RETROSPECTIVE CONE BEAM COMPUTERIZED TOMOGRAPHY STUDY OF THE INFRAORBITAL FORAMEN IN RELATION TO THE MAXILLARY SINUS.

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ABSTRACT

Objectives: As cone beam computerized tomography is used more widely for initial data collection and treatment planning, more valuable anatomic information is at the disposal of clinicians. The scans provide a very accurate display of the patient's anatomy and these beneficial findings can be used to prevent surgical complications as well as advancing anatomical knowledge. This study aims to expand the current knowledge on the location of the infraorbital nerve in relation to the maxillary sinus in a group of patients who had CBCT scans taken for diagnosis and treatment planning. The study also aims to determine if age, gender or ethnicity have a relationship with the location of the nerve in relation to the sinus.

Materials and Methods: 821 CBCT scans were take at Temple University Kornberg School of Dentistry Department of Oral and Maxillofacial Radiology from January 1, 2009 to July 31, 2013. These scans were evaluated using i-CAT computer imaging software. Patients under 18, patients without posterior or maxillary dentitions and patients who's scans did not include the infraorbital nerve were excluded from the study. A total of four hundred three (403) CBCT scans were included in the study. Patients with visible infraorbital nerves were selected and location, age, gender and ethnicity were recorded. Individual scans had infraorbital nerves identified and examined for relationship superior to a specific tooth, and distance above the floor of the sinus.

Results: After reviewing 680 scans, only 403 were included in the study due to exclusions. Scans were subdivided into age, gender, ethnicity and location of the nerve in relation to tooth position. The total average distance from the infraorbital foramen to the floor of the maxillary sinus was 23.94 mm on the right side and 22.84 mm on the left side. The average distance of males was 25.3 mm on the right and 24.27 mm on the left. The females' average distance was 22.77 mm on the right and 21.62 mm on the left. The distance increased as the patients aged. The most common maxillary tooth inferior to the foramen was second premolar 46.65% of time, followed by the first molar 41.69% of the time. The difference between genders, right and left sides, and age groups all showed statistical significance. The differences between the ethnicities were not statistically significant.

Conclusion: Based on the data collected and analyzed in the present study, the infraorbital foramen appeared to be located above the second premolar or first molar 88% of the time. The distance of the foramen from the floor of the sinus was larger in men than women. The right and left side can be different, and the distance tends to increase with the age of the patient. This information can be applied to better achieve local anesthetic delivery success, and avoid complications and nerve damage when performing procedures.

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TABLE OF CONTENTS

Page
ABSTRACT…..... ……ii

ACKNOWLEDGMENTS……..iii

LIST OF TABLES ……..…….....…….…v

LIST OF FIGURES ……..…… ..... ……..…vii

CHAPTER

1. INTRODUCTION…….…… 1

2. MATERIALS AND METHODS ……..…….....…….….5

3. RESULTS…… .....……12

4. DISCUSSION…… .....……37

5. CONCLUSIONS…… .....……41

REFERENCES CITED……..……43

LIST OF TABLES

Table Page

1. Excel worksheet for data collection showing age, gender, ethnicity, maxillary and mandibular dentition, location and distance……..…11
2. Overall location of the foramen above maxillary tooth ……12
3. Occurrences of foramen above teeth on the right side for total population……...14
4. Occurrences of foramen above teeth on the left side for total population…….15
5. Occurrences of foramen above teeth on the right side for male population……..16
6. Occurrences of foramen above teeth on the left side for male population……17
7. Occurrences of foramen above teeth on the right side for female population……..19
8. Occurrences of foramen above teeth on the left side for female population……..20
9. Occurrences of foramen above teeth on the right side for Caucasian population……..21
10. Occurrences of foramen above teeth on the left side for Caucasian population……..22
11. Occurrences of foramen above teeth on the right side for African-American population…….……..24
12. Occurrences of foramen above teeth on the left side for African-American population……..……..25
13. Occurrences of foramen above teeth on the right side for Asian population……..26
14. Occurrences of foramen above teeth on the left side for Asian population……..27
15. Occurrences of foramen above teeth on the right side for Hispanic population……..29

16. Occurrences of foramen above teeth on the left side for Hispanic population……..30

17. ANOVA test of the differences in averages between the different ethnicity groups…….……34

18. ANOVA test of the differences in averages between the different age groups…….……36

LIST OF FIGURES

FIGURE Page

1. Diagram of the human skull with Trigeminal nerve and its branches (Newman et al., 2012)..... ……1

2. IRB Approval Protocol 23570…….……....3

3. Image of the MPR screen using i-CAT software. The axial view is represented on top, and the coronal view below. Measurements were made from infraorbital foramen to the floor of the sinus, and the axial view was used to determine location above the maxillary tooth……..……....……....7

