PREVALENCE AND CHARACTERIZATION OF ALVEOLAR DEHISCENCES AND FENESTRATIONS SEEN IN A SAMPLE OF SOUTH AFRICAN HUMAN SKULLS.

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of

Master of Science in Dentistry

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DECLARATION

I, Sandra Koutras declare that this research report is my own work. It is being submitted for the degree of Master of Science in Dentistry at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at this or any other University.

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Sandra Koutras

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DEDICATION

To the best family I could ever wish for.

ACKNOWLEDGEMENTS

"No Man Is an Island." – John Donne

I wish to express my appreciation to my supervisors Professor Shangase and Dr Mohangi for their aspiring guidance. Furthermore I would like to thank Mr Jason Hemmingway who has willingly shared his time and exercised his patience to the maximum in trying to help me understand statistics. Last but not least, Mr Brendon Billings for his constant willingness to help and facilitate the data collection process.

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ABSTRACT

Background: The purpose of this study was to determine and evaluate the prevalence, distribution and characteristics of dehiscences and fenestrations in skulls of a South African population and to discover if there is a link between their presence and specific characteristics.

Methods and materials: A sample of 333 skulls with both jaws and a partial or complete dentition whose sex, age and ethnicity was known, were obtained from the Raymond A. Dart Collection of Human skeletons in the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg, dating from 1980 to 2014. The size and distribution of these defects was measured. Fenestrations were further classified according to their location. The position of the affected teeth in the arch and the size of these teeth in relation to the width of the jaw were also recorded.

Results: A total of 770 alveolar defects were recorded. Of those, 579 were fenestrations 63.2% in the maxilla; 36.7% in the mandible and 191 dehiscences 72.8% in the mandible and 27.2% in the maxilla. The total number of defects in the maxilla (418) exceeded that of the mandible (352). In the maxilla, the teeth most commonly associated with both dehiscences and fenestrations were the first molars (39.2%) and canines (29.9%). In the mandible, the canines (34.9%) and the first premolars (28.8%) were the most commonly affected teeth. There was a higher proportion of fenestrations as opposed to dehiscences present in all teeth except the canines where dehiscences predominated.

Conclusion: Gender, age and population had no influence on the defects observed in the samples. The number of teeth was the only factor significantly associated with the presence or absence of one or more alveolar defects.

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

In humans, the maxilla and mandible are the tooth bearing bones of the skeleton.[1] The maxillae are paired bones that form the upper jaw. Similarly, the mandible consists of right and left processes fused together at the mandibular symphysis, occurring within the first year following birth.[2]

The maxilla and mandible are made up of basal and alveolar bone. The basal bone is the section of bone located apically and not associated with the teeth.[3] In a healthy dentate individual, the alveolar bone consists of the alveolar process and the alveolar bone proper which are continuous with one another[4] , and together with the alveolar mucosa, gingiva, periodontal ligament and root cementum form the periodontium. These tissues develop together with the tooth root and originate from the dental follicle which is derived from neural crest.[5]

The periodontium, also named "the attachment apparatus" or the "supporting tissues" of the teeth[4], acts collectively to support and invest the tooth root in alveolar bone.[4, 6] It also distributes forces to the alveolar bone and further through to the mandible, maxilla and skull, thereby minimising forces generated during mastication and other tooth contacts.[4]

It is important to distinguish between the alveolar process and the alveolar bone proper. The alveolar process is defined by Lindhe (2008) as: "the parts of the maxilla and the mandible that form and support the sockets of the teeth."[4] These extensions of the body of the maxilla and mandible are usually thicker in the palatal and lingual areas as compared to the buccal areas.[7]

The alveolar process forms during the development and eruption of teeth to provide osseous attachment to the forming periodontal ligament, and resorbs if teeth are lost.[4, 8] Thus, the morphology and structure of the alveolar processes are considered to be “unique” due to their dependence on the teeth, which are positioned in osseous crypts named alveoli.[3]

The alveolar process consists of an external plate of cortical bone formed by harversian and compact bone lamellae together with a thin inner socket wall (alveolar bone proper), formed by compact bone.[8] Cancellous trabeculae are present between the two above named layers which act as supporting bone.[8]

Alveolar bone proper is the portion of the bone that lines the dental alveoli which surround the teeth.[6] It is histologically termed “bundle bone” because it provides the attachment surface into which the terminal ends of the principal fibers of the periodontal ligament (Sharpey’s fibers) perforate.[6] Bundle bone is functionally dependent and thus resorbs if teeth are lost.[4, 9] The most coronal portion of the alveolar bone proper is the alveolar crest which in health, lies 2-3 mm apical to the cemento-enamel junction.[1]

In conventional radiographs of teeth, the alveolar bone proper appears as a radiopaque line surrounding the tooth roots termed the *lamina dura*.[9] The integrity of the *lamina dura* radiographically is considered a sign of a healthy periodontium.[9]

Although the architecture of the alveolar bone varies from patient to patient, with regards to configuration, contour and thickness, all variations are considered healthy.[8] Two commonly encountered alveolar defects which reflect anatomical variations in the shape and morphology of the alveolar bone are dehiscences and fenestrations.[3]

These defects which represent interruptions in the cortical plate contour have been defined in several ways which may contribute to the variability in the incidence and anatomical location of defects found in different studies.[3] There has been a general consensus in describing fenestrations in the literature as opposed to dehiscences.

The Journal of Periodontology Glossary of Terms (2001) defined a fenestration as: “a window-like aperture or opening, such as may be found in the alveolar bone over the root of a tooth.”[10] According to Carranza *et al*., a fenestration is characterised by a localised area of denuded bone overlying the dental root resulting in a root surface covered only by periosteum and overlying gingiva without involvement of the alveolar crest.[8] When the defect extends into and involves the alveolar crest, it is referred to as a dehiscence.[8] The probability exists that fenestrations are actually a stage in the development of a dehiscence.[3]

The term “dehiscence” has been poorly defined in the literature. The Journal of Periodontology Glossary of Terms (2001) does not include dehiscence in its list of definitions.[10] As a result, the definition was obtained from The Journal of Periodontology Glossary of Terms (1977) where it was defined as: “a condition in which the buccal and less often the lingual aspect of the root of the tooth is without all or a portion of its bony covering.”[11]

Davies *et al.,* were the first to define the term dehiscence with numerical stipulations.[12] A dehiscence was defined as: “a defect in which the crest of the buccal bone was at least 4 mm apical to the crest of the interproximal bone.”[12] The weakness in this definition is that periodontitis accounting for interproximal bone loss could confound the presence of a dehiscence.[13]

The documentation on the incidence and clinical significance of alveolar defects started in 1963 when Elliot and Bowers conducted a pilot study on a total of 1153 teeth on 52 human skulls to determine the incidence and anatomical location of fenestrations and dehiscences.[14]

The results showed that there was a 20.1% incidence of alveolar defects; 10.9% of which were fenestrations and 9.2% dehiscences.[14] Since then, several studies have documented the prevalence and distribution of dehiscences and fenestrations in human skulls of varying populations, e.g. American[15] South- East European[3], Bedouin[13], British[12], Mexican –Indian[16] as well as South African.[17-19]

The reported differences in the frequency of these defects were observed with the overall prevalence rates ranging from 0.99% to 13.4% for dehiscences and 0.23% to 16.9% for fenestrations.[20] Fenestrations were most commonly observed in the maxilla and associated with the maxillary first molar.[13, 14, 16, 21] The proximity of the maxillary first molar to the zygomatic pillar was said to be the reason for this.[18] On the contrary, dehiscences were reportedly more commonly observed in the mandible and associated with canines.[18]

Anterior teeth are found to be more frequently affected than posterior teeth with the buccal cortical plate more often involved as compared to the lingual plate and may often present bilaterally.[8] The height and thickness of the buccal and palatal/lingual cortical plates are influenced by tooth alignment, root to bone angulation and occlusal forces.[8] The maxillary buccal/labial cortical plate is very thin along its entire antero-posterior dimension.[22] Due to the greater volume of the permanent canine and mesiobuccal root of the first molar, the buccal plate is even thinner in these regions as compared to the other maxillary teeth.[22]

The maxillary palatal cortical plate is thicker than the buccal bone plate especially in the region of the maxillary incisor.[22] As in the maxilla, the mandibular buccal/labial cortical plate is thinner than the lingual cortical plate except in the regions of the second and third permanent molars.[22]

Although these aberrant alveolar defects are not considered pathological, and to some are regarded as normal anatomical feature variants of the alveolar process, there may be an association of dental or facial pain associated with them.[16] The pain may be spontaneous or elicited by touch to the exposed root area, possibly confusing the clinician as the tooth involved responds positively to vitality testing.[23]

Dehiscences and fenestrations cannot be seen or differentiated on conventional radiographs and probing is of limited usefulness in detecting them, especially in the case of fenestrations.[3] A test requiring substantial experience may be utilised to try to detect these defects by running a finger over the tooth root in an apico-coronal and mesio-distal direction.[24] Bone sounding may be a more accurate way of detecting and differentiating between the two alveolar defects by placing a periodontal probe between the anaesthetised tissue and the root.[24]

Although a definite cause to these defects still remains unclear[3, 8], it is thought that tooth size and position (causing displacement and thus prominence out of the arch), tooth to jaw ratio, trauma from occlusal forces, root prominence (possibly combined with a thin bony plate), orthodontic tooth movement, developmental anomalies, frenal attachments and periodontal and endodontic pathoses may directly influence the frequency of these defects.[4, 13, 15]

The thickness and size of the jaws differ among ethnic groups as they are genetically determined.[25] Tooth and jaw size are independently inherited traits, thus if an individual acquired a small jaw from one parent and large teeth from the other, this would result in crowding, prominent roots and a thin alveolar housing.[26]

Rupprecht *et al.* reported that the presence of dehiscences and fenestrations was positively linked to thin alveolar bone and negatively linked to occlusal attrition.[15] Edel could find no clear correlation between the presence of wear facets and the presence of fenestrations and dehiscences.[13] Larato *et al.* could find no link between the prevalence of fenestrations and occlusal wear either.[16] On the contrary, Stahl *et al.* found an increased extent of wear facets as a result of occlusal forces in most of the teeth identified as having fenestrations.[27] It should be noted that these associations are based on skull material with no evidence of function and cannot be regarded as absolute data.

Larato *et al.* found that root prominence was associated with 90% of teeth with fenestrations and dehiscences,[16] whilst Edel concluded that only 37% of teeth with fenestrations and 35% of teeth with dehiscences were coupled with prominent roots.[13]

Two studies reported an inversely proportional relationship between the prevalence of teeth with a dehiscence or fenestration and age,[12, 15] whilst Stahl *et al.* reported that the number of fenestrations found to increase with age.[27]

Fenestrations and dehiscences are not limited to adult skulls. Larato examined 176 children's skulls of Mexican and Indian origin with a complete primary dentition ranging from 2-5 years of age.[28] Twenty one skulls (11.9%) exhibited alveolar defects of which only 1% of teeth had either a fenestration or a dehiscence. Stahl *et al.* also recorded the presence of 2 fenestrations in 8 children's skulls (of unknown age).[27] These studies concluded that alveolar defects do occur in children and further studies should be conducted to see whether alveolar defects present in childhood predispose an adult to the same defects later on in life.

Hirschfield was one of the earliest periodontists to observe the relationship between alveolar anatomy and gingival form.[29] He noted that a thin alveolar contour would similarly be overlaid by a thin gingival form. Ochsenbein and Ross also later proposed that bone anatomy dictates gingival anatomy.[30]

The gingival biotype or gingival morphology is determined by factors including underlying bone dimension and the anatomical form and position of teeth.[31] According to Ochsenbein and Ross, gingival biotypes can be classified as thick or flat and thin or scalloped.[30] Later, Siebert and Lindhe categorised the gingiva into "thick-flat" and "thin-scalloped" biotypes.[32]

A gingival tissue thickness of ≥ 2 mm is defined as a thick biotype. A thick biotype is characterised by a thick band of keratinised tissue together with a flat gingival contour, thick underlying bony architecture and reportedly more resistance to inflammation and trauma.[33, 34] A gingival tissue thickness of < 1.5 mm is defined as a thin biotype and is characterised by a thin band of keratinized tissue together with a scalloped gingival contour, thin underlying bony architecture and increased sensitivity to inflammation and trauma.[33, 34] It has been suggested that plaque-associated inflammation is more likely to result in deep periodontal pockets in a flat-thick biotype and into gingival recession in a thin scalloped biotype.[34, 35]

Gingival recession is a common dental finding characterised by root cementum exposure; and is said to be clinically accompanied by alveolar bone dehiscences.[36] In other words, alveolar bone dehiscences are predecessors to gingival recession[37] and may therefore cause rapid advancement of periodontal disease. In a study by Richman, all teeth presenting with gingival recession of more than 3 mm were found to have notably more prominent facial tooth contours and associated alveolar bone dehiscences.[36]

Olsson and Lindhe evaluated the relationship between maxillary central incisor tooth form and gingival form.[35] It was concluded that narrower central incisors which tend to have a scalloped gingival anatomy showed greater recession than square central incisors which tend to have a flat gingival profile.[35] In another study by Becker *et al.*, there was no significant difference between the incidence of fenestrations and dehiscences found in the pronounced scalloped anatomical profiles or flat scalloped anatomical profiles according to alveolar bone anatomy.[38] The thickness of alveolar bone defines the boundaries of orthodontic movement. Teeth extending beyond the bony envelope as a result of orthodontic treatment may cause dehiscences and fenestrations and constitute risk factors for gingival recession.

Mucogingival surgical procedures which often strip the periosteum may inadvertently expose fenestrations and dehiscences leading to surgical dilemmas which may seriously impact the outcome of treatment.[19] An example of this could be when a graft procedure exposes a dehiscence or fenestration at the donor site. While the recipient site may be repaired, a defect may be created at the donor site.[20] These alveolar defects are thus regarded as a clinical therapeutic problem[21] that may complicate the outcome of orthodontic therapy, periodontal and oral surgery.[3, 8] Thus it is important for any oral healthcare professional performing surgical procedures to have a sound knowledge of normal bone anatomy, gingival morphology and which teeth are most commonly associated with these defects to prevent adverse outcomes and achieve a satisfactory aesthetic result.[38]

Only three other studies of a similar nature have been performed in South Africa.[17-19] The studies already performed focused on a specific population group and were carried out on either maxillae or mandibles and not skulls with both jaws. It is this paucity in the literature that has prompted a more in depth examination of these defects in skulls of a South African population to be conducted. The aim of this study was to determine the prevalence of dehiscences and fenestrations of South African skulls with both jaws irrespective of race in the Raymond A. Dart Collection; and also characterize these defects.

CHAPTER 2: AIMS AND OBJECTIVES

The purpose of this study was to determine and evaluate the prevalence, distribution and characteristics of dehiscences and fenestrations in skulls of a South African population. These skulls were obtained from the Raymond A. Dart Collection of Human skeletons in the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg dating from 1980 to 2014.

