJ by facial type and measurement site.

4.0 <u>Depth effects on bone width within diagnostic groups of women from the same site</u>

There were significant differences in bone width depending on depth, for the same tooth position.

In females there was a general trend of increasing bone width progressing from site 6D to 7D in all facial groups at both 4mm and 8mm from the CEJ, with correlating widths being greater at 8mm from CEJ than at 4mm from CEJ at all measurement sites and in all facial groups.

In brachyfacial females (Figure 9) statistically thicker bone was seen at 8mm from CEJ at sites 6D ($p<0.05$; @4mm: 1.4mm ± 0.5mm, @8mm: 3.2 ± 1.1) and 7M ($p< 0.05$; @4mm: 2.2mm ± 0.8mm, @8mm: 5.4mm ± 1.7mm). In mesofacial females (Figure 10) statistically thicker bone was seen at 8mm from CEJ at all three sites, at 6D ($p< 0.05$; @4mm: 1.5mm ± 1.1mm, @8mm: 3.0mm ± 1.8mm), at 7M ($p<0.05$; @4mm: 2.2mm ± 1.8mm, @8mm: 5.7mm ± 2.5mm), and at 7D ($p<0.05$; @4mm: 4.9mm ± 2.9mm, @8mm: 7.3mm ± 1.8mm). In dolichofacial females (Figure 11) statistically thicker bone was found at 8mm from CEJ only at site 7D ($p<0.05$; @4mm: 4.9mm ± 2.1mm, @8mm: 6.6mm ± 1.3mm).

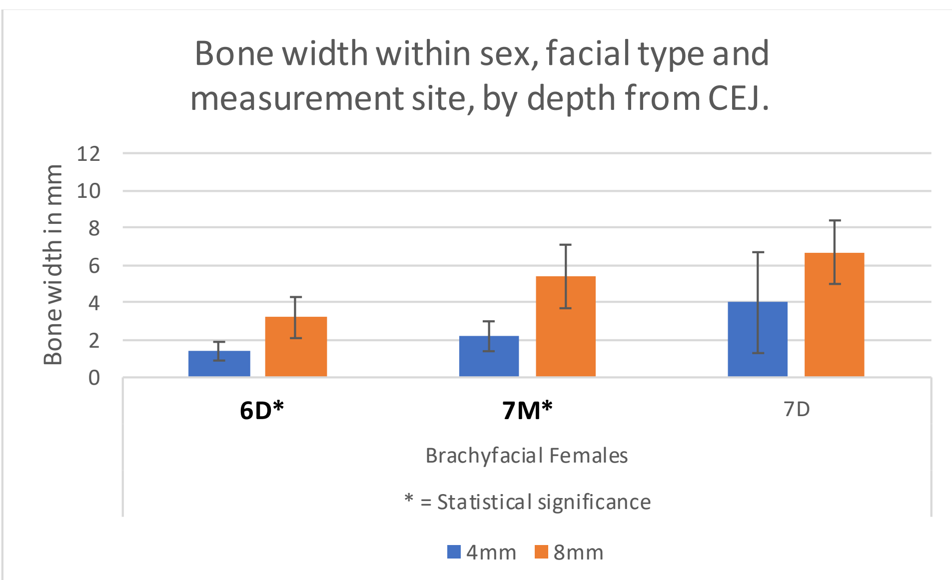

Figure 9 Brachyfacial female bone width within measurement sites, by depth from CEJ.

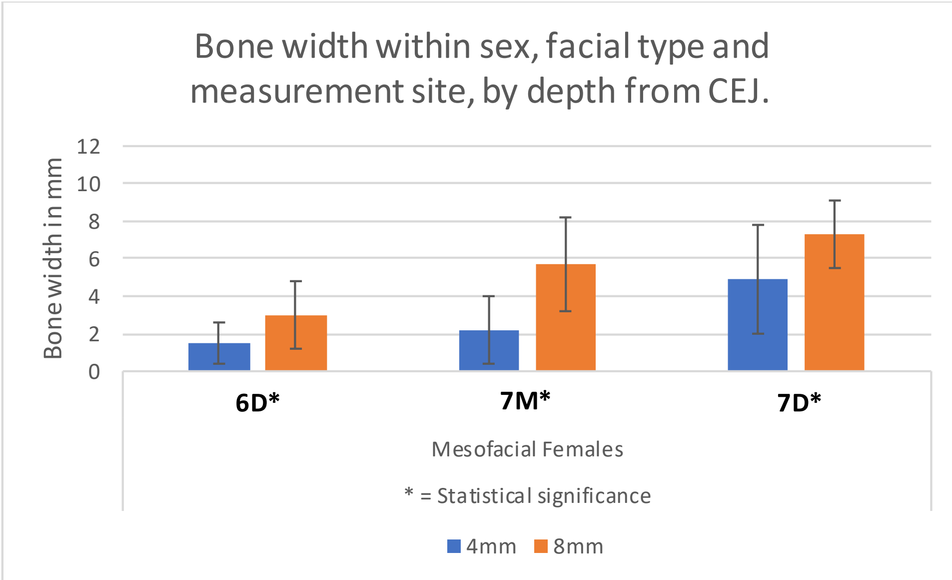

Figure 10 Mesofacial female bone width within measurement sites, by depth from CEJ.

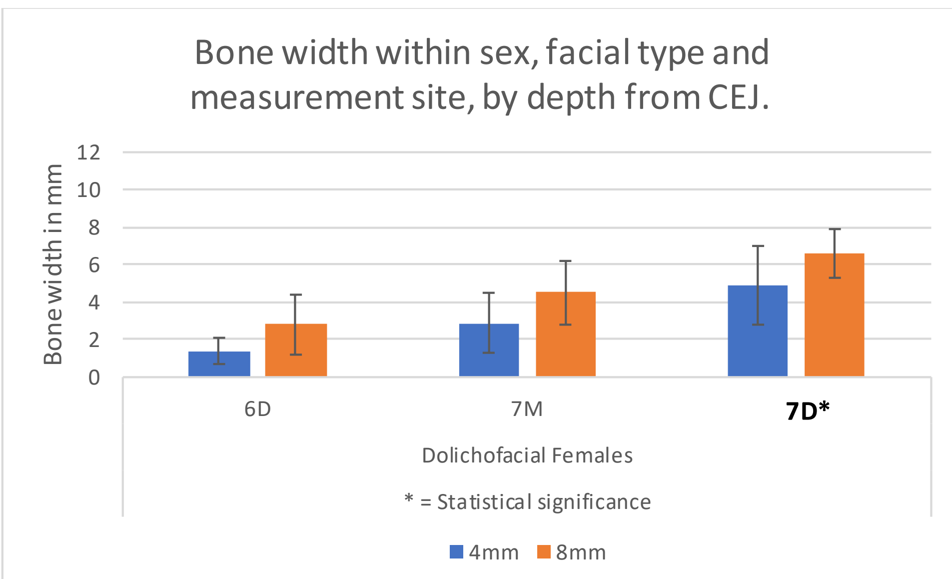

Figure 11 Dolichofacial female bone width within measurement sites, by depth from CEJ.