4. Another image of the MPR screen using i-CAT software. The axial view is represented on top, and the coronal view.…….…….……...8

5. Cadaver skull study on location of the foramen (Varshney et al., 2013)…....10

6. Percentage of occurrences above maxillary tooth..…….13

7. Pie chart of percentage of occurrences above right maxillary tooth for total population…….……14

8. Pie chart of percentage of occurrences above left maxillary tooth for total population…….……15

9. Pie chart of percentage of occurrences above right maxillary tooth for male population…….……17

10. Pie chart of percentage of occurrences above left maxillary tooth for male population…….……18

11. Pie chart of percentage of occurrences above right maxillary tooth for female population……..……19

12. Pie chart of percentage of occurrences above left maxillary tooth for female population……..……20

13. Pie chart displaying percentage of occurrences above right maxillary teeth in Caucasian population……...…….…..22

14. Pie chart displaying percentage of occurrences above left maxillary teeth in Caucasian population……...……...23

15. Pie chart displaying percentage of occurrences above right maxillary teeth in African-American population……...……..24

16. Pie chart displaying percentage of occurrences above left maxillary teeth in African-American population……...…..25

17. Pie chart displaying percentage of occurrences above right maxillary teeth in Asian population……...……..27

18. Pie chart displaying percentage of occurrences above left maxillary teeth in Asian population……...……..28

19. Pie chart displaying percentage of occurrences above right maxillary teeth in Hispanic population……...…….29

20. Pie chart displaying percentage of occurrences above left maxillary teeth in Hispanic population……...…….30

21. Bar graph showing average distance from the foramen to the floor of the sinus in total population, male population and female population……....31

22. Bar graph showing average distance from the foramen to the floor of the sinus in all ethnicity groups as a whole, and broken down into males and females……...33

23. Bar graph of the average distance from the foramen to the floor of the sinus in the different age groups…….……...35

CHAPTER 1
INTRODUCTION

The infraorbital foramen is an anatomic structure through which the infraorbital nerve and vessels pass, and is a continuation of the maxillary division of the trigeminal nerve. The trigeminal nerve is cranial nerve five. The maxillary branch, or V-2, exits through the foramen rotundum before it branches into the infraorbital nerve. Solely a sensory nerve, which innervates the skin of the upper cheek, mucosa of the maxillary sinus, maxillary incisors, canine, premolars, adjacent gingiva and mucosa of the upper lip.

Figure 1: Diagram of the human skull with Trigeminal nerve and its branches (Newman, 2012).

Understanding the relative location of this foramen and nerve can help clinicians achieve successful and profound anesthesia, while limiting the chances of a surgical complication. It is very important for dentists to know the location not only for anesthesia and to reduce surgical complications, but also as a reference point for other anatomic structures. From a surgical point of view, it is located near important structures such as the orbit, nasal and buccal regions (Macedo et al., 2009).

The infraorbital nerve block can only be administered effectively if proper knowledge about the location of the infraorbital foramen is known (Liu et al., 2014). Achieving profound anesthesia with this block will reduce the relative risks to the patient during routine and complex surgical procedures (Ilayperuma et al., 2010). Adequate delivery of anesthesia keeps the patient comfortable, which lowers risks and invariably increases success clinically. Determining the frequency of the infraorbital foramen's location can aid in anesthesia.

The maxillary sinus is an important anatomic location due to its location inferior to the infraorbital nerve and foramen and also because the mucosa of the maxillary sinus is innervated by the infraorbital nerve. The maxillary sinus changes size with age, as a person loses maxillary teeth due to pneumatisation and as a person loses mandibular teeth due to supraeruption of the maxillary teeth. The sinus is another important clinical landmark when performing surgeries and using its location as a reference point will allow the clinician to more accurately identify other structures such as the infraorbital foramen.

Fifty-four percent of maxillary posterior implants require sinus augmentation prior to or at the time of implant placement (Seong et al., 2013). After extractions in the posterior maxilla, the sinus expands or pneumatizes into the space where the tooth previously existed. This leads to the need for sinus augmentations. Adequate anesthesia is necessary for these procedures and if a large surgical flap is elevated, the location of the infraorbital nerve and foramen must be known to prevent surgical complications.

Injury to the infraorbital nerve is a potential complication, which can arise during lateral wall and internal sinus lifts (Newman et al., 2011). Knowledge about its location is important for facial surgery, nerve blocks, avoidance of inadvertent injury and cosmetic filler injections as complex and routine procedures are performed around this anatomic structure regularly. Some complex procedures such as facial fracture surgeries, Lefort procedures, and cosmetic filler injections all which require precise knowledge of the anatomic location of the foramen (Liu et al., 2014).