The Raymond A. Dart Collection of Human skeleton comprises 2605 modern human skeletons representing the major South African population groups.[39] These skeletons have been collected over a period of time from 1921 to present with each individual's age, sex and population group being known and continues to grow.[39] This collection is unique because of its large sample size, broad period of the collection period and population diversity of the skeletons.[39]

The objectives of this study were:

- To determine the size and distribution of the dehiscences and fenestrations.
- To classify the fenestration defects.
- To assess the position of the teeth in the arch and the size of the teeth in relation to the width of the jaw.
- To determine any association between the gender and age, and the defects.
- To compare the findings of this study to similar studies done on populations around the world.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Design

A cross sectional study of a specific collection of archived specimens.

3.2 Study Population

The skulls utilised in this study were obtained from the Raymond A. Dart Collection of Human Skeletons (Dart collection), housed in the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg, South Africa.

3.3 Sample selection

For inclusion in the study, both male and female skulls had to be complete, consisting of a maxilla and a mandible, with a complete or partial dentition, of an age 12 years and older and forming part of a South African population dating from 1980 to present.

Edentulous dry skulls, skulls presenting with post mortem damage (such as chips and cracks to the alveolar process), teeth showing signs of previous presence of periodontal disease (leading to interdental bone loss and subsequent masking of dehiscences)[15] and wisdom teeth (due to their complexity in anatomy and variation in presence and position) were excluded from the study. The periodontium was considered healthy if the alveolar crest of the interproximal bone was no more than 2 mm apical from the interproximal cemento-enamel junction of the correspondent tooth.[3]

The South African populations within the Raymond A. Dart collection are extremely diverse with each racial population group having a variety of origins i.e. tribe or ethnic group.[39]

For example, major ethnic groups falling under the Black African category include the Zulu, Xhosa, Basotho (South Sotho), Bapedi (North Sotho), Venda, Tswana, Tsonga, Swazi and Ndebele, all of which are not culturally or linguistically homogenous.[39]

The South African census (2011) asks people to describe themselves in terms of four racial population groups; those being: Black African, White, Coloured and Indian/Asian.[40] For the purpose of this study the census categories were adopted to eliminate ambiguity and dual categories.

3.4 Sample size

Testing for the minimum sample size to distinguish between true proportions, using a contingency table, requires estimates of the proportions, as well as the power and level of significance. Generally, a significance of 5% ($\alpha = 0.05$) and a power of 80% ($\beta = 0.2$) is considered acceptable.[41]

The studies of Volchansky and Viera[18], Volchansky and Cleaton-Jones[17] and Tal[19] on the Raymond A. Dart Collection provided some insight into the probable proportions that were to be encountered in the proposed study. Across these studies, the prevalence of dehiscences and fenestrations averaged 4.6% and 3.8% respectively. Thus, making an allowance for an average proportion of 0.04, a sample size achieving an 80% power in detecting a specific difference would be required.

Figure 1 illustrates the power for various differences between proportions, from 1% to 5%, as well as that between the total defects observed for the mandibular canine and first molar by Tal.[19] Power calculations were performed according to Zar.[42] A minimum sample size of 6027 was required to detect a difference of 1%, 1506 for 2%, 669 for 3%, 376 for 4%, and a minimum sample of 240 (for a specific tooth type) was required to discriminate a difference of 5%. The mandibular canine and first molar frequencies are 0.223 and 0.086 respectively and with such a large disparity a minimum sample of only 109 would suffice.

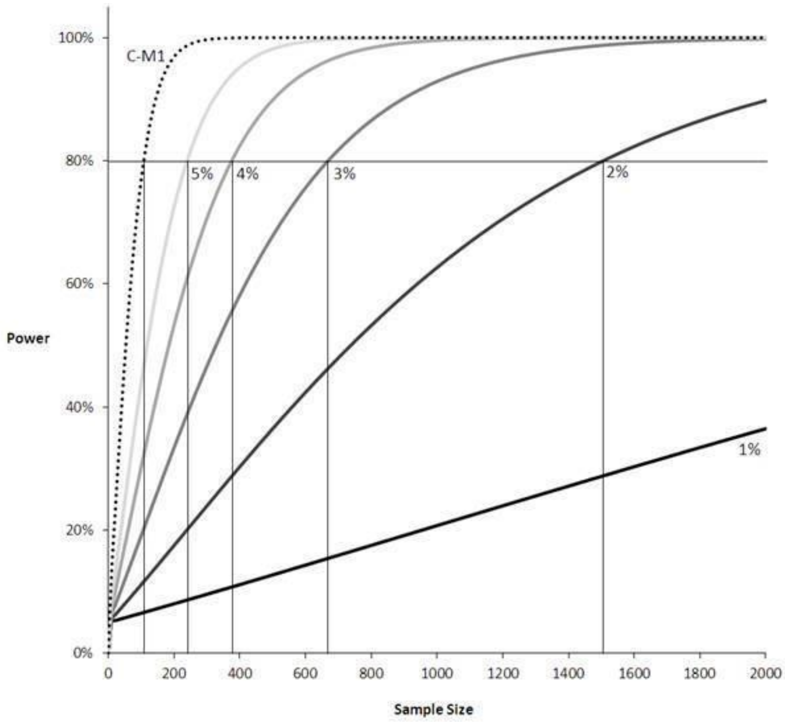


Figure 1. The power of the test as a function of the sample size, assuming the sample sizes are the same. The percent attributed to each curve represents the difference between the two proportions whose mean is 0.04. The canine and first molar comparison (C-M1) proportions are 0.223 and 0.086 respectively. A horizontal line is drawn at the generally accepted 80% power and vertical lines illustrate the sample sizes at which each function achieves 80% power.

Tal[19] looked at the Raymond A. Dart collection and observed 1077 teeth on 100 mandibles, rounded to 11 teeth per individual. Tal[19], Volchansky and Viera[18] and Volchansky and Cleaton-Jones[17] observed an average of 14 teeth per individual, looking at both arcades. Thus, if we assumed that the sample presented with 14 teeth per individual (maxillary and mandibular), a sample of 549 individuals (240 teeth) would allow a frequency difference greater than 5% to be perceived.

3.5 Calibration

Prior to data collection, inter and intra-observer calibration was performed to standardize findings. This was done to ensure reliability and reproducibility respectively during data collection. There was one principal researcher who was calibrated by an experienced periodontist.

For inter-observer calibration (between the principal researcher and the additional examiner), a series of 20 skulls was scrutinised independently. Thereafter the findings were compared utilising the calculation of *kappa* scores.[41] For intra-observer calibration, the same twenty skulls were re-examined by the principal researcher after one week. Findings were once again compared to the initial measurements to ensure intra-observer consistency using Lin's concordance correlation co-efficient of reproducibility.[43] (Appendix 2; Table 2.1; Table 2.2)

3.6 Instrumentation

A specific dental caliper* was used to measure the apico- coronal and mesio-distal dimensions of fenestrations and dehiscences as well as the tooth to ridge width. This device has the ability to make precise measurements displayed on an LCD screen.

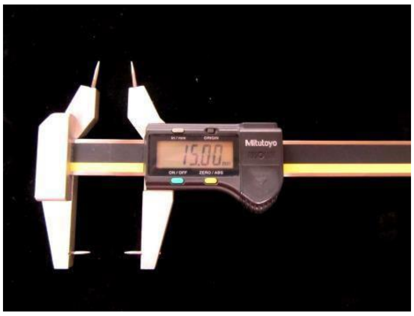


Figure 2. Dental caliper

*Special ABS Coolant Proof Hillson-Fitzgeral Dental Caliper (No 99MAD022M, Series No.500), Mitutoyo IP67 made in Tokyo, Japan

The University of North Carolina-15 (UNC-15 probe) was used to assess whether the periodontium of the teeth displaying the defects had signs of previous disease. (Figure 3)

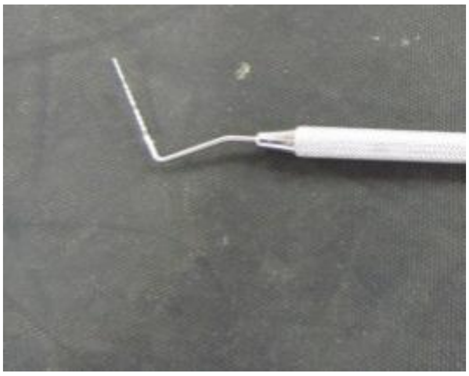


Figure 3. UNC-15 probe

For the assessment of the position of the teeth in the arch, a bendable copper wire (0.5 mm) was used. (Figure 4)

Figure 4. Bendable brass wire

3.7 Measurements

Following calibration, data was collected by the principal researcher. Information was recorded for each specimen on a separate data collection sheet (Appendix 3) commencing with the serial number, age, gender and ethnicity of each specimen.

After noting present and missing teeth, the skulls were assessed for the presence of alveolar dehiscences and fenestrations using the criteria described by Davies *et al*.[12]

A dehiscence (Figure 5a) was registered as a defect in which the crest of the buccal or lingual/palatal was at least 4 mm apical to the crest of the interproximal bone.[12] A fenestration (Figure 5b) was identified as a localised defect of the buccal or lingual/palatal alveolar plate which exposed the root surface but did not involve the alveolar margin.[12]

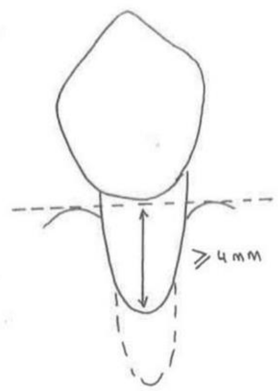


Figure 5a. Dehiscence

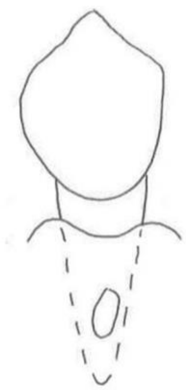


Figure 5b. Fenestration

Teeth with dehiscences which showed signs of having been periodontally involved were ruled out whilst those with fenestrations were not. The periodontium was considered healthy if the alveolar crest of the interproximal bone was ≤ 2 mm apical from the interproximal cemento-enamel junction.[3] (Figure 6) The mesial interproximal alveolar crest was always measured except in the case of a missing neighbouring tooth.

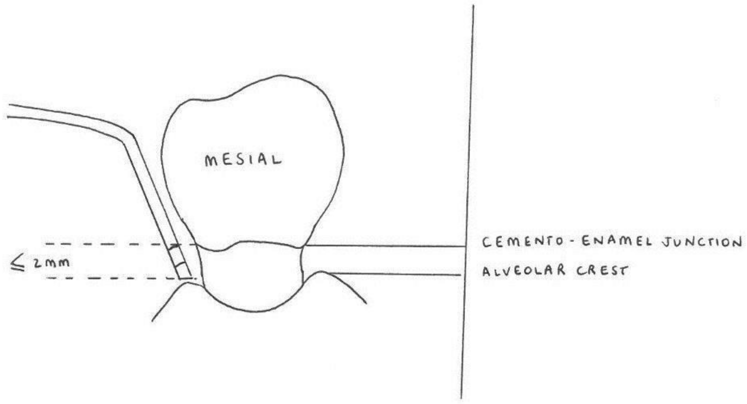
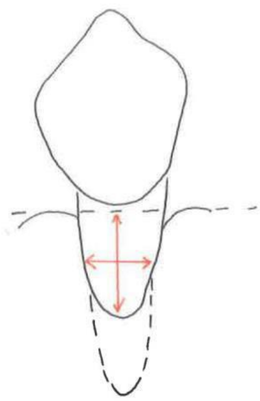


Figure 6. Determination of the position of the alveolar crest in relation to the cemento-enamel junction. A measurement of ≤ 2 mm indicated the tooth was periodontally healthy.

Each tooth was inspected on both its buccal and lingual/palatal surfaces for the presence of fenestrations and dehiscences. The degree of involvement was recorded by measuring the mesio-distal and apico-coronal dimension of each defect using the Hillson-Fitzgerald Dental Caliper.

For dehiscences, the mesio-distal dimension was measured at its widest point and the apico-coronal dimension from the mid-buccal or lingual/palatal surface of the affected root to the most apical extent of the defect in millimetres. An imaginary line adjoining the two interproximal alveolar bone crest peaks was used as a reference point from which the coronal measurement was taken. (Figure 7a)

For fenestrations the mesio-distal and apico-coronal dimensions were measured in millimetres at its widest point. (Figure 7b)



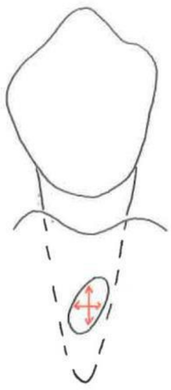


Figure 7a. Measurement of a dehiscence **Figure 7b.** Measurement of a fenestration

Fenestrations were further classified according to their location in relation to root length into three categories: at the level of the apical 1/3, at the level of the middle 1/3 and at the level of the coronal 1/3. (Figure 8) The mean root lengths were taken from Appendix 1.[44]

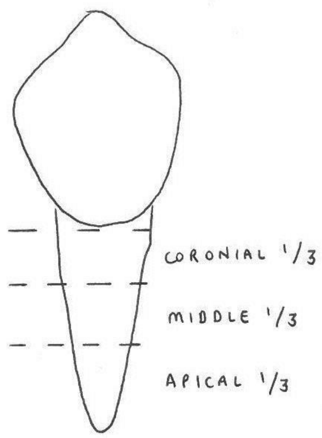


Figure 8. Classification of fenestrations into thirds

Using the Hillson-Fitzgerald Dental Caliper, the width of the teeth associated with fenestrations and/or dehiscences was measured to assess the tooth-to-jaw width relation.

The tooth size was established by measuring the tooth mid-buccal to mid-palatal/lingual at the level of the cemento-enamel junction. (Figure 9) The ridge width was measured 2 mm apically from the mesial interproximal alveolar crest. (Figure 9) If the tooth adjacent to the one with the alveolar defect was missing, the alveolar crest of the tooth on its contralateral side was used.