5.0 <u>Depth effects on bone width within men from the same diagnostic group and site</u>

There were significant differences in bone width depending on depth, for the same tooth position.

In males there was a general trend of increasing bone width progressing from site 6D to 7D in all facial groups at both 4mm and 8mm from the CEJ, with correlating widths being greater at 8mm from CEJ than at 4mm from CEJ at all measurement sites and in all facial groups.

In brachyfacial males (Figure 12), statistically thicker bone width was found at 8mm from CEJ at all three sites, at 6D ($p< 0.05$; @4mm: 1.9mm ± 0.8mm, @8mm: 3.6mm ± 1.8mm), at 7M ($p<0.05$; @4mm: 2.4mm ± 1.2mm, @8mm: 5.4mm ± 2.3mm), and at 7D ($p<0.05$; @4mm: 4.8mm ± 2.5mm, @8mm: 7.5mm ± 2.7mm). In mesofacial males (Figure 13) statistically thicker bone was found at 8mm from CEJ at sites 6D ($p<0.05$; @4mm: 1.0mm ± 0.8mm, @8mm: 2.0mm ± 1.2mm) and 7D ($p<0.05$; @4mm: 3.3mm ± 2.1mm, @8mm: 6.3mm ± 1.9mm). In dolichofacial males (Figure 14), no statistically significant differences were found between bone widths at 4mm or 8mm from CEJ at any site.

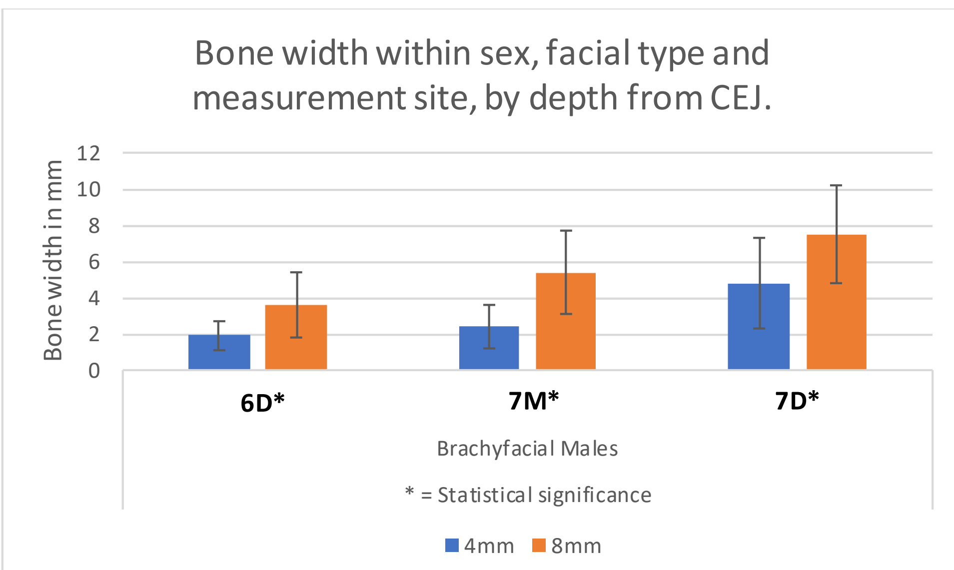

Figure 12 Brachyfacial male bone width within measurement sites, by depth from CEJ.

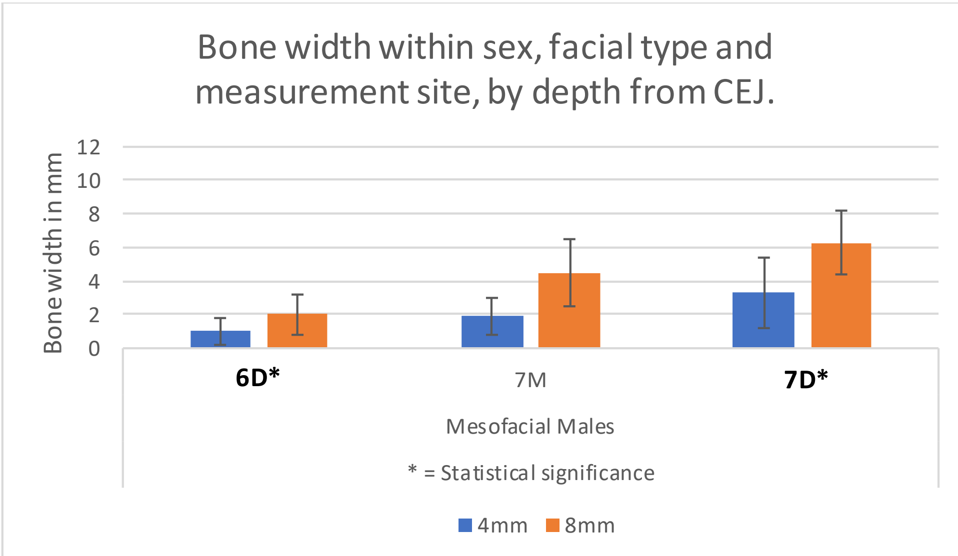

Figure 13 Mesofacial male bone width within measurement sites, by depth from CEJ.

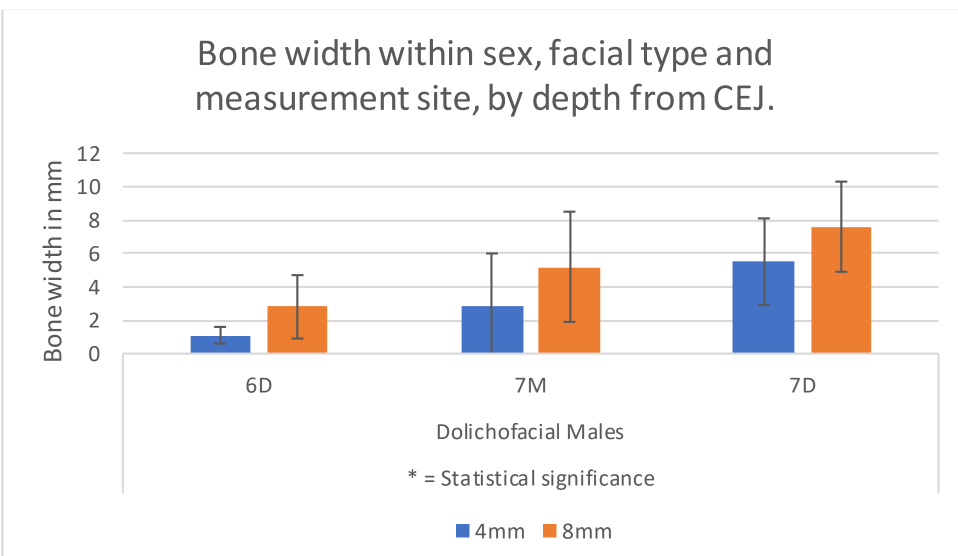

Figure 14 Dolichofacial male bone width within measurement sites, by depth from CEJ.