Previous literature on achieving infraorbital nerve block anesthesia suggests using the first premolar as a landmark for the injection (Malamed, 2004). The anesthesia should then be administered an average of 16mm above the injection site for an adequate nerve block (Malamed, 2004). The location used for the injection may vary for each individual patient and as such, knowing its location can only benefit the doctor and patient at the time of the procedure.

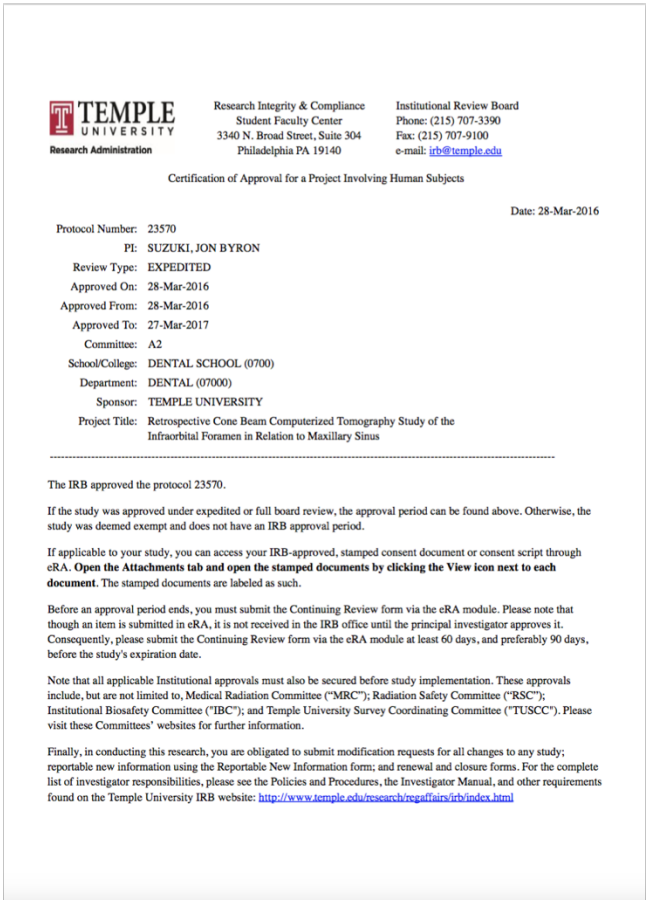
One way to determine the location of the infraorbital foramen is through the use of Cone Beam Computerized Tomography(CBCT). CBCT was introduced in the 1990s by Arai et al. in Japan and Mozzo et al. in Italy (de Vos et al., 2009). CBCT offers a low

cost procedure with easy accessibility and less radiation than multi-slice computerized tomography, its medical counterpart (de Vos et al., 2009). A three dimensional data set is created for use by the doctor. The number of papers on CBCTs has grown drastically since the late 1990s, as CBCT becomes more prevalent in practices and more CBCTs are taken. Utilization of CBCT today span orthodontics, implantology, pathology, maxillofacial surgery, endodontics and general dentistry (de Vos et al., 2009). Benefits of CBCT include production of a three dimensional data set, the data is real sized, high resolution, lower radiation than MSCT, user friendly software, in office imaging, reduced cost and easy accessibility (de Vos et al., 2009). Some disadvantages include low contrast range, limited field of view, limited inner soft tissue formation, movement artifacts and it cannot be used for Hounsfield units (de Vos et al., 2009).

Utilizing this technology, the infraorbital foramen can be identified and its location mapped in relation to the inferior maxillary tooth as well as its distance from the floor of the sinus. The present study aims to evaluate the location of the infraorbital foramen in relationship to the inferior maxillary tooth and its distance from the floor of the maxillary sinus. The patients being studied all had CBCT scans taken at the Temple University Kornberg School of Dentistry Radiology Department. The data was then analyzed in an effort to help further the knowledge currently available on the infraorbital foramen and its relationship to surgical procedures and local anesthesia.