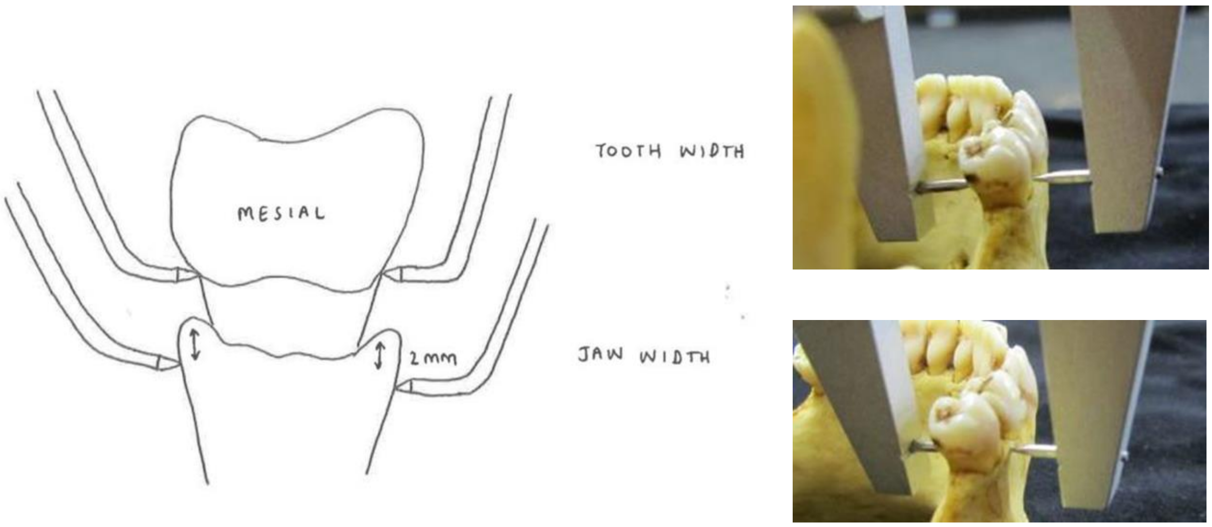


Figure 9. Tooth to Jaw width measurements- tooth width measured at the cemento-enamel junction; jaw width measured 2 mm apical to the alveolar crest.

The position of affected teeth in relation to the arch was also evaluated and classified as buccally, centrally, palatally or lingually with the use of a bendable copper arch wire. (Figure 4) To achieve this, the wire was placed along the central fossae line and the position of the malposed teeth thereafter topographically assessed. (Figure 10) A tooth was classified as out of the arch buccally or palatally/lingually if its fossa line was not in line with the central fossa line as determined by the use of the bendable copper wire.

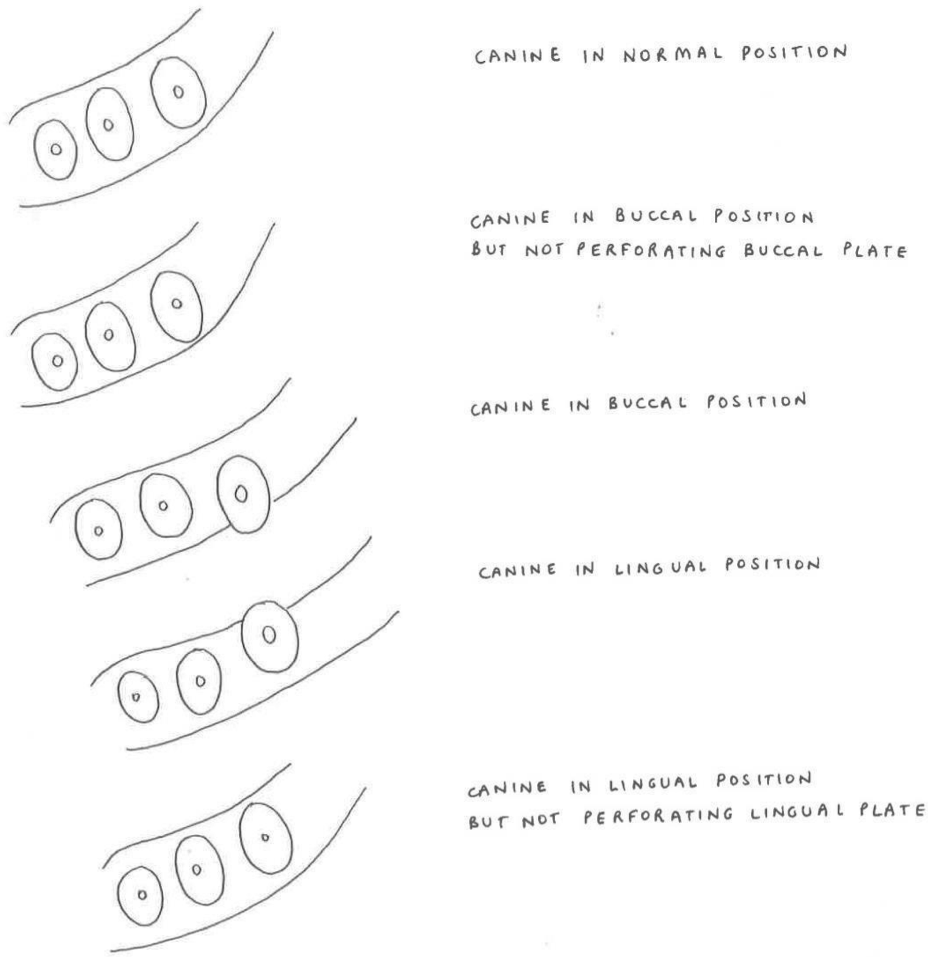


Figure 10. Position of affected teeth in relation to the arch

3.8 Statistical analysis

Different statistical tests were used for each objective. Cohen's kappa was used to measure inter-observer error.[41] It ascertained whether there was a discrepancy between the frequencies and descriptions of the defects recorded between and within examiners.[41] This measure was preferred to the Chi-squared test as it takes into account the agreement occurring by chance. Intra-observer error was measured using Lin's concordance correlation coefficient of reproducibility.[43]

A logistic regression model was used to determine which arch, teeth and teeth surfaces (buccal/palatal-lingual) are the most commonly affected by alveolar dehiscences and fenestrations.

Age was tested by random permutation for dehiscence and fenestration independently. This test will also be applied to test the potential sexual dimorphism of dehiscence and fenestration incidence. As multiple tests increase the type I error rate, significance was evaluated using the Holm-Bonferroni method.[45]

The anatomical position of fenestrations (apical, coronal or central) in relation to root length was presented as fractions and/ or percentages.

Due to counts being extremely low for certain populations the Chi-squared statistic is not reliable[46] and the Fisher's exact test was thus used to determine whether populations differed in their pattern of expressed alveolar defects (these tests were run in R).

CHAPTER 4: RESULTS

The inter- and intra-observer calibration results showed substantial agreement on all parameters (see Appendix 2; Table 2.1; Table 2.2; Table 2.3; Table 2.4)

4.1 Sample size, age and population group

Of the total 333 skulls evaluated for the presence of dehiscences and fenestrations, the majority were those of Black Males (207), followed by Black Females (75), White Males (25) and White Females (18); (Figure 11) . The mean age of the total sample (Figure 12A) was 50.1years, with a range from 13 to 80 years. The mean age among the groups differed significantly with the White samples significantly older than the Black samples. This was calculated using Tukey's pairwise post hoc analyses (Appendix 4; Table 4.3).The mean age of White Females was 62.8 years (Fig 12B), Black Females 45.5 years (Fig 12C), White Males 60.7 years (Fig 12D) and Black Males 49.6 years (Fig 12E). A total of six skulls were of a mixed race (4 females and 2 males) and the race of the remaining two were not specified (N/S; Fig 12F).

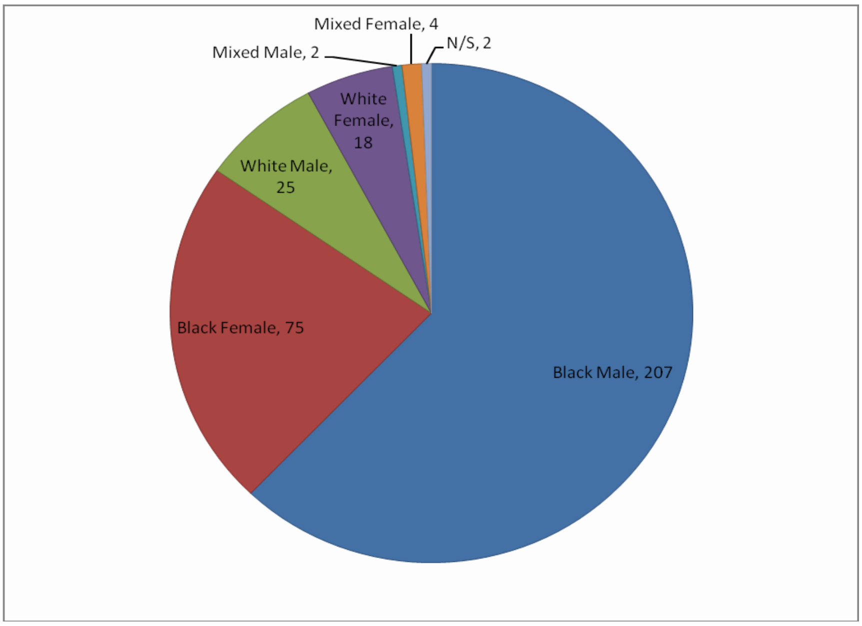


Figure 11. Sample size according to race

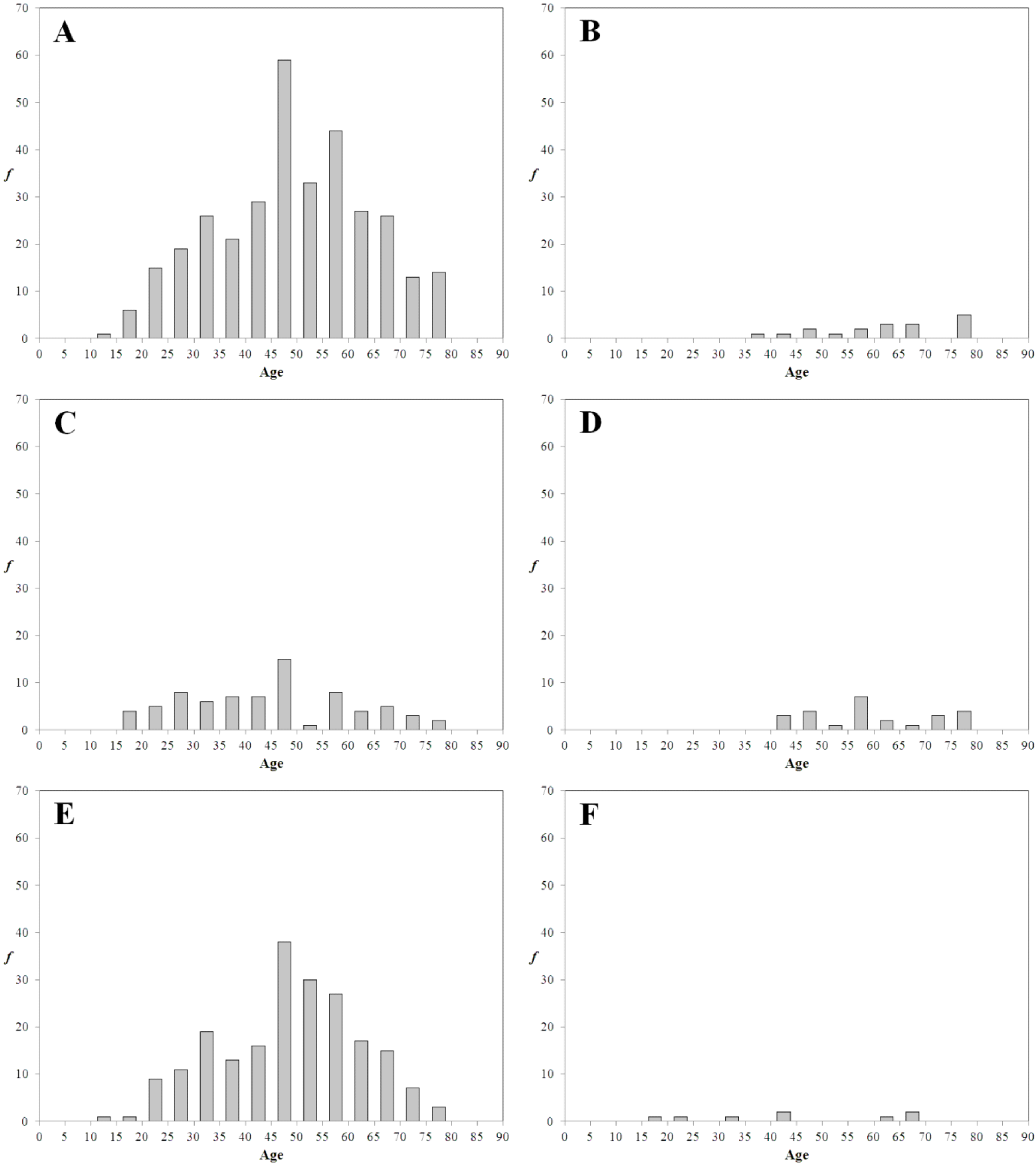


Figure 12. Frequency distributions of age according to race

	Female			Male			
Population	13-19	20-59	60+	13-19	20-59	60+	Total
EURO		7	11		13	12	**43**
MIXE	1	3	0		0	2	**6**
N/S		0	0		1	1	**2**
NDEB		1	1		0	0	**2**
PEDI		0	0		1	1	**2**
S.A.N.	1	17	4	1	37	4	**64**
SHAN		0	0		2	1	**3**
SOTO	1	9	6		23	16	**55**
SWAZ		2	0		5	3	**10**
TSON		0	0		5	1	**6**
TSWA		7	2		13	5	**27**
VEND		1	0		2	0	**3**
XOSA		6	2		17	4	**29**
ZULU		12	3		48	18	**81**
Total	**3**	**65**	**29**	**1**	**167**	**68**	**333**

Table 1. Population groups of skulls classified by gender and age.

The majority of the skulls assessed fell into the 20-59 age category. Only four individuals fell into the 13-19 age category. Over two thirds (70.87%) of the total sample was male with the predominant population group being the Zulus (24.32%). Overall 84.68% of the subjects were Black and 12.91% White (Table 1).

4.2 Distribution of Defects

A total of 6010 teeth were examined of which 2982 (49.6%) were maxillary teeth and 3028 mandibular teeth (50.3%). Although subtle differences existed in the prevalence of maxillary dehiscences (Fig 13A), maxillary fenestrations (Fig13C), total maxillary defects (Fig 13E), mandibular dehiscences (Fig 13B), mandibular fenestrations (Fig13D) and all mandibular defects (Fig 13F) between population groups; they were all not statistically significant.