6.0 <u>Location differences in cortical bone thickness in men and women</u>

Statistical analyses found a single statistically significant site difference in cortical bone thickness depending on facial type and tooth site.

In both males and females, a general trend of progressively decreasing cortical bone thickness from 6D to 7D in all facial types was seen (Figure 15, Figure 16)

When comparing tooth sites within sex and facial type, data showed a general trend of progressively decreasing cortical bone thickness as progressing from sites 6D to 7D. This was common to all facial types for both sexes. Statistical analysis found only site 6D ($p<0.05$: 8.0mm ± 2.1mm) of brachyfacial males (Figure 16) which was statistically different from other tooth sites (7M: 6.2mm ± 2.1mm, and 7D: 5.8mm ± 2.0mm).

In terms of cortical bone thickness, comparisons of tooth sites by facial type, no discernable pattern could be described nor did any facial type exhibit a statistically significant difference from its counterparts within measurement site and sex, for neither males nor females (Figure 17, Figure 18).

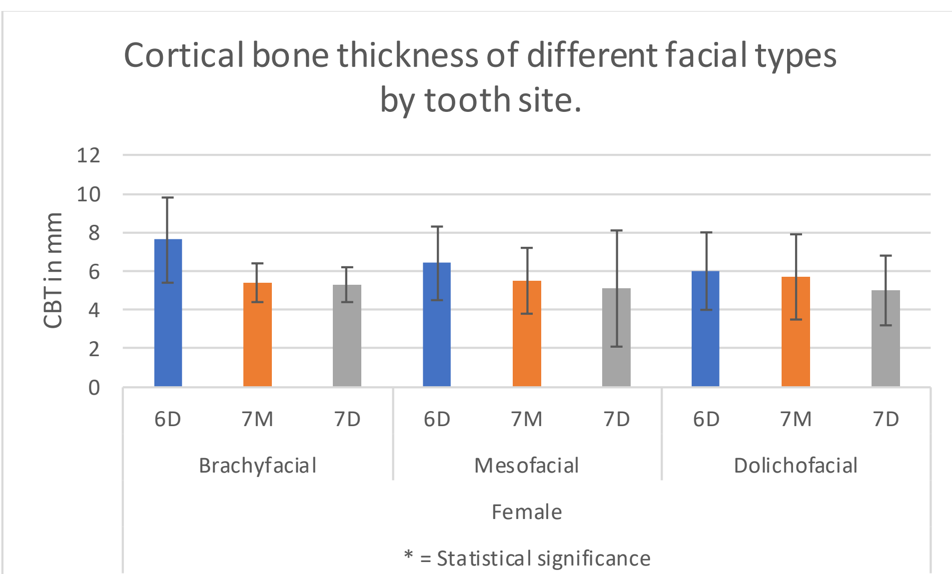

Figure 15 Female cortical bone thickness within facial types by measurement site.

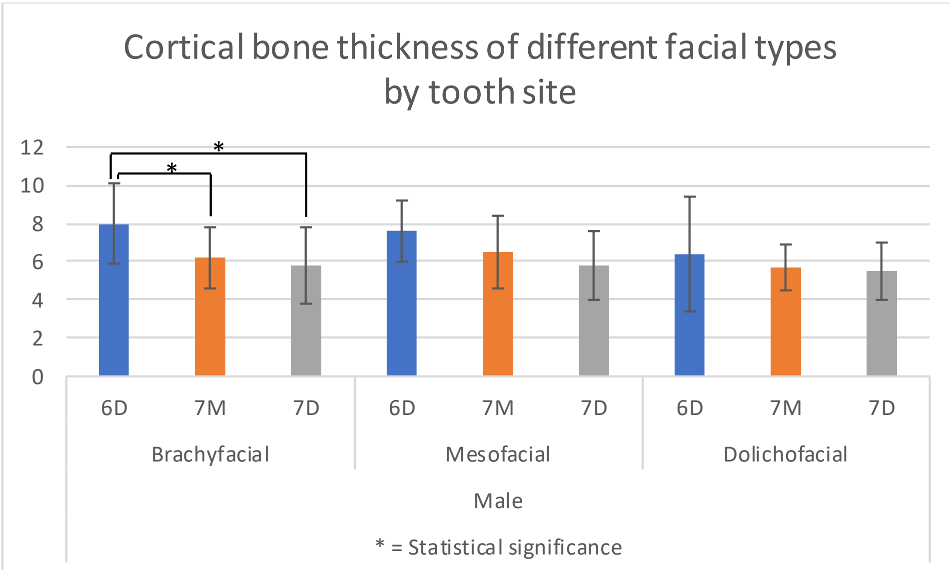

Figure 16 Male cortical bone thickness within facial types by measurement site.

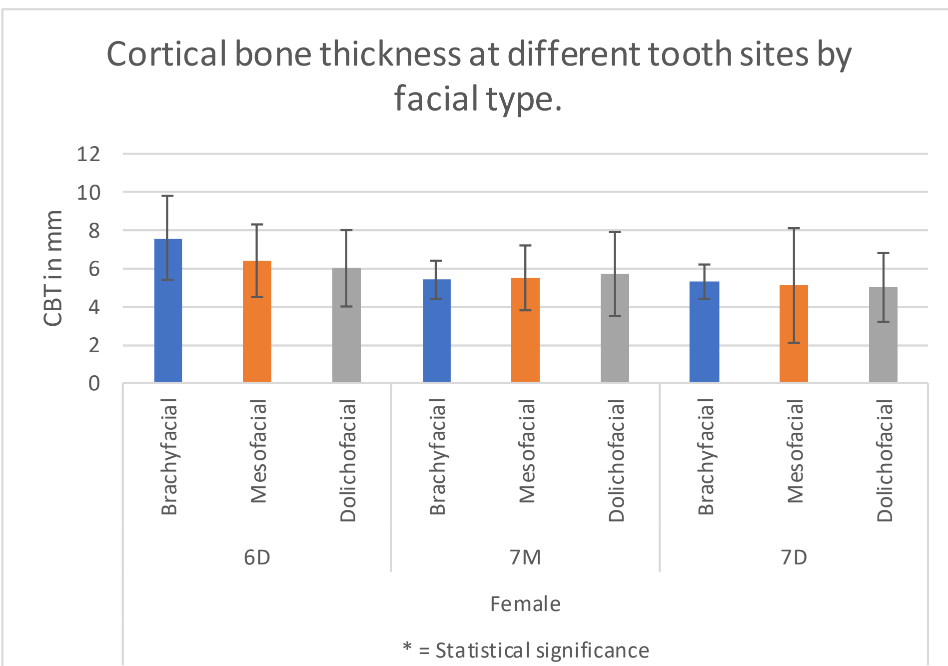

Figure 17 Female cortical bone thickness within measurement site by facial type.