CHAPTER 2
MATERIALS AND METHODS

The study was based on a retrospective evaluation of CBCT scans taken from 2009 to July 21, 2013. The study received Temple University Office for Human Subjects Protections Institutional Review Board approval (Figure 2). Eight hundred and twenty-one (821) scans were examined initially. CT images with inadequate information (e.g. absence of infraorbital foramen, field of image without the inclusion of the infraorbital foramen, poor quality images, and edentulous posterior maxillae) were excluded. A total of 680 scans of which subject factors of gender, age, ethnicity and dentition status were analyzed in the study. The CBCT scans were taken using i-CAT machine (Imaging Science International, Inc. Hatfield, PA, USA) with a flat panel image detector. Images were taken at 120 kvp, 5 mA, and a voxel size of 0.3mm with an exposure time of 8.9 seconds. Fourteen (14) bits gray scales and 8.9 second scan times were used. The number of slices in the volume is 327.



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Certification of Approval for a Project Involving Human Subjects

Date: 28-Mar-2016

Protocol Number:	23570
PI:	SUZUKI, JON BYRON
Review Type:	EXPEDITED
Approved On:	28-Mar-2016
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Committee:	A2
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Department:	DENTAL (07000)
Sponsor:	TEMPLE UNIVERSITY
Project Title:	Retrospective Cone Beam Computerized Tomography Study of the Infraorbital Foramen in Relation to Maxillary Sinus

The IRB approved the protocol 23570.

If the study was approved under expedited or full board review, the approval period can be found above. Otherwise, the study was deemed exempt and does not have an IRB approval period.

If applicable to your study, you can access your IRB-approved, stamped consent document or consent script through eRA. **Open the Attachments tab and open the stamped documents by clicking the View icon next to each document**. The stamped documents are labeled as such.

Before an approval period ends, you must submit the Continuing Review form via the eRA module. Please note that though an item is submitted in eRA, it is not received in the IRB office until the principal investigator approves it. Consequently, please submit the Continuing Review form via the eRA module at least 60 days, and preferably 90 days, before the study's expiration date.

Note that all applicable Institutional approvals must also be secured before study implementation. These approvals include, but are not limited to, Medical Radiation Committee ("MRC"); Radiation Safety Committee ("RSC"); Institutional Biosafety Committee ("IBC"); and Temple University Survey Coordinating Committee ("TUSCC"). Please visit these Committees' websites for further information.

Finally, in conducting this research, you are obligated to submit modification requests for all changes to any study; reportable new information using the Reportable New Information form; and renewal and closure forms. For the complete list of investigator responsibilities, please see the Policies and Procedures, the Investigator Manual, and other requirements found on the Temple University IRB website: http://www.temple.edu/research/regaffairs/irb/index.html

Figure 2: IRB Approval Protocol 23570.

Obtained CBCT images were viewed and examined using the i-CAT vision viewing software, giving a panoramic reconstruction view module and the MPR screen module, i.e. axial, sagittal and coronal slices. The MPR screen module was mainly used for data collection. All images were assessed under standardized conditions at the same workplace by three examiners. Questionable findings were discussed amongst the three examiners until a unanimous decision was reached.