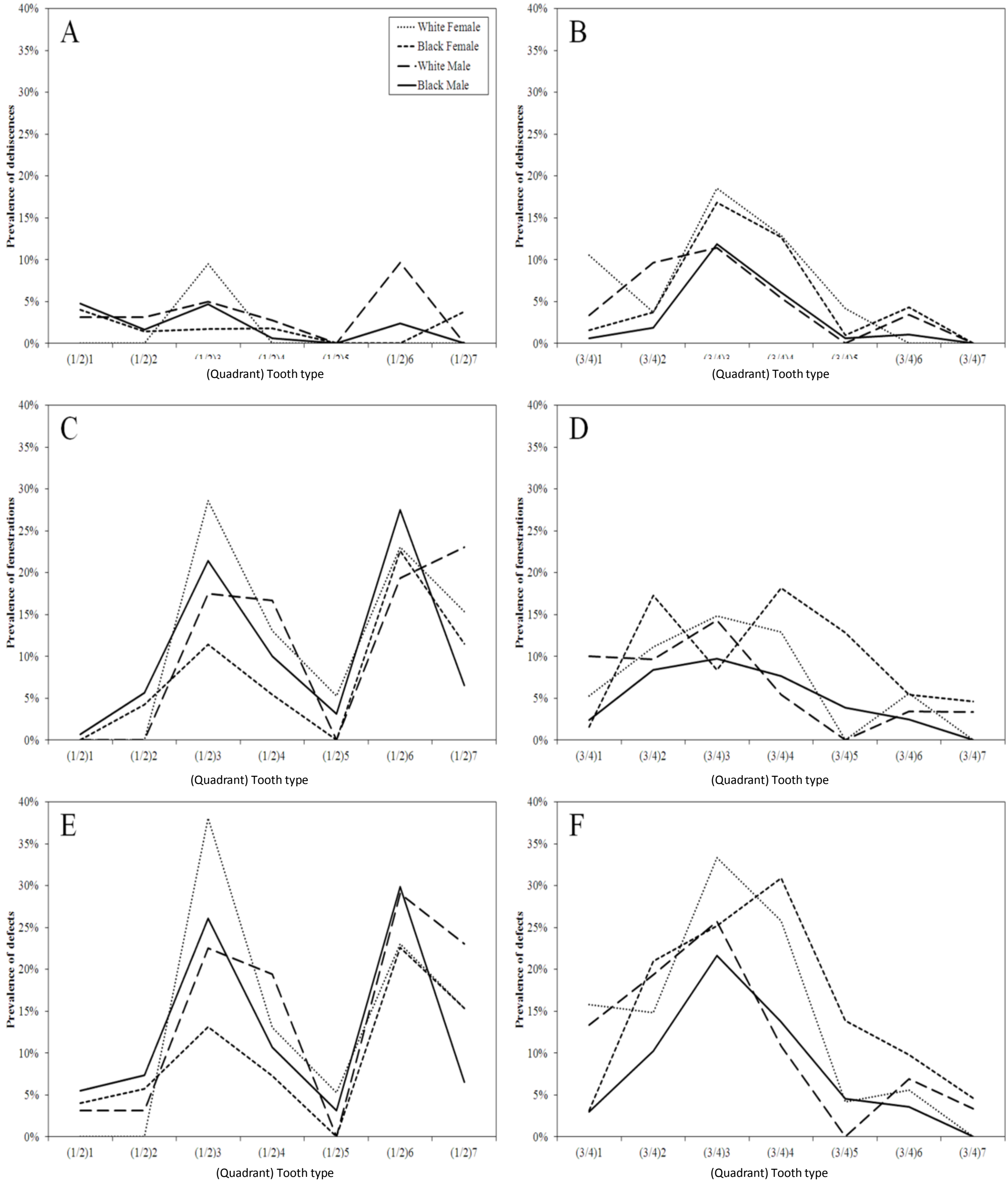


Figure 13- Frequency of defects at each tooth by population and sex

4.2.1 Maxilla

There were a total number of 418 defects observed in the maxilla, of which 52 were dehiscences and 366 fenestrations. (Table 3)

Dehiscences

Of the 52 dehiscences, twenty (38.4%) were located on the canines and eleven (21.1%) on the first molars. Six of the eleven dehiscences were located on the mesiobuccal root of the first molars (54.5%). Ten percent of canines associated with dehiscences were buccally located and another ten percent palatally located in relation to the central fossa line. The remainders (80%) were associated with centrally positioned teeth. Teeth #15, #17 and #25 were the only teeth which did not express dehiscences.

Fenestrations

Of the 366 fenestrations, 41.8% were located on the first molars, 27.3% on the canines and 13.9% on the first premolars. The majority of fenestrations (50.9%) were located on the distobuccal root and 47.0% on the mesiobuccal root of the first molars with 88.9% of molars associated with fenestrations centrally positioned. Only two fenestrations were identified palatally. One hundred fenestrations were identified on the maxillary canines, all of which were buccally located and 82% of which were associated with centrally positioned teeth. A total of 92.1 % of fenestrations located on the first premolar were buccally placed.

4.2.2 Mandible

There were a total of 352 alveolar defects observed in the mandible, 139 of which were dehiscences and 213 fenestrations. (Table 3)

Dehiscences

The canines (36.6%) and the first premolars (20.9%) were the teeth most commonly associated with dehiscences. All defects associated with these teeth were buccally located with 70% of involved canines and 82.5% of the affected first premolars centrally located in relation to the central fossa line. The remainder of the canine teeth were buccally (22.9%) and palatally (7.1%) positioned. The remainder of the first premolars were lingually positioned (10%) and buccally positioned (7.5%). Teeth #37, #45, #47 were the only teeth not associated with dehiscences.

Fenestrations

The first premolars had the highest incidence of fenestrations (27.7%), followed by the canines (24.9%) and the lateral incisors (18.8%). All fenestrations associated with the first premolars were buccally located with 74.6% of those teeth centrally positioned. Eight and a half percent of associated teeth were buccally positioned and 16.9% lingually positioned. Only one of the 53 fenestrations associated with the canines and one of the 40 fenestrations associated with the lateral incisors was lingually located, with both affected teeth centrally positioned.

	Maxillary							Mandibular						
FREQUENCIES	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Tooth present only unilaterally	53	78	63	69	82	73	74	37	54	56	67	78	77	75
No defect observed on tooth pair	93	104	141	177	195	112	188	118	121	150	164	178	161	176
Unilateral fenest.	4	2	3	1	0	0	1	2	7	27	15	4	4	0
Unilateral dehisc.	0	5	35	30	6	43	16	6	17	19	25	12	8	2
Both defects, unilaterally	0	0	3	0	0	3	0	0	0	0	1	0	1	0
Bilateral fenest.	1	0	3	0	0	0	0	0	0	15	6	0	0	0
Bilateral dehisc.	0	2	21	6	1	29	4	0	9	9	8	4	1	0
Bilaterally, but different defect	1	0	3	0	0	0	0	1	2	7	6	0	1	0
Both defects, bilaterally	0	1	0	1	0	1	0	0	0	0	0	0	0	0
Bilateral fenest. & unilateral dehisc.	1	0	1	0	0	1	0	0	0	0	1	0	0	0
Bilateral dehisc. & unilateral fenest.	0	0	3	1	0	2	0	0	0	3	1	0	0	0
Total unilateral defects	4	7	41	31	6	46	17	8	24	46	41	16	13	2
Total bilateral defects	3	3	31	8	1	33	4	1	11	34	22	4	2	0
Total pairs	100	114	213	216	202	191	209	127	156	230	227	198	176	178
Total teeth	253	306	489	501	486	455	492	291	366	516	521	474	429	431
PERCENTAGES OR TOTAL PAIRS														
No defect observed on tooth pair	93%	91%	66%	82%	97%	59%	90%	93%	78%	65%	72%	90%	91%	99%
Unilateral fenest.	4%	2%	1%	0%			0%	2%	4%	12%	7%	2%	2%	
Unilateral dehisc.		4%	16%	14%	3%	23%	8%	5%	11%	8%	11%	6%	5%	1%
Both defects, unilaterally			1%			2%					0%		1%	
Bilateral fenest.	1%		1%							7%	3%			
Bilateral dehisc.		2%	10%	3%		15%	2%		6%	4%	4%	2%	1%	
Bilaterally, but different defect	1%		1%					1%	1%	3%	3%		1%	
Both defects, bilaterally		1%		0%		1%								
Bilateral fenest. & unilateral dehisc.	1%		0%			1%					0%			
Bilateral dehisc. & unilateral fenest.			1%	0%		1%				1%	0%			
Total unilateral defects	4%	6%	19%	14%	3%	24%	8%	6%	15%	20%	18%	8%	7%	1%
Total bilateral defects	3%	3%	15%	4%	0%	17%	2%	1%	7%	15%	10%	2%	1%	

Table 2. Frequencies of unilateral and bilateral defects

T-pos in jaw	11	12	13	14	15	16	17	21	22	23	24	25	26	27	31	32	33	34	35	36	37	41	42	43	44	45	46	47	Grand Total
Dehiscences	**5**	**3**	**9**	**4**		**5**		**5**	**2**	**11**	**1**		**6**	**1**	**2**	**5**	**38**	**20**	**4**	**6**		**4**	**6**	**32**	**20**		**2**		**191**
B	**5**	**3**	**9**	**2**				**5**	**2**	**11**					**2**	**3**	**38**	**20**	**4**	**2**		**2**	**6**	**32**	**20**				**166**
BUCCAL	1		1							1					1		9			1			1	7	3				25
CENTRAL	4	3	7	2				4	2	9					1	1	28	18	4	1		2	5	21	15				127
LINGUAL																2	1	2						4	2				11
PALATAL			1					1		1																			3
DB													**1**							**1**									**2**
CENTRAL													1							1									2
MB						**4**							**2**							**2**							**2**		**10**
BUCCAL																											1		1
CENTRAL						2							2							1									5
LINGUAL						1														1							1		3
PALATAL						1																							1
P/L				**2**		**1**					**1**		**3**	**1**		**2**				**1**		**2**							**13**
BUCCAL																						1							1
CENTRAL				2							1					2						1							6
LINGUAL						1																							1
PALATAL													3	1						1									5
Fenestrations		**8**	**47**	**27**	**3**	**74**	**16**	**2**	**7**	**53**	**24**	**8**	**79**	**18**	**3**	**20**	**23**	**28**	**13**	**7**	**4**	**6**	**20**	**30**	**31**	**14**	**13**	**1**	**579**
B		**8**	**47**	**26**	**3**			**2**	**7**	**53**	**21**	**8**	**1**	**1**	**1**	**19**	**22**	**28**	**11**			**5**	**20**	**30**	**31**	**12**	**1**		**357**
BUCCAL		2	4						1	4		1				2	2	3					5	2	2				28
CENTRAL		6	41	22	3			2	4	41	14	4	1	1	1	10	19	22	7			5	12	25	22	7	1		270
LINGUAL				1							1					7	1	3	4				3	3	7	5			35
PALATAL			2	3					2	8	6	3																	24
DB						**40**	**16**				**1**		**38**	**14**					**1**	**2**	**2**					**1**	**5**	**1**	**121**
BUCCAL														2															2
CENTRAL						37	16				1		35	10					1	1	2					1	5	1	110
PALATAL						3							3	2						1									9
MB				**1**		**33**							**39**	**3**					**1**	**5**	**2**					**1**	**7**		**92**
CENTRAL				1		30							34	3					1	4	1					1	5		80
LINGUAL						1																					2		3
PALATAL						2							5							1	1								9
P/L						**1**					**2**		**1**		**2**	**1**	**1**					**1**							**9**
BUCCAL						1							1		1							1							4
CENTRAL											2				1	1	1												5
Grand Total	**5**	**11**	**56**	**31**	**3**	**79**	**16**	**7**	**9**	**64**	**25**	**8**	**85**	**19**	**5**	**25**	**61**	**48**	**17**	**13**	**4**	**10**	**26**	**62**	**51**	**14**	**15**	**1**	**770**

Table 3. Distribution and position of alveolar defects per tooth

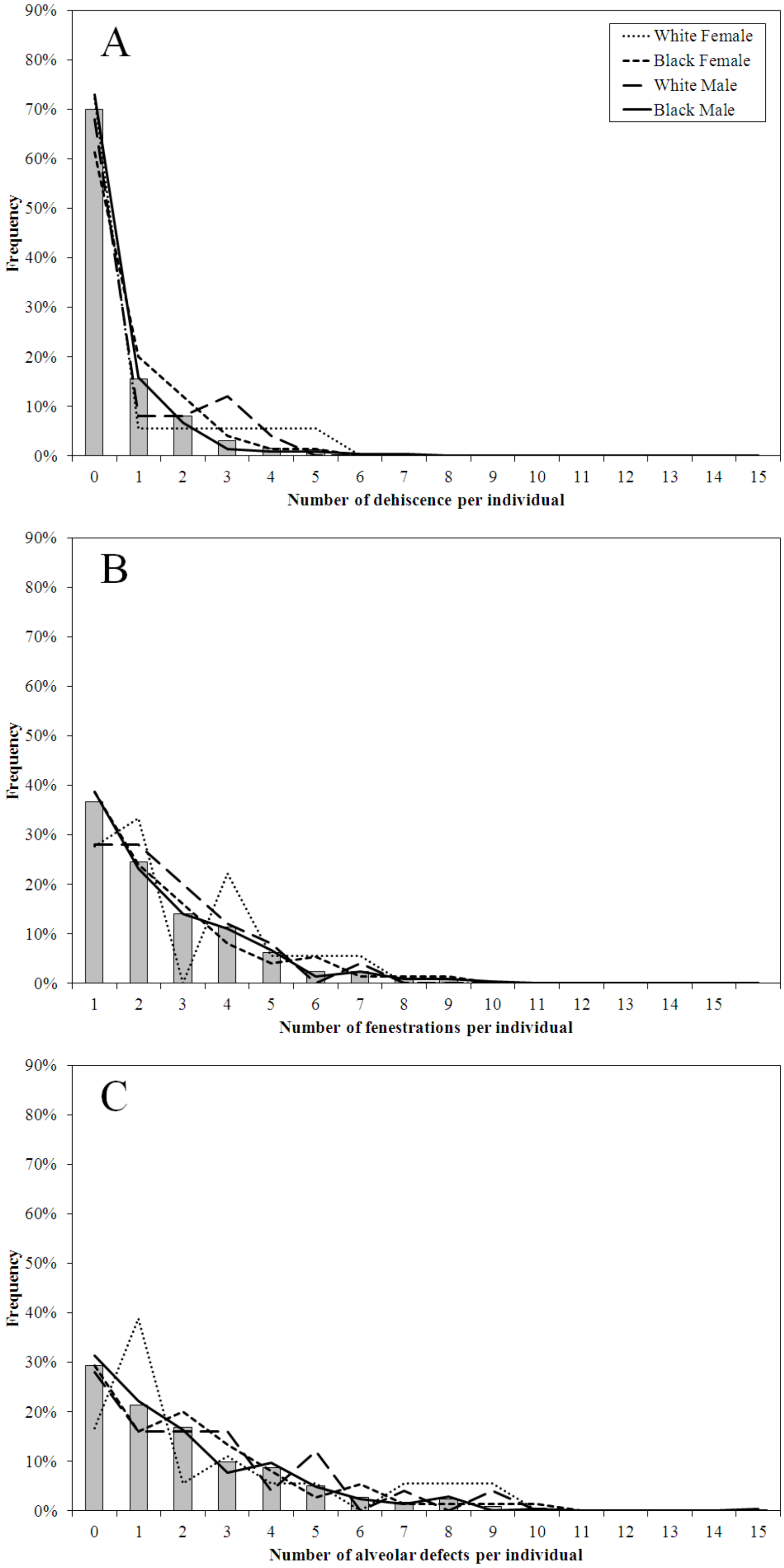


Figure 14. Frequency of defects observed in a single individual

The majority of skulls (70%) presented with no dehiscences followed by 15.6% with one dehiscence and 8.1% with 2 dehiscences. (Fig 14 A) Skulls with one and two dehiscences were found predominantly in Black females. (Appendix 5; Table 5.1)

Just over a third of skulls (36.6%) presented with no fenestrations. (Fig 14B) The remaining 63.4% of skulls displayed one or more of these defects. White Females were most often associated with one fenestration (33.3%), peaking again at three fenestrations (22.2%). White males were the group most commonly associated with two fenestrations (20%). A Black Male's skull displayed nine fenestrations; the highest number of fenestrations recorded in the sample. (Appendix 5; Table 5.2)

A total of 98 skulls (29.4%) presented with neither of the two alveolar defects. (Fig 14C) The remaining 70.6% of skulls presented with one or more defects. A Black Male's skull exhibiting fifteen alveolar defects represented the highest number of defects found in a single individual. (Appendix 5; Table 5.3)

Maxilla versus mandible

Dehiscences

There were a number of significant differences (Monte Carlo p=0.0002) between frequencies of dehiscences at each tooth type. The frequency pattern of dehiscences at the central incisors (#11,21,31,41) differed significantly from that at the canines (#13,23,33,43) and first premolars (#14,24,34,44), while the pattern at the first premolars (#14,24,34,44) also differed from that at the first molars (#16,26,36,46;Figure 15).