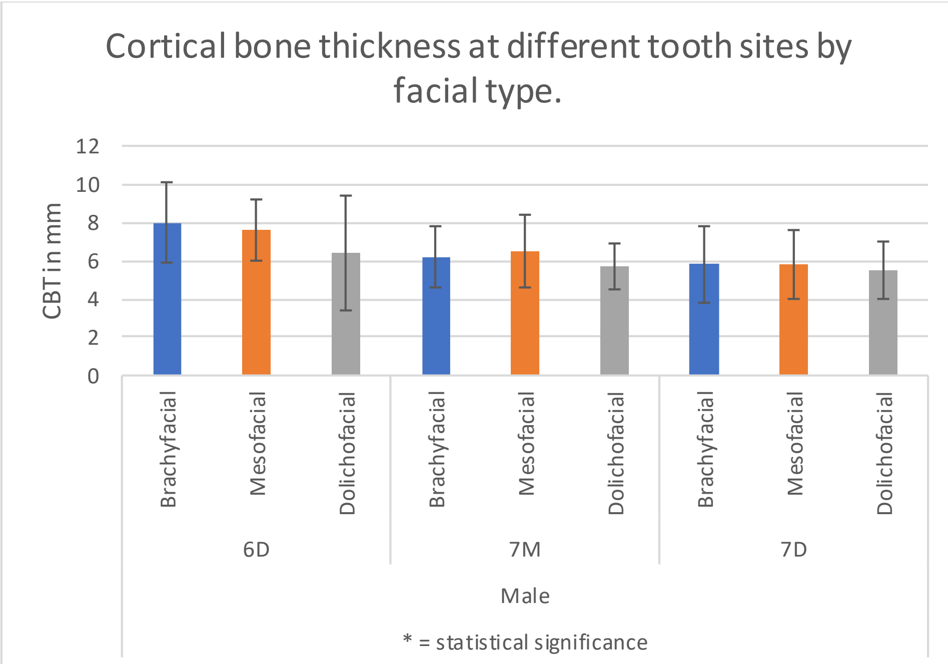

Figure 18 Male cortical bone thickness within measurement site by facial type.

7.0 <u>Sex effects on bone thickness within facial types and location.</u>

A general trend of decreasing bone thickness with progression from 6D to 7D was noted among both males and females. At each site, males had thicker bone than females. At each site, brachyfacial subjects had the greatest measured thickness, followed by mesofacial, while dolichofacial subjects had the least measured thickness (Figure 19, Figure 20, Figure 21). The thickest bone for each sex was found at site 6D for all three facial types, while the thinnest was found at site 7D. No statistically significant differences were noted between the sexes when looking at bone thickness by facial type and measurement site.

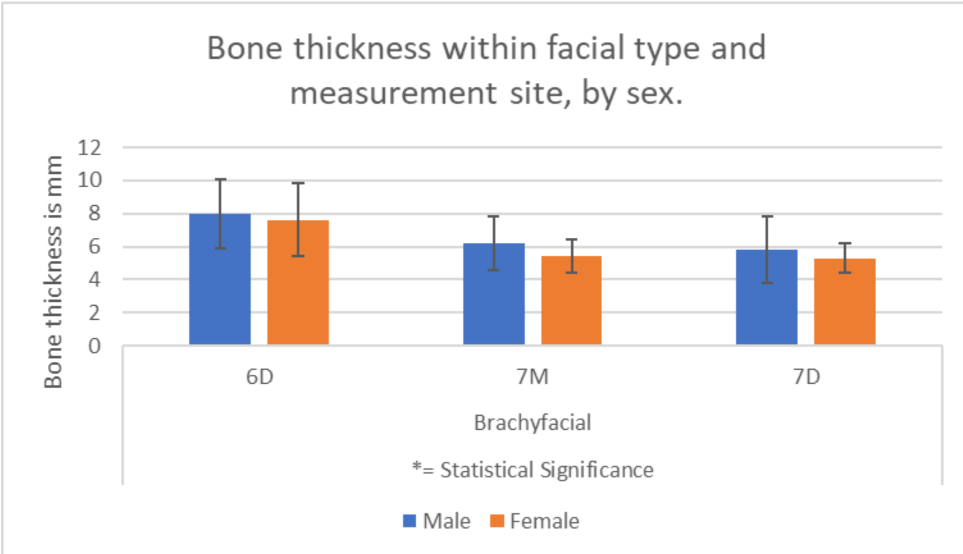

Figure 19 Brachyfacial bone thickness by sex.

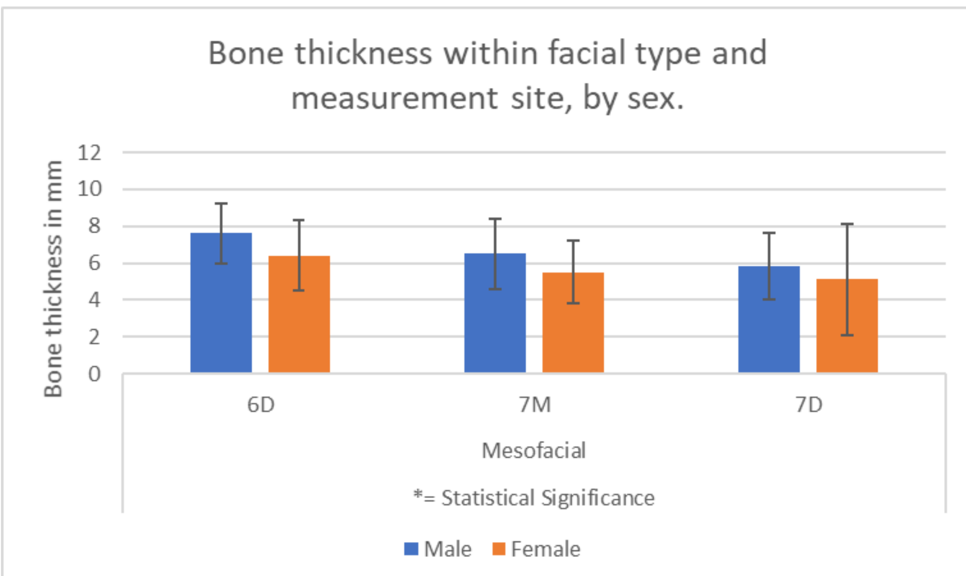

Figure 20 Mesofacial bone thickness by sex.