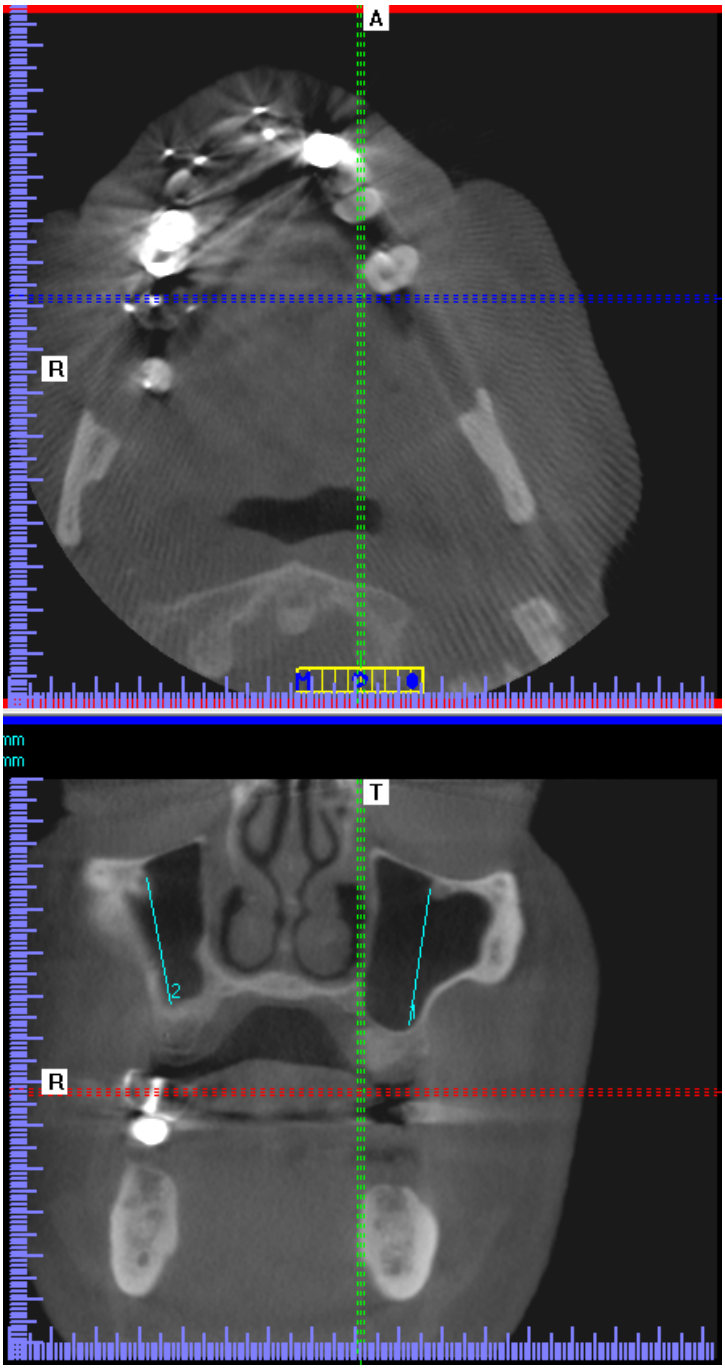

Figure 3: Image of the MPR screen using i-CAT software. The axial view is represented on top, and the coronal view below. Measurements were made from infraorbital foramen to the floor of the sinus, and the axial view was used to determine location above the maxillary tooth.

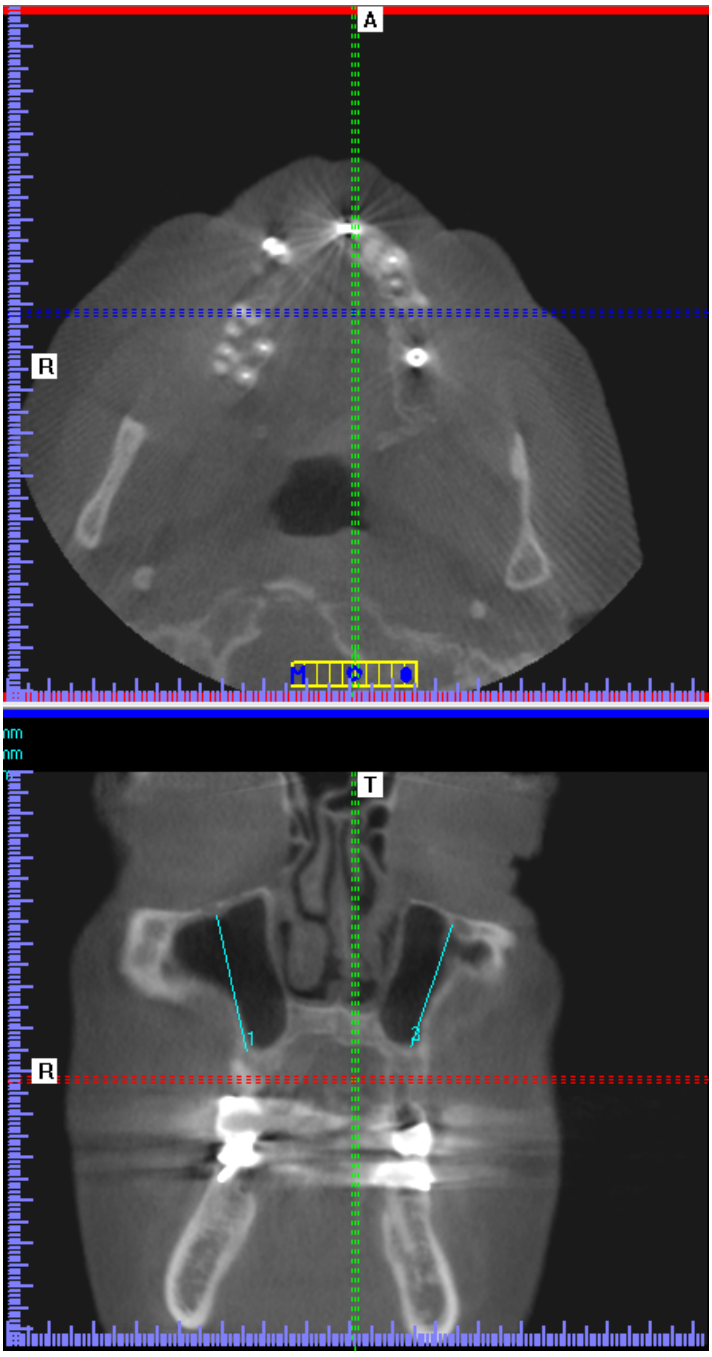

Figure 4: Another image of the MPR screen using i-CAT software. The axial view is represented on top, and the coronal view below.