There was a greater number of dehiscences associated with the maxillary central incisors (#11,21) compared to the mandibular central incisors (#31,41). There were more dehiscences associated with the mandibular canines (#33, 43) and first premolars (#34, 44) compared to the maxilla (#13,23,14,24). The increased association of the mandibular first premolar (#34, 44) with the presence of dehiscences was significantly different from that in both maxillary and mandibular first molars (#16,26,36,46) which showed a low prevalence of dehiscences.(Figure 15)

To locate specific differences, pairwise post-hoc chi-squared tests were performed and significant values adjusted for multiple comparisons using the Bonferroni method. (Table 4)

	1	2	3	4	5	6	7
1		1.0000	***0.0088****	***0.0004****	0.3708	1.0000	1.0000
2	3.88845		1.0000	1.0000	1.0000	1.0000	1.0000
3	12.4444	0.6143		1.0000	1.0000	0.0829	1.0000
4	18.5185	3.4927	2.45455		1.0000	***0.0038****	0.1898
5	5.62963	1.6667	1.12913	0.49495		0.9145	0.5323
6	0.42308	2.0297	8.30769	14	4.07407		1.0000
7	0.48485	1.9479	3.37037	6.81481	5	0.76768	

Table 4. Pairwise comparisons between observed frequencies of dehiscences in the maxilla and mandible. Values below the diagonal are the chi squared values and above are the Bonferroni corrected p values. Significant values are marked with an asterisk.

Fenestrations

There were multiple significant differences (Monte Carlo $p < 0.0001$) in the frequency pattern of fenestrations between teeth of the maxilla and mandible. The most significant pattern was that seen at the first molars (#16,26,36,46) differing to that of all teeth except the second molars (#17,27,37,47). The pattern of frequency of fenestrations at the second molars (#17,27,37,47) also differed from all other teeth except the canines(#13,23,33,43) and first molars (#16,26,36,46;Table 5).

	1	2	3	4	5	6	7
1		1.0000	**_0.0106*_**	0.6203	1.0000	**_0.0000*_**	**_0.0000*_**
2	1.02736		**_0.0000*_**	0.2161	1.0000	**_0.0000*_**	**_0.0000*_**
3	12.0895	25.925		**_0.0441*_**	**_0.0033*_**	**_0.0002*_**	0.2106
4	4.73608	6.5841	9.46131		1.0000	**_0.0000*_**	**_0.0002*_**
5	1.71498	0.3954	14.2857	2.49336		**_0.0000*_**	**_0.0000*_**
6	38.8664	71.902	19.3347	48.5921	50.3802		1.0000
7	22.6264	34.379	6.63014	19.2065	24.297	0.02929	

Table 5. Pairwise comparisons between observed frequencies of fenestrations in the maxilla and mandible. Values below the diagonal are the chi squared values and above are the Bonferroni corrected p values. Significant values are marked with an asterisk.

Total alveolar defects

There was a significant difference between arches when all defects were considered (Monte Carlo $p<0.0001$).However, the pattern at the molar teeth (#16,26,36,46,17,27,37,47) was the only one differing significantly from that observed at the remaining teeth. Maxillary molars (# 16,26), had a higher frequency of defects than the mandibular molars (#36,46), this is the opposite to that seen at the remaining teeth. First and second molars (#16,26,36,46,17,27,37,47), differed significantly from every other tooth except each other. There is also a difference between the frequency pattern seen at the lateral incisor (#12,22,32,42) and the canine (#13,23,33,43;p=0.0181).

	1	2	3	4	5	6	7
1		1.0000	1.0000	1.0000	1.0000	**_0.0001*_**	**_0.0047*_**
2	2.76022		**_0.0181*_**	1.0000	1.0000	**_0.0000*_**	**_0.0000*_**
3	0.20135	11.^{10}1		0.1907	0.2684	**_0.0000*_**	**_0.0002*_**
4	0.72587	1.7631	6.80704		1.0000	**_0.0000*_**	**_0.0000*_**
5	1.87064	0.0259	6.19922	0.82388		**_0.0000*_**	**_0.0000*_**
6	20.169	70.39	48.5481	73.954	50.1193		1.0000
7	13.6073	37.25	19.9216	33.6585	28.6887	0.24089	

Table 6. Pairwise comparisons between observed frequencies of both fenestrations and dehiscence in the maxilla and mandible. Values below the diagonal are the chi squared values and above are the Bonferroni corrected p values. Significant values are marked with an asterisk.

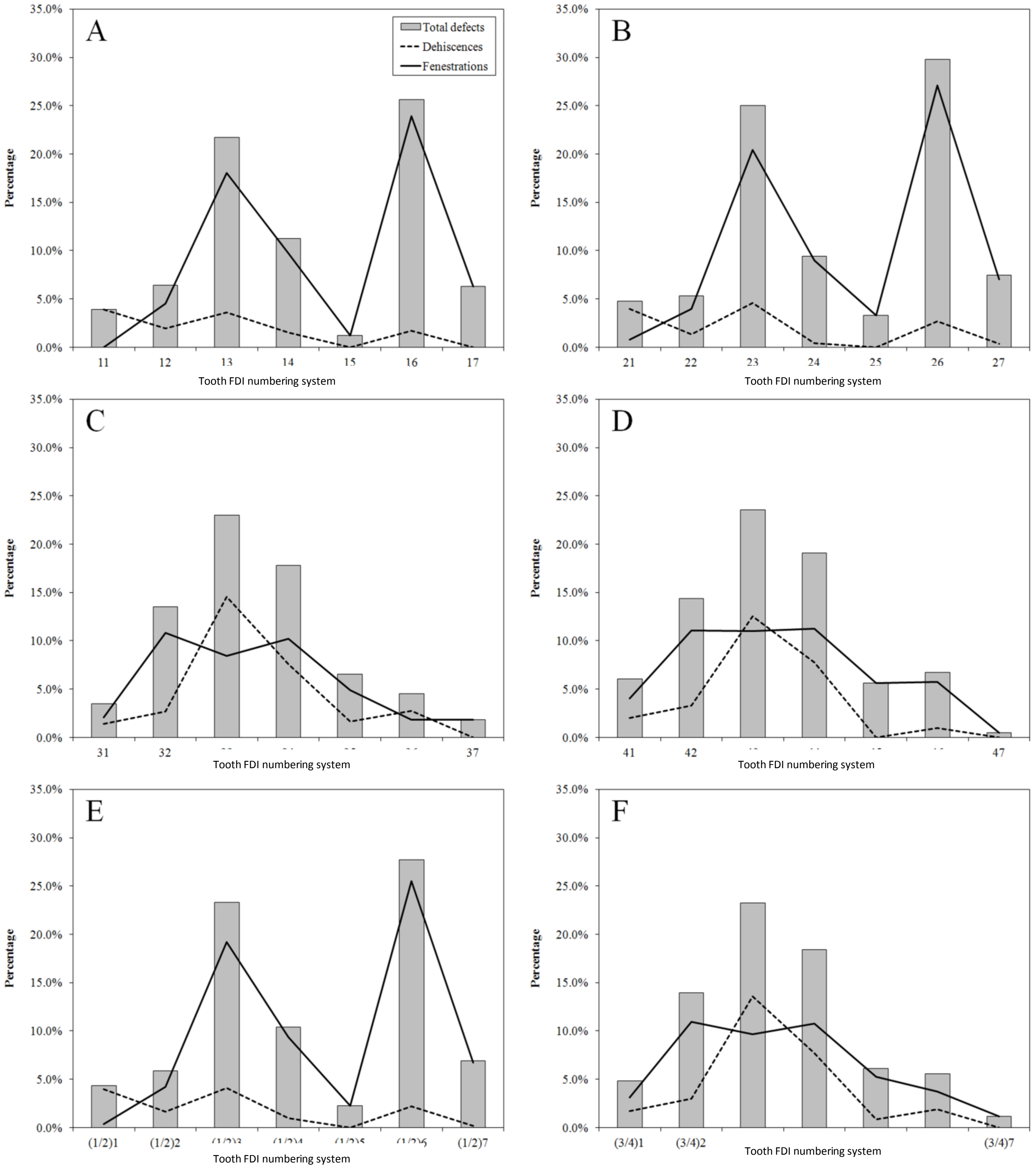


Figure 15. Frequency of defects by tooth per quadrant

Left versus right quadrants

The first and second quadrants showed very similar patterns with regards to distribution of dehiscences and fenestrations as did the third and fourth quadrants. No significant differences were found between the frequencies observed in the left and right quadrants. (Maxilla - Chi2=3.5818, Monte Carlo p=0.6865 (n/s); Mandible - Chi2=5.8056, Monte Carlo p=0.346 (n/s)).

Fenestrations

Owing to the fact that no significant differences were found between the frequencies observed in the left and right quadrants, counts were pooled for further analysis. Maxilla - Chi2=3.5883, Monte Carlo p=0.7696 (n/s); Mandible - Chi2=6.2382, Monte carlo p=0.4116 (n/s)).

Differences between dehiscences and fenestrations

To locate specific differences, pairwise post-hoc chi-squared tests were performed and significant values (Maxilla - Chi2=68.257, Monte Carlo p<0.0001 (sig. diff)) adjusted for multiple comparisons using the Bonferroni method.[44] The pattern observed at the central incisor(#11,21,31,41) regarding dehiscences and fenestrations differed significantly from that at the remaining teeth. (Table 7; Figure 15E)

	1	2	3	4	5	6	7
1		***0.0202****	***0.0000****	***0.0000****	***0.0004****	***0.0000****	***0.0000****
2	10.8977		1.0000	1.0000	1.0000	0.2089	0.1607
3	29.6035	1.0605		1.0000	1.0000	0.5169	0.6767
4	33.0764	3.6022	1.75484		1.0000	1.0000	1.0000
5	18.3333	3.6921	2.29741	1.14887		1.0000	1.0000
6	55.8647	6.6445	5.05072	0.13445	0.94176		1.0000
7	34.8226	7.1126	4.58657	1.41104	0.33088	1.04356	

Table 7. Pairwise comparisons between observed frequencies of dehiscences and fenestrations in the maxilla. Values below the diagonal are the chi squared values and above are the Bonferroni corrected p values. Significant values are marked with an asterisk. Values 1-7 represent teeth numbers where 1 is the central incisor and 7 is the second molar.

To locate specific differences, pairwise post-hoc chi-squared tests were performed and significant values (Mandible - Chi2=36.043, Monte Carlo p<0.0001 (sig. diff)) adjusted for multiple comparisons using the Bonferroni method. The frequencies of dehiscences and fenestrations at the mandibular canine (#33,43) differs from the pattern observed at the lateral incisor(#12,22,32,42) and second premolar (#15,25,35,45;Table 8;Figure15F).

	1	2	3	4	5	6	7
1		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.18452		***0.0002****	0.3112	1.0000	1.0000	1.0000
3	2.60285	19.404		0.3130	***0.0004****	0.5217	0.2107
4	0.17908	5.9378	5.92796		0.1235	1.0000	1.0000
5	2.74158	0.7337	18.5344	7.58624		1.0000	1.0000
6	0.02227	1.1942	5.03497	0.55556	2.86272		1.0000
7	2.42347	1.342	6.62879	3.44945	0.78161	2.30159	

Table 8. Pairwise comparisons between observed frequencies of dehiscences and fenestrations in the mandible. Values below the diagonal are the chi squared values and above are the Bonferroni corrected p values. Significant values are marked with an asterisk. Values 1-7 represent teeth numbers where 1 is the central incisor and 7 is the second molar.

	Column Labels																											
Row Labels	**12**	**13**	**14**	**15**	**16**	**17**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**Grand Total**
B																												
Average of A-C	3,37	3,70	2,54	3,30			3,46	3,32	4,24	2,35	1,65	4,89	2,60	1,23	1,70	3,00	3,90	4,49			2,01	2,17	2,35	2,98	2,99	5,15		3,13
Count of A-C	8	45	26	3			2	7	52	20	8	1	1	1	19	22	28	11			5	20	29	30	12	1		351
Average of M-D	1,38	1,53	1,03	1,75			1,26	1,38	1,54	1,01	1,08	1,95	1,66	1,40	1,05	1,60	1,68	2,21			0,85	1,14	1,45	1,34	1,84	2,75		1,42
Count of M-D	8	45	26	3			2	7	52	20	8	1	1	1	19	22	28	11			5	20	29	30	12	1		351
DB																												
Average of A-C					3,19	2,06				0,85		2,45	2,38					3,39	5,44	2,05					5,69	1,24	1,26	2,63
Count of A-C					38	16				1		38	14					1	2	2					1	5	1	119
Average of M-D					1,45	1,23				0,03		1,11	1,09					1,35	1,52	2,08					1,87	1,11	1,81	1,26
Count of M-D					38	16				1		38	14					1	2	2					1	5	1	119
L																												
Average of A-C														1,38	2,37	4,32					2,28							2,35
Count of A-C														2	1	1					1							5
Average of M-D														0,72	0,69	4,82					0,81							1,55
Count of M-D														2	1	1					1							5
MB																												
Average of A-C			3,78		3,01					2,25		2,92	3,01					5,31	1,41	1,79					8,60	3,02		2,95
Count of A-C			1		33					1		39	4					1	5	2					1	7		94
Average of M-D			0,85		1,44					0,53		1,50	1,23					1,73	0,84	1,49					1,35	1,55		1,42
Count of M-D			1		33					1		39	4					1	5	2					1	7		94
P																												
Average of A-C					0,47					0,79		2,45																1,24
Count of A-C					1					1		1																3
Average of M-D					0,77					0,55		1,02																0,78
Count of M-D					1					1		1																3
Total Average of A-C	**3,37**	**3,70**	**2,59**	**3,30**	**3,07**	**2,06**	**3,46**	**3,32**	**4,24**	**2,21**	**1,65**	**2,72**	**2,52**	**1,33**	**1,73**	**3,05**	**3,90**	**4,47**	**2,56**	**1,92**	**2,05**	**2,17**	**2,35**	**2,98**	**3,59**	**2,50**	**1,26**	**2,98**
Total Count of A-C	**8**	**45**	**27**	**3**	**72**	**16**	**2**	**7**	**52**	**23**	**8**	**79**	**19**	**3**	**20**	**23**	**28**	**13**	**7**	**4**	**6**	**20**	**29**	**30**	**14**	**13**	**1**	**572**
Total Average of M-D	**1,38**	**1,53**	**1,03**	**1,75**	**1,44**	**1,23**	**1,26**	**1,38**	**1,54**	**0,93**	**1,08**	**1,31**	**1,15**	**0,95**	**1,03**	**1,74**	**1,68**	**2,11**	**1,03**	**1,78**	**0,84**	**1,14**	**1,45**	**1,34**	**1,81**	**1,48**	**1,81**	**1,38**
Total Count of M-D	**8**	**45**	**27**	**3**	**72**	**16**	**2**	**7**	**52**	**23**	**8**	**79**	**19**	**3**	**20**	**23**	**28**	**13**	**7**	**4**	**6**	**20**	**29**	**30**	**14**	**13**	**1**	**572**