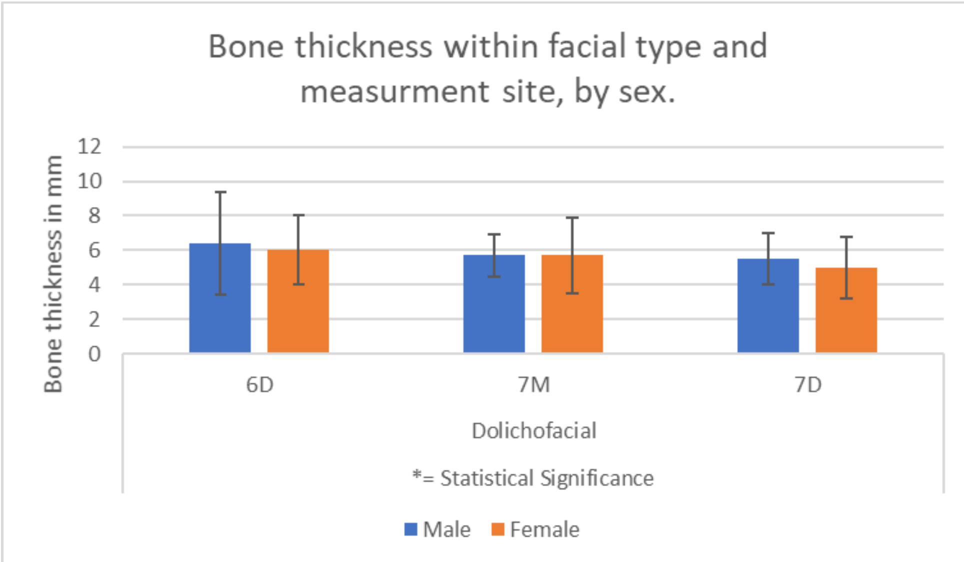

Figure 21 Dolichofacial bone thickness by sex.

8.0 Sex effects on bone width within facial types, depth from CEJ, and location.

A general trend of increasing bone width with progression from 6D to 7D was noted among both males and females at both depths of 4mm and 8mm from CEJ. Bone width was typically greater at 8mm from CEJ than at 4mm from CEJ for both males and females at all locations (Figures 22-27). For each facial type, the greatest bone width was found at site 7D and the least bone width was found at site 6D, with the measurements at 8mm from CEJ being greater than those at 4mm from CEJ. No statistically significant differences were noted between the sexes when looking at bone width by facial type and measurement site.

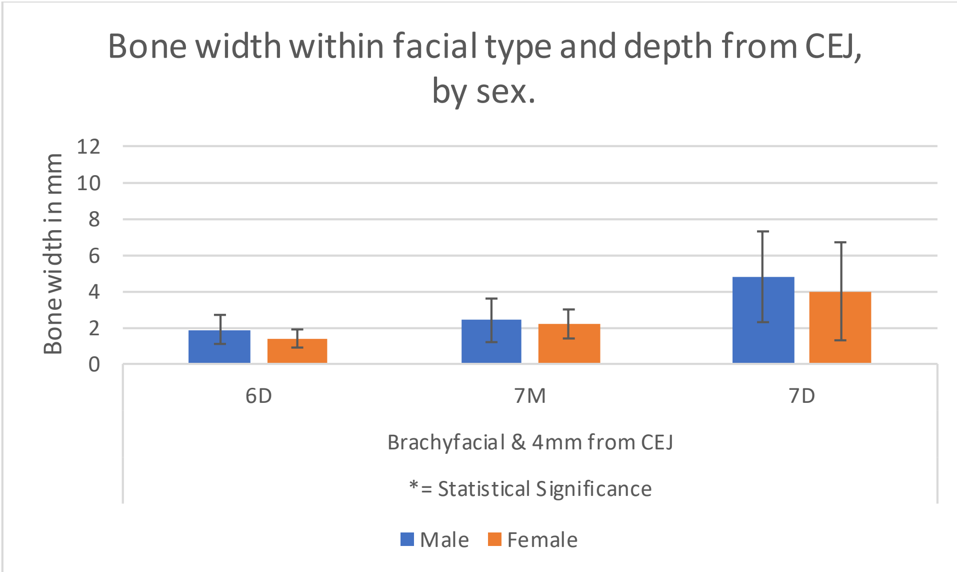

Figure 22 Brachyfacial bone width at 4mm from CEJ by sex.

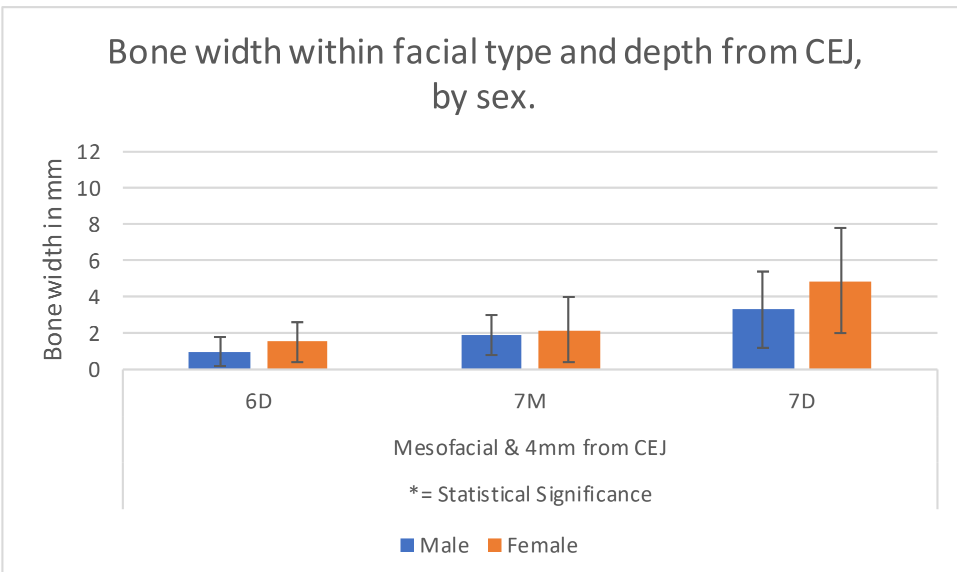

Figure 23 Mesofacial bone width at 4mm from CEJ by sex.