The mean age of patients at the time of the scan was 48.53 years (range 18-90). There were 360 females and 320 males. There were 408 Caucasians, 160 African-Americans, 61 Asians, and 51 Hispanics. The subjects were categorized into 4 age groups: 18-35 years, 36-53 years, 54-71 years, and 72-90 years. After exclusions there were 175 males and 228 females included in the study. The ethnicities remaining after exclusions were 264 Caucasians, 78 African-Americans, 39 Asians and 22 Hispanic patients. There were 75 patients 18-35 years, 97 patients 36-53 years, 187 patients 54-71 years and 44 patients 72-90 years.

The findings of the location of the infraorbital foramen were categorized into position above the maxillary tooth directly inferior, and the distance from the most posterior superior portion of the foramen to the floor of the maxillary sinus. The locations were determined for right and left side. The span of the location was above the 2^{nd} molars (teeth #2,15) to the canines (teeth # 6,11).

Figure 6: Presence of infraorbital foramen in line with first molar tooth

Figure 5: Cadaver skull study on location of the foramen (Varshney et al., 2013).

The dentition status of each side was categorized as complete dentition, partial dentition, partial dentition with implants, complete implant supported dentition or edentulous. The complete implant supported dentition and edentulous ridges were excluded.

Data was recorded using spreadsheets created in Microsoft Excel spreadsheets. The data was further divided into additional spreadsheets based on age, gender and ethnicity. T-test analysis was used to find statistical significance in the average distance from the infraorbital foramen to the floor of the maxillary sinus, between the genders and between right and left sides. An analysis of variance(ANOVA) statistical test was used

to find statistical significance between the average distance from the infraorbital foramen to the floor of the maxillary sinus and between the different ethnicities and age groups.

	B	C	D	E	F	G	H	I	J
1	Age	Gender	Ethnic	Max Teeth	Mand	Rt Tooth	Lt Tooth	Distance to floor(mm)	Distance to floor(mm)
2	70	M	Asian	PE	PE	6	11	13.97	13.81
3	30	F	C	CD	CD	6	12	15.21	13.6
4	78	M	AA	PE	PE	2	15	30.91	31.97
5	76	M	AA	PE	PE	2	15	38.72	32.7
6	58	M	AA	CD	CD	2	15	23.6	25.2
7	51	F	C	PE	PE	2	15	25.08	22.9
8	51	M	C	PE	PE	2	14	32	35.2
9	46	F	Asian	PE	CD	2	15	23.13	27.9
10	61	F	Asian	CD	CD	3	14	31.8	29.42
11	18	F	AA	CD	CD	3	14	20.8	21.04
12	89	M	C	PE	PE	3	14	29.2	28.4
13	82	M	C	PE	PE	3	14	32.11	28.58
14	82	M	C	PE	PE	3	14	22.01	28.14
15	80	M	C	PI	PE	3	14	21.31	22.8
16	80	M	C	PE	PE	3	14	34.8	28.47
17	78	M	C	PE	PE	3	14	28	28
18	78	M	C	CD	CD	3	14	33.22	32.29
19	77	F	Asian	PE	PE	3	13	26	28
20	77	M	AA	PE	CE	3	14	26.4	23.6

Table 1: Excel worksheet for data collection showing age, gender, ethnicity, maxillary and mandibular dentition, location and distance.

CHAPTER 3
RESULTS

Of the 680 CBCT scans which were reviewed, 403 were included for measurement of distance from the infraorbital foramen to the floor of the sinus and the location above the inferior maxillary tooth. This was converted to average distances amongst the groups studied on the right and left side respectfully and percent of occurrence above the most inferior tooth on each side. The total percentage of infraorbital foramen located above the inferior maxillary tooth was broken down by tooth and tooth number.

The infraorbital foramen was located above the 2nd molar 2.11% of the time with 17 occurrences, above the 1st molar 41.69% of the time with 336 occurrences, above the 2nd premolar 46.65% of the time with 376 occurrences, above the 1st premolar 8.6% of the time with 68 occurrences and above the canine 1.1% of the time with 9 occurrences (Table 2, Figure 6).

	2nd molar	1st molar	2nd premolar	1st premolar	Canine	
Total	17	336	376	68	9	806
Percentage	2.11%	41.69%	46.65%	8.60%	1.10%	

Table 2: Overall location of the foramen above maxillary tooth.