Table 9. Apico-coronal and mesio-distal dimensions of fenestrations

The total average apico-coronal dimension of fenestrations for all teeth affected by fenestrations was 2.98 mm which was higher than the mesio-distal dimension at 1.38 mm. (Table 9) The fenestration with the highest average apico-coronal dimension was on the mandibular left second premolar (#35) followed by the maxillary left canine (#23). Similarly, the widest mesio-distal dimension was found on the left second mandibular premolar (#35) followed by the right mandibular second premolar. (Table 9)

The total average apico-coronal measurement of all teeth affected by dehiscences was 6.49 mm as compared to the total average mesio-distal measurement of 2.92 mm. (Table 10) The teeth with the highest average apico-coronal dimension in descending order were the left mandibular central incisor (#31) followed by the right first maxillary molar (#16) and the right mandibular lateral incisor (#42). The teeth with the highest average mesio-distal dimensions were the right maxillary canine (#13) followed by the right maxillary canine (#23) and right maxillary first molar (#26). (Table 10)

	Column Labels																					
Row Labels	**11**	**12**	**13**	**14**	**16**	**21**	**22**	**23**	**24**	**26**	**27**	**31**	**32**	**33**	**34**	**35**	**36**	**41**	**42**	**43**	**44**	**46 Grand Total**
B																							
Average of A-C	8,01	4,36	7,63	7,72		6,07	4,37	6,83				8,53	5,58	6,34	7,01	6,34	5,87	6,83	8,08	5,66	6,95		6,54
Count of A-C	5	3	9	2		5	2	11				2	3	38	20	4	2	1	6	32	20		165
Average of M-D	3,71	3,03	3,93	2,74		3,49	2,10	3,89				1,60	1,42	3,19	2,34	2,55	1,88	2,63	2,52	2,95	2,42		2,93
Count of M-D	5	3	9	2		5	2	11				2	3	38	20	4	2	1	6	32	20		165
DB																							
Average of A-C										5,27							7,22						6,25
Count of A-C										1							1						2
Average of M-D										2,18							2,15						2,17
Count of M-D										1							1						2
L																							
Average of A-C									4,53	6,56	5,10		5,46				4,44	6,21					5,61
Count of A-C									1	2	1		2				1	2					9
Average of M-D									2,84	4,52	3,59		2,44				5,10	1,75					3,22
Count of M-D									1	2	1		2				1	2					9
MB																							
Average of A-C					8,23					5,88							5,09					6,31	6,75
Count of A-C					4					2							2					2	10
Average of M-D					2,01					2,46							1,89					2,08	2,09
Count of M-D					4					2							2					2	10
P																							
Average of A-C				4,62	7,79					6,50													5,88
Count of A-C				2	1					1													4
Average of M-D				2,27	6,42					6,26													4,31
Count of M-D				2	1					1													4
Total Average of A-C	**8,01**	**4,36**	**7,63**	**6,17**	**8,14**	**6,07**	**4,37**	**6,83**	**4,53**	**6,11**	**5,10**	**8,53**	**5,53**	**6,34**	**7,01**	**6,34**	**5,60**	**6,42**	**8,08**	**5,66**	**6,95**	**6,31**	**6,49**
Total Count of A-C	**5**	**3**	**9**	**4**	**5**	**5**	**2**	**11**	**1**	**6**	**1**	**2**	**5**	**38**	**20**	**4**	**6**	**3**	**6**	**32**	**20**	**2**	**190**
Total Average of M-D	**3,71**	**3,03**	**3,93**	**2,51**	**2,89**	**3,49**	**2,10**	**3,89**	**2,84**	**3,73**	**3,59**	**1,60**	**1,83**	**3,19**	**2,34**	**2,55**	**2,46**	**2,04**	**2,52**	**2,95**	**2,42**	**2,08**	**2,92**
Total Count of M-D	**5**	**3**	**9**	**4**	**5**	**5**	**2**	**11**	**1**	**6**	**1**	**2**	**5**	**38**	**20**	**4**	**6**	**3**	**6**	**32**	**20**	**2**	**190**

Table 10. Apico-coronal and mesio-distal measurements of dehiscences

Tooth to jaw ratio

The average tooth to jaw size ratio for teeth displaying fenestrations was 1.15 indicating an almost equal tooth to jaw width size. (Table 11) The highest tooth to jaw ratio was that of tooth #21 at 1.76. In this instance however, only two teeth were measured. Teeth presenting with dehiscences had a higher tooth to jaw size ratio (1.33) than those with fenestrations with tooth #46 having the highest tooth to jaw ratio of 2.50. (Table 12)

Tooth to jaw ratio

	Column Labels																											
Values	12	13	14	15	16	17	21	22	23	24	25	26	27	31	32	33	34	35	36	37	41	42	43	44	45	46	47	Grand Total
Average of Ratio	1,00	1,27	1,16	1,07	1,11	1,14	1,76	1,27	1,24	1,09	1,13	1,07	0,99	1,20	1,02	1,24	1,17	1,11	1,20	1,12	1,17	1,06	1,28	1,17	1,10	1,21	0,67	1,15
Count of Ratio	8	45	27	3	72	16	2	7	52	23	8	79	19	3	20	23	28	13	7	4	6	20	29	30	14	13	1	572

Table 11. Tooth to jaw ratio (as is to 1) of teeth associated with fenestrations

Tooth to jaw ratio

	Column Labels																						
Values	11	12	13	14	16	21	22	23	24	26	27	31	32	33	34	35	36	41	42	43	44	46	Grand Total
Average of Ratio	1,42	1,36	1,32	1,38	1,31	1,37	1,29	1,50	1,25	1,16	1,16	1,33	1,11	1,29	1,28	1,32	1,19	1,26	1,26	1,32	1,39	2,50	1,33
Count of Ratio	5	3	9	4	5	5	2	11	1	6	1	2	5	38	20	4	6	3	6	32	20	2	190

Table 12. Tooth to jaw ratio (as is to 1) of teeth associated with dehiscences

Teeth numbers	12	13	14	15	16	17	21	22	23	24	25	26	27	31	32	33	34	35	36	37	41	42	43	44	45	46	47	Grand Total
CORONAL1/3			1										1	1	1	2	2			1		1	1			1		12
MIDDLE 1/3	1	3	1		6		1	1	5	1		5	1	2	15	13	9	3	3	3	4	15	15	11	5	8		131
APICAL 1/3	7	42	25	3	66	16	1	6	47	22	8	74	17		4	8	17	10	4		2	4	13	19	9	4	1	429
Grand Total	**8**	**45**	**27**	**3**	**72**	**16**	**2**	**7**	**52**	**23**	**8**	**79**	**19**	**3**	**20**	**23**	**28**	**13**	**7**	**4**	**6**	**20**	**29**	**30**	**14**	**13**	**1**	**572**

Table 13. Location of fenestrations in relation to root length

The majority of fenestrations (75%) were located in the apical 1/3, followed by 22.9% in the middle third and 2.9% in the coronal third.(Table 13) Maxillary fenestrations were generally located in the apical 1/3 (77.9%) with the first molars the most commonly associated teeth in this region. In the mandible, fenestrations were most commonly located in the middle 1/3(80.9%) with the lateral incisors and canines, most commonly affected. (Table 13)

To test whether sex, population, age and the number of teeth predisposed one to having an alveolar defect, a logistic regression was performed (using R). (Table 14)

Variable	Estimate	Std. Error	z value	P
sex	0.253732	0.292496	0.867	0.386
population	0.494438	0.424327	1.165	0.244
age	-0.010448	0.009586	-1.09	0.276
n. teeth	0.089441	0.019498	4.587	**4.49E-06***

Table 14. Results of the logistic regression

Gender, age and population had no impact on the presence of alveolar defects in this sample. Only the number of teeth present was significantly associated with the presence or absence of one or more alveolar defects. To investigate this further, a scatter plot (Figure 16) was drawn for the frequency of individuals with particular numbers of teeth, separately for individuals with and without defects.

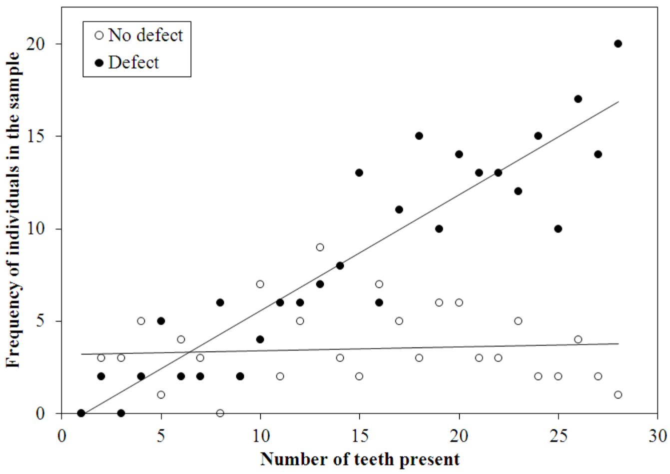


Figure 16. A scatter plot depicting the frequency of individuals with particular numbers of teeth presenting with and without defects

The association between tooth number and observed defects is supported by a strong correlation (r=0.91993, p<0.0001), and it particularly interesting if one considers that no pattern was observed for individuals with no defect (r=0.074155, p=0.7129; although a concave quadratic function may approximate it). This would suggest that defects occur at a set rate and increasing the number of teeth would increase the likelihood of finding a defect.

To further test the effects of sex, age, population and tooth number on the presence of defects, a Manova was performed between these independent variables and the number of observed fenestrations and dehiscences in an individual.(Table 15)

MANOVA

Tests on independent variables

	Wilks lambda	F	df1	df2	P
Sex	0.9923	1.233	2	319	0.2927
population	0.9949	0.8118	2	319	0.445
Age	0.9912	1.423	2	319	0.2426
n. teeth	0.8893	19.85	2	319	7.51E-09*

Tests on dependent variables

	R^2	F	df1	df2	P
Fraw	0.1103	9.919	4	320	1.41E-07*
Draw	0.06907	5.936	4	320	0.0001281*

Table 15. The effects of sex, age, population and tooth number on the number of observed fenestrations and dehiscences in an individual

Again, only the number of teeth present was statistically associated with both the number of fenestrations and dehiscences observed.

When the raw defect counts were swopped for the percentage of the present teeth, no variables were found to be associated (Overall defects: ANOVA, $F_{4,320}$=1.4987, p=0.20232; Dehiscences: ANOVA, $F_{4,320}$=2.122, p=0.077869; Fenestrations: ANOVA, $F_{4,320}$=1.1829, p=0.3182).

CHAPTER 5: DISCUSSION

The incidence and distribution of dehiscences and fenestrations have been documented by different authors in different population groups with noteworthy results. This study demonstrates that South African skulls are also commonly affected by these alveolar defects.

Population differences

The 333 skulls evaluated were predominantly of Black individuals with the total number of males exceeding that of females. Furthermore, skulls of Black individuals were significantly younger than those of the White individuals. The large discrepancy in number between Black and White individuals in the present study and in the Raymond A. Dart collection may be reflective of the country's demographics as confirmed by the 2011 South African census. The large discrepancy in numbers between Black and White individuals in this study may also be as a result of bodies that are not claimed amongst the Black population group, and fewer body donations by White individuals for research purposes.

There was no significant association between the prevalence of alveolar defects and population groups or gender. This lack of significance could however be due to a discrepancy between Black and White individuals within the study sample. It was difficult to compare our findings to those of the previous studies, as most of these studies usually looked at only one racial group at a time,[3, 12, 13, 17-19] and the influence of gender on the prevalence of alveolar defects was seldom assessed. The study by Rupprecht *et al.* as an exception compared African-American and Caucasian subjects and found both alveolar defects to be higher amongst the females with no significant difference between the two racial groups.[15]

Previous studies reported a decrease in the prevalence of alveolar defects with increasing age.[13, 15] The possible explanation for this is that, teeth are most likely to be lost with increased age, thus reducing the number of teeth at risk to have an alveolar defect.[47] Our study also confirmed this by showing that the higher the number of teeth present on a skull, the higher the number of defects were observed.

On the contrary, Tal noted that there was an inconsistent pattern with the frequency of defects and increasing age[19], and similarly Larato could not find any correlation between the number of alveolar defects and age.[16] This concurred with our findings where age did not affect whether one or more defects were observed in an individual.

The 6010 teeth examined in our study (the highest number of teeth examined to date with regards to this topic) displayed a total of 770 alveolar defects of which 75.2% were fenestrations and 24.8% were dehiscences. A total of 12.8% of teeth examined displayed alveolar defects. This is lower than 20.1% and 14.5% recorded by Elliot and Bowers and Edel *at al.* respectively[13, 14], but higher than the 6.3% reported by Abdelmalek and Bissada and the 7.5% found by Larato.[16, 21] Surprisingly, this is the exact percentage recorded by Nimigean *et al.* and extremely close to the percentage recorded by Rupprecht *et al.* (13%) even though their sample size and the number of teeth examined was nearly half of those in this study.[3, 15]

Past studies have attributed the variability in the prevalence of alveolar defects to race. This is based on a hypothesis that possible aetiological factors to these defects could be genetically determined.[21] This study's results, which parallel those of Rupprecht *et al.* and Nimigean *et al.*, within its limitation of a smaller sample size for Whites would contradict this hypothesis.[3, 15]

Of the 12.8% affected teeth, 9.6% represented those associated with fenestrations and 3.17% of those associated with dehiscences. These findings are comparable to those reported in earlier studies. Edel found 9.70% fenestrations and 4.40% dehiscences in 990 teeth examined belonging to 87 Bedouins.[13] Rupprecht *et al.* found 9.0% of teeth associated with fenestrations and 4.1% with dehiscences in 146 Modern American skulls examined[15], whilst Nimigean *et al.* found fenestrations in 8.56% and dehiscences in 4.25% of all teeth examined.[3]

The most worthwhile comparison would be with the results of Volchansky & Vieira, Tal and Volchansky and Cleaton-Jones who conducted their studies on skulls of a South African population.[17-19] They however only examined the maxilla or the mandible in isolation and not both jaws together.