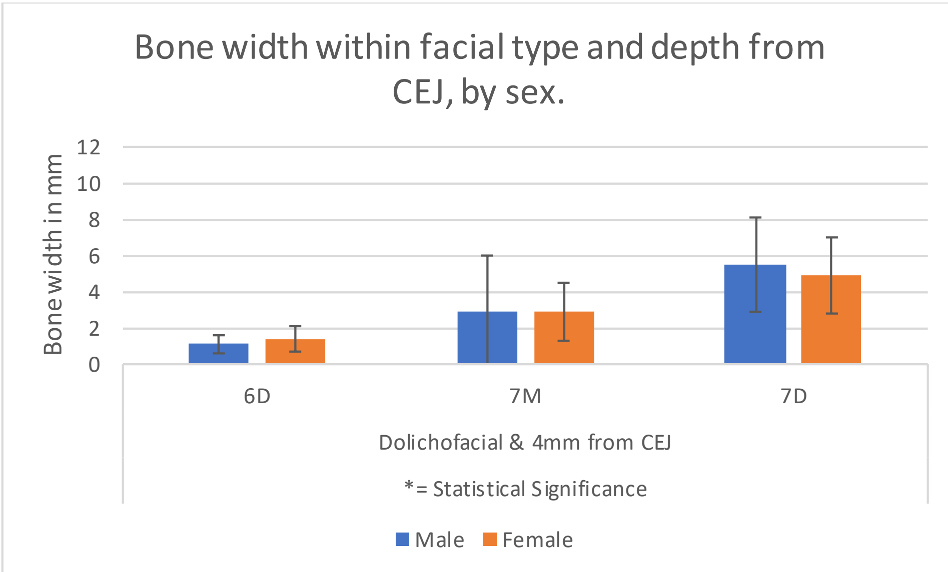

Figure 24 Dolichofacial bone width at 4mm from CEJ by sex.

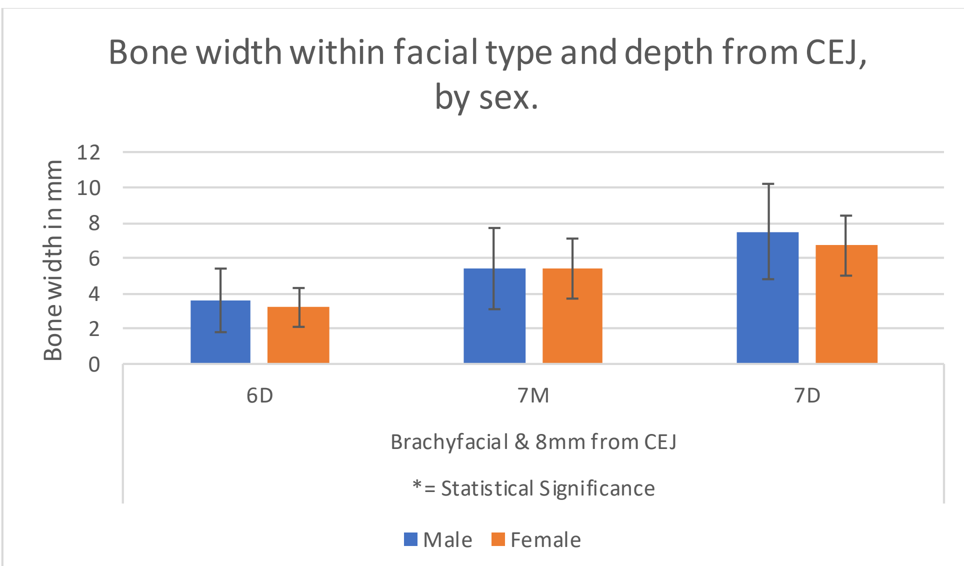

Figure 25 Brachyfacial bone width at 8mm from CEJ by sex.

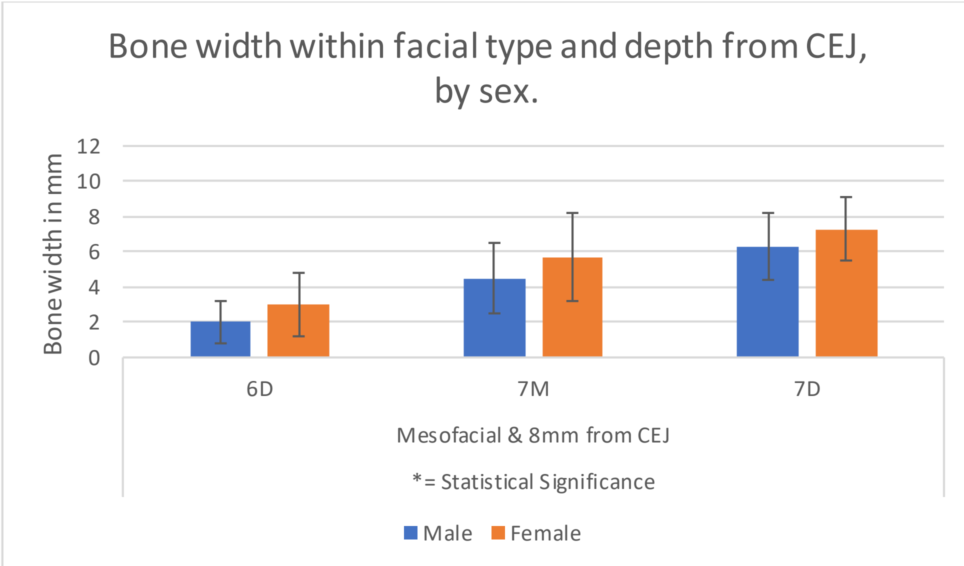

Figure 26 Mesofacial bone width at 8mm from CEJ by sex.

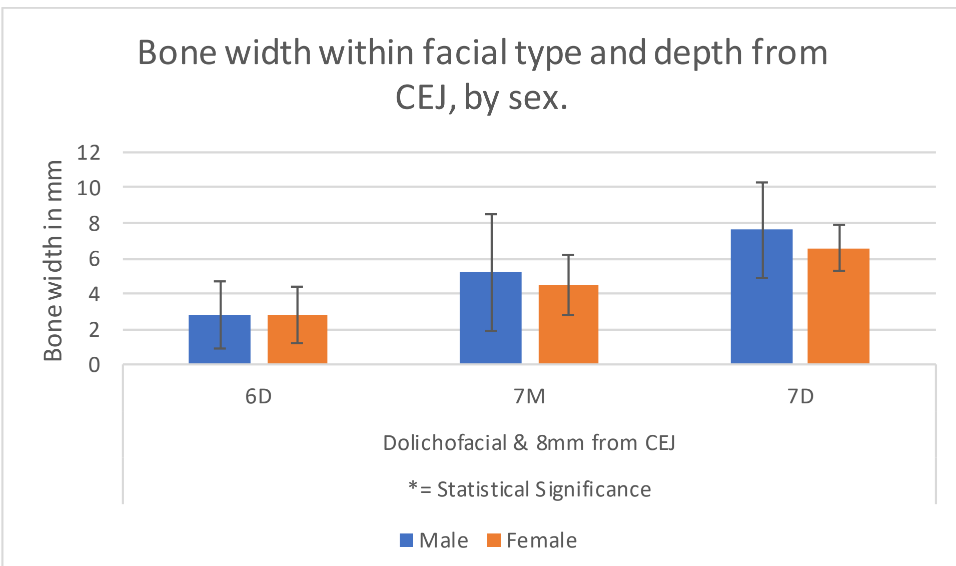

Figure 27 Dolichofacial bone width at 8mm from CEJ by sex.