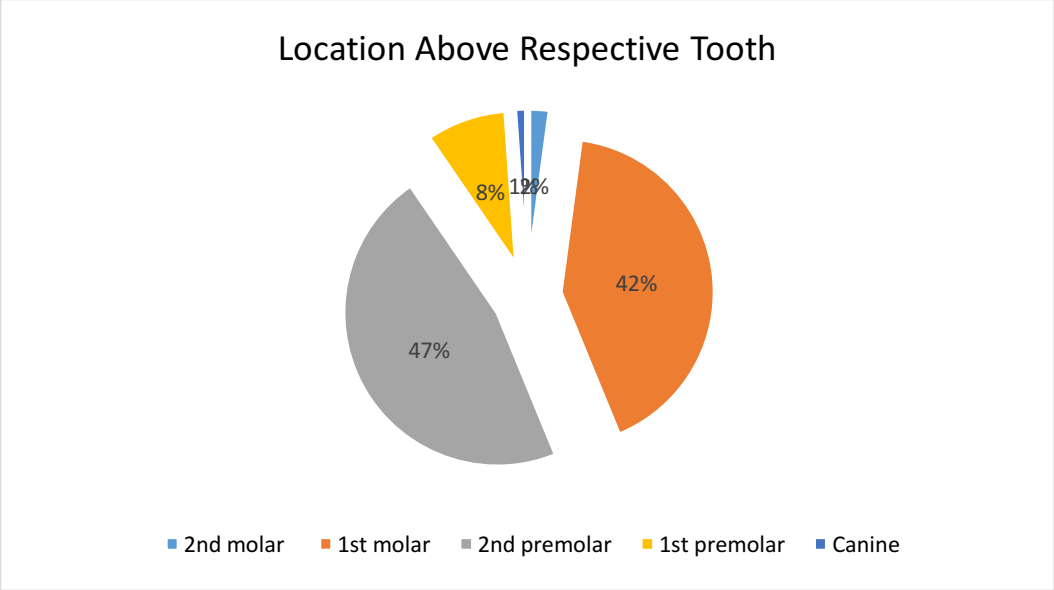

Figure 6: Percentage of occurrences above maxillary tooth.

The total population, genders, ethnicity and age were then further broken down to location above the respected inferior tooth on the right and left sides. The total population on the right side showed 1% above tooth #2 with 6 occurrences, 44% above tooth #3 with 176 occurrences, 46% above tooth #4 with 186 occurrences, 7% above tooth #5 with 30 occurrences and 1% above tooth #6 with 5 occurrences (Table 3, Figure 7). The total population on the left side showed 1% above tooth #11 with 4 occurrences, 9% above tooth #12 with 38 occurrences, 47% above tooth #13 with 190 occurrences, 40% above tooth #14 with 160 occurrences and 3% above tooth #15 with 11 occurrences (Table 4, Figure 8).

Location Superior to Tooth Total Population Right Side	
Tooth #2	6
Tooth #3	176
Tooth #4	186
Tooth #5	30
Tooth #6	5
Total	403

Table 3: Occurrences of foramen above teeth on right side for total population.