To accurately compare the results of our study with those of our fellow peers, the percentages of the teeth associated with alveolar defects seen in the maxilla and mandible are reported separately. In our study, 6.96% of maxillary teeth and 5.86% of mandibular teeth were associated with defects. This is comparable to Volchansky and Vieira where 8.4% of maxillary teeth were associated with defects[18] but almost half the figures reported by Tal who reported 10.6% of the mandibular teeth associated with defects.[19] This could be as a result of the examination of all mandibular teeth (including wisdom teeth) and the use of earlier definitions from the Journal of Periodontology of Terms (1977)[11] which did not take numerical stipulations into account when identifying dehiscences.

This study recorded 1.74% of maxillary teeth associated with dehiscences and 12.27% with fenestrations. These findings concur with those recorded by Volchansky and Vieira who recorded 1.79% involvement in the 100 maxillae and 1400 teeth examined.[18]

On the contrary, this study showed nearly twice as many teeth displaying fenestrations than did Volchansky and Vieira at 6.64%.[18] This could be as a result of only the buccal/labial alveolar plates of the maxilla being evaluated for alveolar defects in their study.

Of the 3028 mandibular teeth examined in our study, 4.59% were associated with dehiscences and 7.03% with fenestrations. These are comparable to Volchansky and Cleaton-Jones who examined 643 teeth and found 6.5% of those associated with dehiscences and 6.2% with fenestrations[17] but inconsistent with Tal who found 7.1% of teeth associated with dehiscences and 3.5% with fenestrations in 1077 mandibular teeth examined.[19]

The total amount of defects in the maxilla (14%) exceeded that of the mandible (11.6%) which is in agreement with Kawasaki *et al.*[48] but opposite to Abdelmalek and Bissada who found more defects in the mandibles of an Egyptian population.[21] This is probably due to the majority of jaws examined being those of the mandible.

The distribution of alveolar defects in the maxilla and the mandible was consistent with other studies[3, 13-15, 48] where the number of fenestrations found in the maxilla are higher (63.2%) compared to the mandible and the number of dehiscences found in the mandible higher than those found in the maxilla (72.8%). Additionally, fenestrations were more prevalent than dehiscences in both arcades.

Maxilla

There were a higher proportion of fenestrations as opposed to dehiscences in all maxillary teeth except the canines where dehiscences predominated. The maxillary teeth most commonly associated with both dehiscences and fenestrations were the first molars (39.2%) and canines (29.9%). The presence of alveolar defects in the maxillary first molar area as a result of an overlying thin cortical plate was first documented by Prichard.[49] Subsequently, Volchansky and Vieira suggested the close proximity of the molar root to the zygomatic pillar and root prominence adding to the vulnerability of this tooth for developing a defect.[18]

The robust anatomy of the canine results in a very thin buccal cortical plate overlying it, thus making these teeth more prone to developing alveolar defects.[22] The maxillary palatal cortical plate is thicker than the buccal plate, with its thickest portion at the incisor area resulting in a decreased susceptibility for incisors to developing alveolar defects.[22] The findings of this study support this theory, where the maxillary central incisors were the teeth exhibiting the least alveolar defects (1.6%).

Mandible

The mandibular teeth exhibiting the most alveolar defects were the canines (34.9%) followed by the first premolars (28.8%) which parallel the findings of the study by Volchansky and Cleaton-Jones.[17] On the other hand, the teeth least involved were the second molars (1.4%).

This could be attributed to the anatomy of the mandible, which has a thin buccal cortical plate except in the region of the second and third molar and a lingual plate, which is thicker than the buccal plate except in the incisor region.[50] Thus, teeth in this region are more susceptible to developing an alveolar defect as seen in the present study. The bucco-lingual dimension of the mandibular incisor roots exceeding the alveolar ridge width is a common occurrence as the ridge width is narrowest anteriorly.[50] As a result, the incisor roots may either perforate the cortical plate or have a very thin bone overlying them consequently making them more prone to developing alveolar defects.[51]

Distribution of fenestrations and dehiscences

Earlier studies reported the teeth most commonly associated with fenestrations in descending order were the: maxillary first molars, mandibular lateral incisors and mandibular canines.[12, 13] More recently, Rupprecht *et al.* reported the maxillary first molars, maxillary canines and mandibular canines as being the most commonly affected teeth.[15] In agreement with other studies[12-14, 21], this study found fenestrations mostly associated with the maxillary first molars (26.4%). The next most commonly associated teeth were the maxillary canines and mandibular first premolars accounting for 17.27% and 10.2% of all fenestrations respectively. This is similar to what was found by Nimigean *et al.* and Kawasaki *et al*.[3, 48]

Dehiscences in previous studies were variable but generally associated with mandibular canines, mandibular first premolars and maxillary canines.[3, 12, 13] Rupprecht *et al.* however found dehiscences were most commonly associated with not only the mandibular canines but the maxillary first molars too.[15]

Our study concurs with the general findings of several other studies [3, 12, 13, 48]where dehiscences were mostly associated with the mandibular canines (36.65%) followed by the mandibular first premolars (20.94%) and maxillary canines (10.47%). Unlike Rupprecht *et al.*, the present results do not find maxillary first molars to be particularly affected by dehiscences.[15]

The number of fenestrations (75.2%) found in our study is higher compared to the percentage of fenestrations found in studies by Rupprecht *et al.* (61.6%) and Nimigean *et al*. (69.60%)[3, 15] On the contrary, the percentage of dehiscences (24.8%) found in this study is nearly half of that found in the studies of Rupprecht *et al.* (40.4%) and Nimigean *et al.* (53.62%)[3, 15] The differing diagnostic criteria used by different authors may play a critical role in the disparity of the results.

Position and size of defects

The majority of defects (97.0%) in this study were located buccally, with only 22 defects (6.8% of which were dehiscences and 1.55% of which were fenestrations) located palatally/lingually. The upper first premolars and molars presented with the most palatal defects. The mandibular central incisors followed by the mandibular lateral incisors displayed the most lingual defects. This can be explained by the narrow bucco-lingual width of the mandible in the incisor region resulting in an increased possibility of incisor teeth to developing defects.[50]

In two other studies, only two teeth of the entire sample examined were associated with alveolar defects located on the palatal/lingual surfaces.[13, 14] Elliot and Bowers in the one study, found both defects to be dehiscences associated with maxillary first molars;[14] whilst Edel in the other study found both defects to be fenestrations associated with mandibular central incisors.[13] Rupprecht *et al.* found dehiscences on palatal (1.6%) and mandibular lingual (3.9%) surfaces although the numbers of defects were not reported.[15] This is in contrast with other studies[16, 17, 19, 21, 52] where no alveolar defects were observed palatally or lingually.

In this study, even though there was a high prevalence of both unilateral and bilateral defects, as also reported by Elliot and Bowers,[14] there was no specific predilection for a specific tooth/ teeth.

Only two earlier studies recorded the mean measurements of both alveolar defects where they found the mean height and width of fenestrations to outweigh that of dehiscences.[15, 52]

The exact method used to measure the defects was unclear and the instrumentation used could be less accurate to the current study (UNC-15 probe used in the study of Rupprecht *et al.).*[15] This is contrary to the findings of this study which also found the total average apico-coronal measurements outweighing the mesio-distal measurements in both types of alveolar defects. Thus, alveolar defects are generally longer as opposed to being wider.

<u>Prevalence of alveolar defects in the arcades</u>

Anterior versus posterior:

The majority of alveolar defects in this study were located posteriorly (55.7%) compared to anteriorly (44.3%) which is in contrary to that reported by Carranza and Larato.[8, 16] Dehiscences presented more commonly in the anterior regions of both the maxilla and the mandible (67.3% and 62.6% respectively) with the greatest number of defects located in the anterior mandible. This is as a result of the thinner cortical plates in the incisor region.[50] On the contrary, fenestrations occurred most commonly in the posterior regions of the maxilla (68.0%) and mandible (52.1%) with the greatest number of defects occurring in the posterior maxilla. This is in agreement with other studies.[3, 13, 16, 21, 27]

<u>Prevalence of alveolar defects between the mesiobuccal and distobuccal root</u>

Maxilla:

The present study found that dehiscences in maxillary first molars were slightly more commonly associated with the mesiobuccal root (54.6%) than the distobuccal root. However, this is not statistically significant. This is in agreement with Rupprecht *et al.* who found dehiscences mostly associated with the mesiobuccal root of maxillary molars (52.6%)[15] but in contrast with Larato who reported dehiscences most commonly located on the distobuccal root of maxillary first molars. (66.67%)[16] Edel found dehiscences almost equally distributed between both roots.[13]

Similarly, fenestrations in this study were almost equally distributed between the distobuccal and mesiobuccal root of maxillary first molars (50.9% and 47.1% respectively). Although not statistically significant, it is in agreement with Edel and Rupprecht *et al.*[13,15] On the contrary, Larato found fenestrations occurring most commonly on the mesiobuccal root of first molars (66.67%) but did not mention this in his materials and methods or discussion but instead in a results table.[16]

Mandible:

This study showed that there is an even distribution of dehiscences present on the mesial and distal roots of mandibular first molars. However, fenestrations associated with the mandibular first molar were most commonly associated with the mesial root(60%). Furthermore, in maxillary and mandibular second molars, fenestrations were associated mostly with the distal root (90.9% and 60% respectively). Rupprecht *et al.* found that both dehiscences and fenestrations in mandibular molars were found more readily on the mesial root (84.6% and 63.6%).[15]

Left versus right quadrants and teeth

Although there were ten more alveolar defects on the left hand side as opposed to the right hand side(390 versus 380) and the left hand side exhibited eleven more dehiscences than the right hand side (101 versus 90), these low numbers could be indicative of habits and reflect habits such as chewing side preference and toothbrushing. Fenestrations had an equal distribution between the left hand side and the right hand side.

This is in contrary to a study done by Cleaton-Jones and Volchansky where the right hand side was more commonly affected by dehiscences than the left hand side in all teeth apart from the molars which were equally affected.[17]

In this study, the left maxillary first molar displayed a slightly higher number of fenestrations in comparison to the right maxillary first molar. This is in agreement with Elliot and Bowers and Larato[14,16] , but in contradiction to Edel who found the right maxillary molar to have the greatest incidence of fenestrations.[13]

Larato reported more defects located in the first quadrant compared to the second quadrant.[16] Although more defects were located on the left hand side as compared to the right hand side, no differences were observed in the distribution of alveolar defects in all four quadrants. This could as a result of chewing habits, with each individual preferring one chewing side as compared to the other. Incorrect toothbrush use during cleaning may lead to recession with subsequent dehiscence formation.[53]

<u>Ratio of defects</u>

This study found a ratio of dehiscences to fenestrations was 1:3. This is in contrast to Tal who reported a ratio of 1:0.49[19], Larato with a ratio of 1: 0.74[16], Abdelmalek and Bissada with 1:0.71[21] and 1:1.04 in a study by Volchansky and Cleaton-Jones.[15] The present study documented more fenestrations than dehiscences. This could be linked to the large sample size used in our study compared to the other studies.

<u>Association with root prominence</u>

The protocol used to define and measure root prominence varies between studies leading to lack of standardization and consequent difficulty in the interpretation of results. The only clear definition is that by Edel *et al*. who defined root prominence as: "a root where the total buccal curvature is manifested by a convexity in the external surface of the jaw."[13] This was further classified as average if the root was within the confines of the alveolar housing or prominent if the root produced a convexity in the external surface of the jaws.[13] Root prominence was measured differently in this study, where the use of bendable copper wire was placed along the central fossa line to assess the position of teeth in relation to the arch.

Edel *et al*.[11] found that 37% of teeth with fenestrations and 35% with dehiscences were associated with prominent roots.[13] Similarly, Rupprecht *et al.* found root prominence in 35.6% of teeth with dehiscences, however only 8.1% of teeth with fenestrations had root prominence.[15] These findings are in contrast with Larato who found 90% of alveolar defects associated with prominent tooth roots in relation to the arch.[16] However, Larato did not define root prominence or how it was measured.[16] Tal found that malpositioned teeth and teeth with prominent roots were more prone to be associated with these defects.[19]

Prominent roots in relation to the arch were found to play no role in the prevalence of alveolar defects in this study. The majority of buccal dehiscences (76.5%) were associated with centrally positioned teeth and only 15.1% were in a buccal position. Likewise, 75.6% of teeth associated with buccal fenestrations were centrally positioned with only 7.8% of affected teeth in a buccal position.

Interestingly, out of all the palatal/lingual fenestrations neither of the teeth were palatally nor lingually positioned but rather over half were centrally positioned (55.6%). Furthermore, of the five dehiscences located lingually, none of the teeth were lingually positioned but rather 60% of the teeth were centrally located. The reasoning for this is that even though a tooth was buccal or palatal/lingual to the central fossa line, it might not have perforated the buccal plate resulting in an alveolar defect. (Figure 10)

Classification and location of fenestrations

In earlier studies the classification of fenestrations in accordance to root length has not been clearly defined, however multiple authors have used different classifications. *Stahl et al.* graded fenestrations on a scale ranging from 1 to 3 where 1 represented the smallest visible opening, and 3 where the buccal vertical dimension extended into the alveolar crest.[27] The definition of grade 2 was not reported.[27] Edel *et al.* recorded whether fenestrations were located at the apical, coronal or junction of the apical and coronal halves[13] and found that the majority of maxillary (89.5%) and mandibular fenestrations (60%) were located in the apical half of the root as opposed to the coronal half. (1.3%; 36%). The remaining defects were located at the junction of the coronal and apical halves.[13]

Nimigean *et al.* classified the position of fenestrations in relation to root length into four groups.[3] Of the total fenestrations, 48.6% were located in the apical 1/3, 28.2% in the middle third, 18.9% in the coronal third and 4.3% extending from the apical to the middle third.[3] In the maxilla, the majority of fenestrations were located in the apical 1/3 and in the mandible in the coronal 1/3.[3] No fenestrations in the mandible were located in the apical 1/3.[3]

Rupprecht *et al.* found the majority of fenestrations (72.7%) located on the apical third of the root.[15] In the maxilla, 92% of fenestrations were located in the apical third with the remainder on in the middle 1/3.[15] In the mandible fenestrations occupied the middle and apical 1/3 evenly.[15]

To decrease bias and subjectivity, the current study classified fenestrations according to their location in relation to root length. The mean root lengths were taken from Appendix 1.[44]

A total of 75% of fenestrations were located in the apical third of the root. This is line with other studies.[3, 13, 15] Mandibular lateral incisors and canines presented with the majority of fenestrations in the middle 1/3 (80.9%). This could be due to their anatomical shape within the thin anterior mandibular alveolar bony housing. It is interesting to note that the mandibular canines were commonly associated with dehiscences. This could be as a result of the resorption of the thin marginal bone thus converting a fenestration into a dehiscence.