Discussion

This study investigated the impact of sex and facial type on mandibular buccal shelf bone width and cortical thickness. The results showed a trend of increasing buccal shelf bone width with progression from sites 6D to 7D. This trend holds true for both males and females, diagnostic facial types, and when measured at 4mm or 8mm from CEJ.

Buccal shelf bone width values measured at 8mm from the CEJ were always greater than corresponding measurements at 4mm from CEJ. This trend holds true for both males and females, all measurement sites, and in all diagnostic facial types. The findings are consistent with the typical remodeling/growth pattern of the mandible where bone is resorbed from the internal surfaces of the cortex and deposited on the external surfaces resulting in a wider inferior aspect than the narrower superior aspect. If the measurements are made parallel to the occlusal plane, and if the molars are relatively upright, it should be expected to see larger width values as with increasing distance from the CEJ.

Cortical bone thickness measurements showed a trend of progressively decreasing magnitude with progression distally from site 6D to site 7D. When comparing the values between males and females, the values were similar at all measurement sites within diagnostic facial type groupings. This would indicate little if any impact of sex on cortical bone thickness values within diagnostic facial types. All cortical bone thickness measurements were above the recommended limit of 2 mm for miniscrew insertion without a pilot hole being drilled[7]. Also of note, all the cortical bone thickness measurements were well above the averages reported by Park et al. (2.48mm at the first molar and 3.17mm at the second molar). This is likely due to the current study protocol of measurements being made parallel to the buccal surface of the molar root. Park reported an insertion method of 10-20 degrees from the long axis of the respective molar[18].

In 2020, Vargas et. al, reported findings from their study which investigated facial heights impact on mandibular buccal shelf and infrazygomatic crest bone thickness. Vargas' study described similar findings as was found in this investigation, a progression of increasing mandibular buccal shelf width and thickness with progression distally from the first to second molar regions[17]. Unlike the results of this study, Vargas reported a correlation between brachyfacial facial type and increased mandibular buccal shelf width and thickness. However, the reported Spearman correlation coefficients ranged from -0.437 to 0.119 indicating a weak correlation at best[17].

A 2021 article published by Aleluia et al. investigated the effects of facial types (hypodivergent, normodivergent, hyperdivergent) on mandibular buccal shelf thickness and bone height. Their study incorporated an investigation of the effect of sex and right vs left sided differences influence on MBS thickness and bone height. Their results reported no significant differences in mean MBS bone thickness or height were found based on sex or right vs left difference[19]. Like the data presented in the current study, Aleluia also reported increasing bone width with distal and inferior progression from the first molar[19]. However, similar to Vargas, they also found a correlation between individuals with a short face height or hypodivergent facial type and increased MBS bone width when compared to their normodivergent (mesofacial) and hyperdivergent (dolichofacial) counterparts[19].

One limitation of the study was the lack of information concerning subject's prior history. It is unknown if any of the subjects had received orthodontics prior to imaging. This would impact the orientation and placement within the bone of the mandibular molars therefore possibly impacting the amount of buccal shelf bone width. Another limitation is that, unlike Aleluia et al., no comparison of the difference in right vs left sided measurements was made.

Future work should focus on investigating the impact of the angulation of insertion on the relative thickness of cortical bone. The findings of this study suggest that all sites required predrilling prior to miniscrew insertion parallel to the long axis of the root. It would be beneficial to compare the impact of changing the insertion angle.

It is possible that a combination of insertion site, distance from CEJ, and angle to root long axis, would produce sufficient cortical bone width without the need for predrilling. It would be worthwhile to investigate the impact of both sex and facial type on the need for predrilling under the various combinations of site, distance from CEJ, and miniscrew insertion angle relative to tooth root long axis.

Conclusions

This project tested the working hypothesis that both sex and facial type (dolichofacial, mesofacial, and brachyfacial) affect the width and thickness of bone of the mandibular buccal shelf. The findings of this study can be summarized as follows:

1. Neither sex nor facial type had a significant impact on mandibular buccal shelf morphology.
2. All measured sites showed cortical bone thickness values that indicate the requirement of a pilot hole being drilled prior to miniscrew insertion.

3. Mandibular buccal shelf bone width progressively increases when progressing distally with respect to position in the mandible or inferiorly with respect to distance from the CEJ.

Table 2 Female CBT within facial type by measurement site.

Female cortical bone thickness by facial type, measured the distobuccal cusp of the first molar, the mesiobuccal and distobuccal cusp of the second molar.

Females				
Facial Type	Measurement Site	Cortical Bone Thickness (Mean ± StdDev) mm	P Value	β Value
Brachyfacial	6D	7.6 ± 2.2	0.051	0.58
	7M	5.4 ± 1.0		
	7D	5.3 ± 0.9		
Mesofacial	6D	6.4 ± 1.9	0.36	0.215
	7M	5.5 ± 1.7		
	7D	5.1 ± 3.0		
Dolichofacial	6D	6.0 ± 2.0	0.35	0.227
	7M	5.7 ± 2.2		
	7D	5.0 ± 1.8		

Table 3 Male CBT within facial type by measurement site.

Male cortical bone thickness by facial type, measured the distobuccal cusp of the first molar, the mesiobuccal and distobuccal cusp of the second molar.

Males				
Facial Type	Measurement Site	Cortical Bone Thickness (Mean ± StdDev) mm	P Value	β Value
Brachyfacial	6D	8.0 ± 2.1	0.01	0.801
	7M	6.2 ± 1.6		
	7D	5.8 ± 2.0		
Mesofacial	6D	7.6 ± 1.6	0.063	0.545
	7M	6.5 ± 1.9		
	7D	5.8 ± 1.8		
Dolichofacial	6D	6.4 ± 3.0	0.568	0.136
	7M	5.7 ± 1.2		
	7D	5.5 ± 1.5		

Table 4 Female bone width within facial types and 4mm from CEJ by measurement site.

Female buccal shelf bone width within facial type measured 4mm from the CEJ at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar.

Females					
4mm from CEJ					
Facial Type	Site	Width (Mean ± StdDev) mm	Significance	p Value	β Value
Brachyfacial	6D	1.4 ± 0.5		0.073	0.512
	7M	2.2 ± 0.8			
	7D	4.0 ± 2.7			
Mesofacial	6D	1.5 ± 1.1		0.001	0.96
	7M	2.2 ± 1.8			
	7D	4.9 ± 2.9	*		
Dolichofacial	6D	1.4 ± 0.7	*	<0.001	1
	7M	2.9 ± 1.6	*		
	7D	4.9 ± 2.1	*		

Table 5 Male bone width within facial types and 4mm from CEJ by measurement site.

Male buccal shelf bone width by facial type measured 4mm from the CEJ at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar.

Males					
4mm from CEJ					
Facial Type	Site	Width (Mean ± StdDev) mm	Significance	p Value	β Value
Brachyfacial	6D	1.9 ± 0.8		<0.001	0.992
	7M	2.4 ± 1.2			
	7D	4.8 ± 2.5	*		
Mesofacial	6D	1.0 ± 0.8		0.003	0.906
	7M	1.9 ± 1.1			
	7D	3.3 ± 2.1	*		
Dolichofacial	6D	1.1 ± 0.5		<0.001	0.979
	7M	2.9 ± 3.1			
	7D	5.5 ± 2.6	*		

Table 6 Female bone width within facial type and 8mm from CEJ by measurement site.

Female buccal shelf bone width by facial type measured 8mm from the CEJ at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar.

Females					
8mm from CEJ					
Facial Type	Site	Width (Mean ± StdDev) mm	Significance	p Value	β Value
Brachyfacial	6D	3.2 ± 1.1	*	0.011	0.828
	7M	5.4 ± 1.7			
	7D	6.7 ± 1.7	*		
Mesofacial	6D	3.0 ± 1.8	*	<0.001	0.996
	7M	5.7 ± 2.5			
	7D	7.3 ± 1.8			
Dolichofacial	6D	2.8 ± 1.6	*	<0.001	1
	7M	4.5 ± 1.7	*		
	7D	6.6 ± 1.3	*		

Table 7 Male bone width within facial type and 8mm from CEJ by measurement site.

Male buccal shelf bone width by facial type measured 8mm from the CEJ at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar.

Males					
8mm from CEJ					
Facial Type	Site	Width (Mean ± StdDev) mm	Significance	p Value	β Value
Brachyfacial	6D	3.6 ± 1.8		<0.001	0.971
	7M	5.4 ± 2.3			
	7D	7.5 ± 2.7	*		
Mesofacial	6D	2.0 ± 1.2	*	<0.001	0.999
	7M	4.5 ± 2.0	*		
	7D	6.3 ± 1.9	*		
Dolichofacial	6D	2.8 ± 1.9	*	0.001	0.971
	7M	5.2 ± 3.3			
	7D	7.6 ± 2.7			

Table 8 Bone thickness within facial type and site by sex.

Bone thickness within facial type, site measured at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar, by sex.

Facial Type	Measurement Site	Cortical Bone Thickness (Mean ± StdDev) mm		Significance	P value
		Male	Female		
Brachyfacial	6D	8 ± 2.1	7.6 ± 2.2		0.9
	7M	6.2 ± 1.6	5.4 ± 1		0.5
	7D	5.8 ± 2	5.3 ± 0.9		0.09
Mesofacial	6D	7.6 ± 1.6	6.4 ± 1.9		0.8
	7M	6.5 ± 1.9	5.5 ± 1.7		0.5
	7D	5.8 ± 1.8	5.1 ± 3		0.2
Dolichofacial	6D	6.4 ± 3	6 ± 2		0.2
	7M	5.7 ± 1.2	5.7 ± 2.2		0.2
	7D	5.5 ± 1.5	5 ± 1.8		0.6

Table 9 Bone width within facial type, site, and 4mm from CEJ, by sex.

Bone width by facial type measured 4mm from the CEJ at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar, by sex.

4mm from CEJ					
Facial Type	Measurement Site	Width (Mean ± StdDev) mm		Significance	P Value
		Male	Female		
Brachyfacial	6D	1.9 ± 0.8	1.4 ± 0.5		0.2
	7M	2.4 ± 1.2	2.2 ± 0.8		0.2
	7D	4.8 ± 2.5	4 ± 2.7		1
Mesofacial	6D	1 ± 0.8	1.5 ± 1.1		0.4
	7M	1.9 ± 1.1	2.2 ± 1.8		0.2
	7D	3.3 ± 2.1	4.9 ± 2.9		0.2
Dolichofacial	6D	1.1 ± 0.5	1.4 ± 0.7		0.8
	7M	2.9 ± 3.1	2.9 ± 1.6	*	0.02
	7D	5.5 ± 2.6	4.9 ± 2.1		0.4

Table 10 Bone width within facial type, site, and 8mm from CEJ, by sex.

Bone width by facial type measured 8mm from the CEJ at the distobuccal cusp of the first molar, the mesiobuccal cusp and the distobuccal cusp of the second molar, by sex.

8mm from CEJ					
Facial type	Measurement Site	Width (Mean ± StdDev) mm		Significance	P Value
		Male	Female		
Brachyfacial	6D	3.6 ± 1.8	3.2 ± 1.1		0.4
	7M	5.4 ± 2.3	5.4 ± 1.7		0.5
	7D	7.5 ± 2.7	6.7 ± 1.7		0.4
Mesofacial	6D	2 ± 1.2	3 ± 1.8		0.2
	7M	4.5 ± 2	5.7± 2.5		0.7
	7D	6.3 ± 1.9	7.3 ± 1.8		0.8
Dolichofacial	6D	2.8 ± 1.9	2.8 ± 1.6		0.4
	7M	5.2 ± 3.3	4.5 ± 1.7	*	0.03
	7D	7.6 ± 2.7	6.6 ± 1.3		0.3

OREGON HEALTH & SCIENCE UNIVERSITY OHSU

IRB MEMO

Research Integrity Office
3181 SW Sam Jackson Park Road - L106RI
Portland, OR 97239-3098
(503)494-7887 irb@ohsu.edu

NOT HUMAN RESEARCH

April 14, 2020

Dear Investigator:

On April 14, 2020, the IRB reviewed the following submission:

Title of Study:	Anatomic assessment of mandibular buccal shelf for miniscrew insertion: A comparison of sex and facial type.
Investigator:	Jeffrey Nickel
IRB ID:	STUDY00021422
Funding:	None

The IRB determined that the proposed activity is not research involving human subjects. IRB review and approval is not required.

Certain changes to the research plan may affect this determination. Contact the IRB Office if your project changes and you have questions regarding the need for IRB oversight.

If this project involves the collection, use, or disclosure of Protected Health Information (PHI), you must comply with all applicable requirements under HIPAA. See the HIPAA and Research website and the Information Privacy and Security website for more information.

Sincerely,

The OHSU IRB Office

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