In the maxilla, 77.9% of the fenestrations were located in the apical 1/3 of the root. These findings concur with the results reported by Rupprecht *et al,*[15] Results contrary to these findings have however been reported; where fenestrations were most commonly located in the middle third of the root.[16]

This study did not assess attrition or occlusal wear as a possible contributing factor to the presence of alveolar defects as did previous studies. Whilst this might be a limitation, the reason for excluding this parameter in the present study is that occlusion cannot be simulated in dry human skulls. Another limitation is that the position of teeth in the jaws and the tooth to jaw width ratio of non-affected teeth, preferably on the contralateral side of affected teeth were not assessed. Had this been assessed, we would have been able to compare findings on these parameters between the affected and non-affected teeth; thus making the results more conclusive.

Clinical implications

Periodontal and oral surgery that involves alveolar bone exposure; and the possible exposure of underlying dehiscences and fenestrations may complicate the outcome of surgery and negatively impact on the healing process.[51] Furthermore, the periosteum may be stripped during surgery, rendering the possible risk of a coronally positioned fenestration becoming a dehiscence as a result of necrosis of the thin marginal bone overlying the osseous lesion.[18] Thus wherever possible, minimal reflection of flaps are advocated to reduce the possibility of marginal bone necrosis during surgical management of periodontitis, especially for teeth site that are most likely to exhibit alveolar defects.

The presence of dehiscences predisposes to gingival recession with resultant sensitivity due to cementum exposure, increased risk for root caries and progression of periodontal breakdown.[33, 34] It has been reported that fenestrations and dehiscences may cause facial or dental pain elicited upon touch or spontaneously which is often mistaken for pain caused by factors other than these defects.[16]

Rehabilitation of patients with dental implants has become a preferred treatment modality to replace missing teeth.[54] The placement of implants in areas with pre-existing alveolar defects may compromise their long term success or increase the risk of failure.[55] Guided bone regeneration procedures are necessary to generate bone over the exposed implant surface at the time of placement.[55]Anticipation and identification of such defects during treatment planning will prevent complications in time. The flapless placement of an implant in the site exhibiting an alveolar defect can negatively affect osseointegration and the aesthetic result.[56] This may be more pronounced where placement is done immediately on sites that are most likely to have these defects. Pre-operative investigations such as sectional cone beam computed tomography and cone beam computed tomography should become protocol prior to implant placement to avoid complications as these defects cannot be seen on conventional radiographs.[3]

Tooth repositioning through bucco-lingual and mesio-distal movements during orthodontic therapy, may result in a breakthrough or expansion of the alveolar bone housing with resultant fenestration and dehiscence formation.[36] Use of appropriate pre-treatment investigative/ diagnostic aids is therefore recommended as this would help the operator plan efficiently and be better prepared for intra-operative adversities.

CHAPTER 6: SUMMARY AND CONCLUSION

The purpose of this study was to determine and evaluate the prevalence, distribution and characteristics of dehiscences and fenestrations in 333 skulls with both jaws. A total of 6010 teeth of a South African population were assessed to determine if there was any significant association between the presence of these defects with other parameters examined in this research.

The findings of this study show that the maxillary first molars and canines are the teeth most commonly associated with fenestrations, whilst the mandibular canines and first premolars were commonly associated with dehiscences. Statistically, in this study, the more number of teeth present per jaw the greater was the prevalence of alveolar defects. Thus, with advances in dentistry and consequent increased retention of teeth into older age, it is likely that more defects will be seen. Accordingly, knowledge of these sites most likely to be affected by these defects will guide the clinician when specific procedures are planned at these areas e.g. mucogingival procedures, orthodontic management of crowed teeth or implant therapy. It is for this reason therefore, that high risk areas should be carefully assessed so as to prevent adverse surgical outcomes and provide the best possible treatment for the patient.

Within the parameters of a fixed cohort of specimens as in this study, the following recommendations are suggested:

- Comparison between the tooth to jaw ratio of teeth affected with alveolar defects to their contralateral partners (when unaffected by alveolar defects).
- Use of Cone beam Computed Tomography (CBCT) for verification and comparison of several characteristics and associations of these defects

CONTENTS OF APPENDICES

APPENDIX 1

Maxillary Teeth								
Central incisor	10.5	13.0	8.5	7.0	7.0	6.0	3.5	2.5
Lateral incisor	9.0	13.0	6.5	5.0	6.0	5.0	3.0	2.0
Canine	10.0	17.0	7.5	5.5	8.0	7.0	2.5	1.5
First premolar	8.5	14.0	7.0	5.0	9.0	8.0	1.0	0.0
Second premolar	8.5	14.0	7.0	5.0	9.0	8.0	1.0	0.0
First molar	7.5	b 1 12 13	10.0	8.0	11.0	10.0	1.0	0.0
Second molar	7.0	b 1 11 12	9.0	7.0	11.0	10.0	1.0	0.0
Third molar	6.5	11.0	8.5	6.5	10.0	9.5	1.0	0.0
Mandibular Teeth								
Central incisor	9.0	12.5	5.0	3.5	6.0	5.3	3.0	2.0
Lateral incisor	9.5	14.0	5.5	4.0	6.5	5.8	3.0	2.0
Canine	11.0	16.0	7.0	5.5	7.5	7.0	2.5	1.0
First premolar	8.5	14.0	7.0	5.0	7.5	6.5	1.0	0.0
Second premolar	8.0	14.5	7.0	5.0	8.0	7.0	1.0	0.0
First molar	7.5	14.0	11.0	9.0	10.5	9.0	1.0	0.0
Second molar	7.0	13.0	10.5	8.0	10.0	9.0	1.0	0.0
Third molar	7.0	11.0	10.0	7.5	9.5	9.0	1.0	0.0

Table 1-1. Average measurements of teeth used to classify fenestration defects

APPENDIX 2

Table 2.1 Intra-observer results (reliability) for fenestrations

Fenest	absent	present	Totals
Absent	184	1	185
present	1	20	21
Totals	185	21	206

kappa = 0.946975547

Table 2.2 Intra-observer results (reliability) for dehiscences

Dehi	absent	present	Totals
Absent	200	2	202
present	0	4	4
Totals	200	6	206

kappa = 0.795228628

Kappa values of 0.947 and 0.795 suggest almost perfect to substantial agreement in the identification of fenestrations and dehiscences respectively.

< 0 no agreement, 0.00–
0.20 slight
0.21–0.40 fair
0.41–0.60 moderate
0.61–0.80 substantial
0.81–1.00 almost perfect agreement

Apical coronal, mesio-distal, tooth-to-jaw measurements at sites of fenestration and dehiscence are highly correlated (Lin's concordance correlation coefficient Pc values of 0.999, 0.996, 0.997 and 0.988 respectively), and considered highly repeatable.

Table 2.3 Inter-observer (reproducibility) for fenestrations

Fenest	absent	present	Totals
Absent	186	4	190
present	1	20	21
Totals	187	24	211

kappa = 0.875692235

Table 2.4 Inter-observer (reproducibility) for dehiscences

Dehi	absent	present	Totals
Absent	212	1	213
present	2	11	13
Totals	214	12	226

kappa = 0.872986137

Kappa values of 0.876 and 0.873 suggest almost perfect agreement in the identification of fenestrations and dehiscence respectively between observers.

Apical-coronal, mesio-distal, tooth-to-jaw width measurements at sites of fenestration and dehiscence between observers were highly correlated (Lin's concordance correlation coefficient Pc values of 0.935, 0.909, 0.971 and 0.942 respectively), and considered highly repeatable.

APPENDIX 3

Data Collection Sheet: Dehiscences and Fenestrations

Series #:
Age:
Race:
Ethnicity:
Sex: | Male | Female |

	FENESTRATION							DEHISCENCE					
TOOTH #	B/L/P	A-C	M-D	T- jaw size	T-pos in jaw	Classification		B/L/P	A-C	M-D	T- jaw size	T-pos in jaw	Classification
17													
16													
15													
14													
13													
12													
11													
21													
22													
23													
24													
25													
26													
27													
37													
36													
35													
34													
33													
32													
31													
41													
42													
43													
44													
45													
46													
47													

F Fractured crown equi/supra crestal
Fx Fractured crown subcrestal

APPENDIX 4

Bin	*TOTAL*	*WF*	*BF*	*MixF*	*WM*	*BM*	*MixM*	*n/sM*
0-5	0	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0	0
10-15	1	0	0	0	0	1	0	0
15-20	6	0	4	1	0	1	0	0
20-25	15	0	5	1	0	9	0	0
25-30	19	0	8	0	0	11	0	0
30-35	26	0	6	1	0	19	0	0
35-40	21	1	7	0	0	13	0	0
40-45	29	1	7	1	3	16	0	1
45-50	59	2	15	0	4	38	0	0
50-55	33	1	1	0	1	30	0	0
55-60	44	2	8	0	7	27	0	0
60-65	27	3	4	0	2	17	1	0
65-70	26	3	5	0	1	15	1	1
70-75	13	0	3	0	3	7	0	0
75-80	14	5	2	0	4	3	0	0
80-85	0	0	0	0	0	0	0	0
85-90	0	0	0	0	0	0	0	0

Table 4.1 Age distribution amongst the skulls evaluated for alveolar defects.
Table used to generate simple histograms, WF, White female, BM, Black Male;
MixF, mixed (possibly coloured) Female; n/sM, not specified male.

The mean age among the groups differed significantly (ANOVA: F=12.27, $p=1.29x10^{-7}$), with Tukey's pairwise post hoc analyses revealing that the White samples were significantly older than the Black samples (BF/WF $p=9.23x10^{-6}$; WM/BM p=0.0053; BF/BM p=0.622; WF/WM p=0.924).

	SS	Df	MS	F	p (same)
Between groups:	7315.44	3	2438.48	12.27	1.29E-07*
Within groups:	63815.7	321	198.803		
Total:	71131.2	324			

Table 4.2 ANOVA for age between samples

	BF	WF	BM	WM
BF		9.23E-06*	0.6221	4.50E-05*
WF	7.259		0.000524*	0.9244
BM	1.708	5.552		0.005322*
WM	6.377	0.8824	4.669	

Table 4.3 Post-hoc Tukey's pairwise analyses. Q values below the diagonal, p values above. Asterisk indicates significance at α=5%.

APPENDIX 5

Number	Total	%	WF	%	BF	%	WM	%	BM	%
0	233	70.0%	13	72.2%	46	61.3%	17	68.0%	151	72.9%
1	52	15.6%	1	5.6%	15	20.0%	2	8.0%	33	15.9%
2	27	8.1%	1	5.6%	9	12.0%	2	8.0%	14	6.8%
3	10	3.0%	1	5.6%	3	4.0%	3	12.0%	3	1.4%
4	5	1.5%	1	5.6%	1	1.3%	1	4.0%	2	1.0%
5	4	1.2%	1	5.6%	1	1.3%	0	0.0%	2	1.0%
6	1	0.3%	0	0.0%	0	0.0%	0	0.0%	1	0.5%
7	1	0.3%	0	0.0%	0	0.0%	0	0.0%	1	0.5%
8	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
9	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
10	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
11	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
12	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
13	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
14	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
15	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	333		18		75		25		207	

Table 5.1 Number of individuals and their proportion presenting with a certain number of dehiscences for the total sample and broken down by sex and population

Number	Total	%	WF	%	BF	%	WM	%	BM	%
0	122	36.6%	5	27.8%	29	38.7%	7	28.0%	80	38.6%
1	82	24.6%	6	33.3%	18	24.0%	7	28.0%	48	23.2%
2	47	14.1%	0	0.0%	12	16.0%	5	20.0%	29	14.0%
3	38	11.4%	4	22.2%	6	8.0%	3	12.0%	23	11.1%
4	21	6.3%	1	5.6%	3	4.0%	2	8.0%	14	6.8%
5	8	2.4%	1	5.6%	4	5.3%	0	0.0%	3	1.4%
6	8	2.4%	1	5.6%	1	1.3%	1	4.0%	5	2.4%
7	3	0.9%	0	0.0%	1	1.3%	0	0.0%	2	1.0%
8	3	0.9%	0	0.0%	1	1.3%	0	0.0%	2	1.0%
9	1	0.3%	0	0.0%	0	0.0%	0	0.0%	1	0.5%
10	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
11	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
12	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
13	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
14	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
15	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	333		18		75		25		207	

Table 5.2 Number of individuals and their proportion presenting with a certain number of fenestrations

Number	Total	%	WF	%	BF	%	WM	%	BM	%
0	98	29.4%	3	16.7%	22	29.3%	7	28.0%	65	31.4%
1	71	21.3%	7	38.9%	12	16.0%	4	16.0%	46	22.2%
2	56	16.8%	1	5.6%	15	20.0%	4	16.0%	34	16.4%
3	33	9.9%	2	11.1%	10	13.3%	4	16.0%	16	7.7%
4	29	8.7%	1	5.6%	6	8.0%	1	4.0%	20	9.7%
5	17	5.1%	1	5.6%	2	2.7%	3	12.0%	10	4.8%
6	9	2.7%	0	0.0%	4	5.3%	0	0.0%	5	2.4%
7	6	1.8%	1	5.6%	1	1.3%	1	4.0%	3	1.4%
8	8	2.4%	1	5.6%	1	1.3%	0	0.0%	6	2.9%
9	3	0.9%	1	5.6%	1	1.3%	1	4.0%	0	0.0%
10	2	0.6%	0	0.0%	1	1.3%	0	0.0%	1	0.5%
11	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
12	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
13	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
14	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
15	1	0.3%	0	0.0%	0	0.0%	0	0.0%	1	0.5%
	333		18		75		25		207	

Table 5.3 Number of individuals and their proportion presenting with a certain number of alveolar defects

APPENDIX 6

University
of the Witwatersrand,
Johannesburg

Human Research Ethics Committee (Medical)
(formerly Committee for Research on Human Subjects (Medical)

Secretariat: Research Office, Room SH10005, 10th floor, Senate House • Telephone: +27 11 717-1234 • Fax: +27 11 339-5708
Private Bag 3, Wits 2050, South Africa

Ref: W-CJ-120926-1 26/09/2012

TO WHOM IT MAY CONCERN:

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical).

Investigator: **Dr S Koutras.**

Project title: **Prevalence of alveolar dehiscences and fenestrations in South African human skulls.**

Reason: In terms of Chapter 8, sections 62-64 of the National Health Act No 61 of 2003 donated bodies and their tissues may be used for, among other purposes, health research. Use of such material is subject only to permission from the responsible person in the School of Anatomical Sciences - the Head or person designated by the Head. The School of Anatomical Sciences has an overarching waiver 101109-1. The current waiver is issued within this for a study in the Raymond A Dart collection of human skeletons.

UNIVERSITY OF THE WITWATERSRAND
PROF PE CLEATON-JONES
HREC (MEDICAL)
2012 -09- 2 6
JOHANNESBURG

Professor Peter Cleaton-Jones
Chair: Human Research Ethics Committee (Medical)

copy: Anisa Keshav, Research Office, Senate House, Wits

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