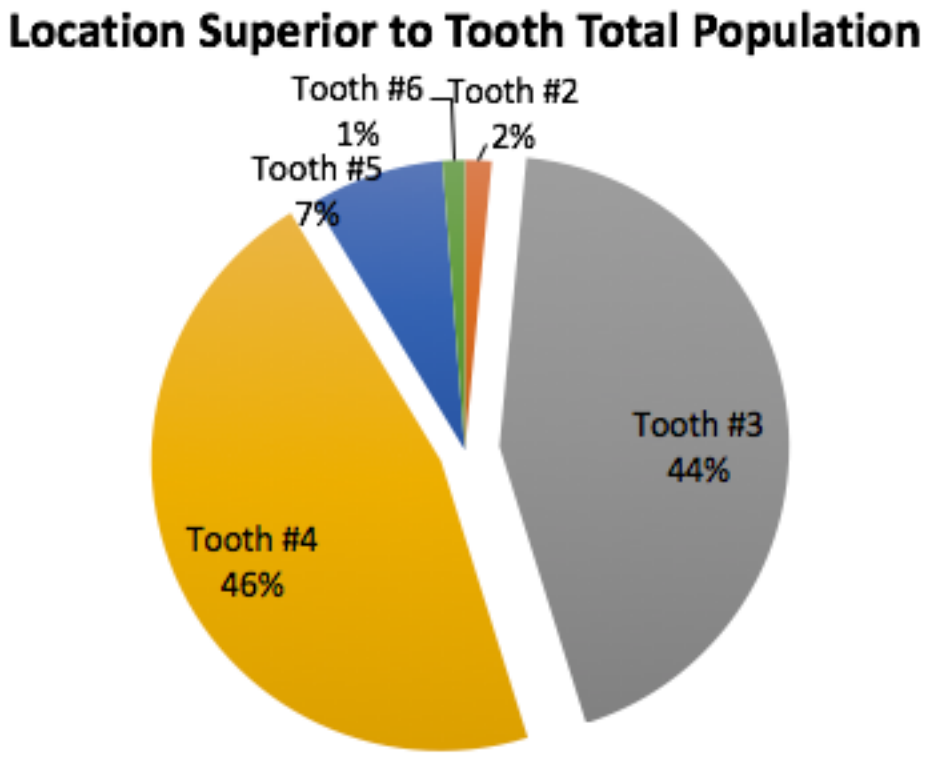

Figure 7: Pie chart of percentage of occurrences above right maxillary tooth for total population.

Location Superior to Tooth Total Population Left Side	
Tooth #11	4
Tooth #12	38
Tooth #13	190
Tooth #14	160
Tooth #15	11
Total	403

Table 4: Occurrences of foramen above teeth on left side for total population.

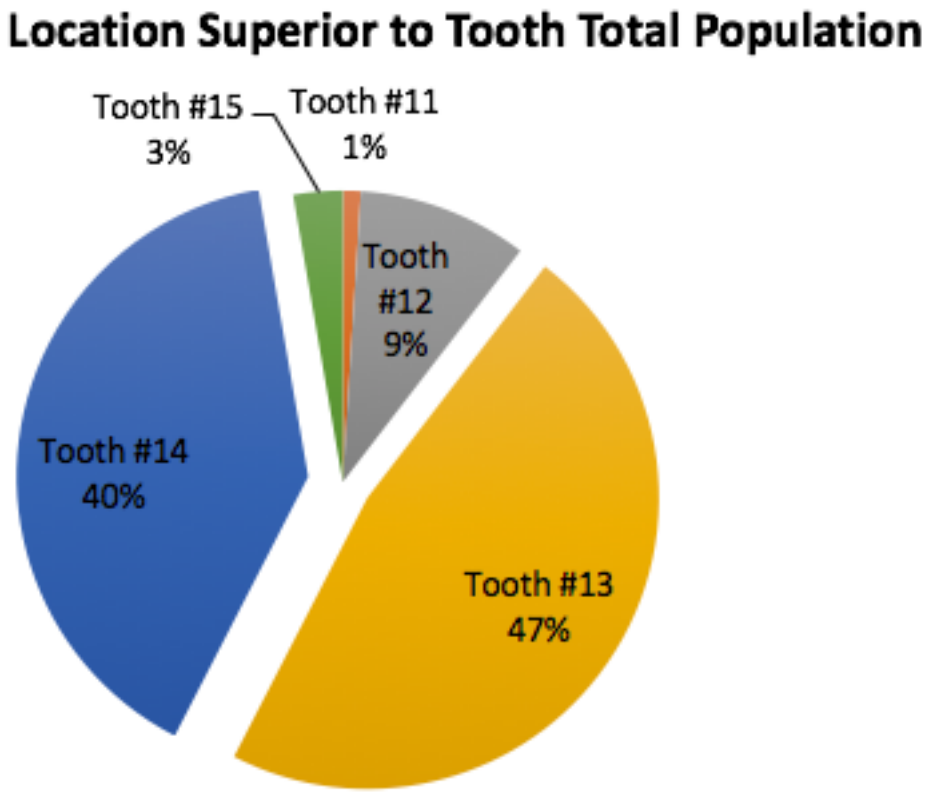

Figure 8: Pie chart of percentage of occurrences above left maxillary tooth for total population.

The total male population on the right side showed 2% above tooth #2 with 4 occurrences, 39% above tooth #3 with 68 occurrences, 52% above tooth #4 with 90 occurrences, 6% above tooth #5 with 11 occurrences, and 1% above tooth #6 with 2 occurrences as seen in Table 5 and Figure 9. Furthermore, the total male population on the left side showed 1% above tooth #11 with 2 occurrences, 9% above tooth #12 with 16 occurrences, 47% above tooth #13 with 82 occurrences, 40% above tooth #14 with 69 occurrences, and 3% above tooth #15 with 6 occurrences (Table 6, Figure 10).

Location Superior to Right Tooth Total Males	
Tooth #2	4
Tooth #3	68
Tooth #4	90
Tooth #5	11
Tooth #6	2
Total	175

Table 5: Occurrences of foramen above teeth on right side for male population.

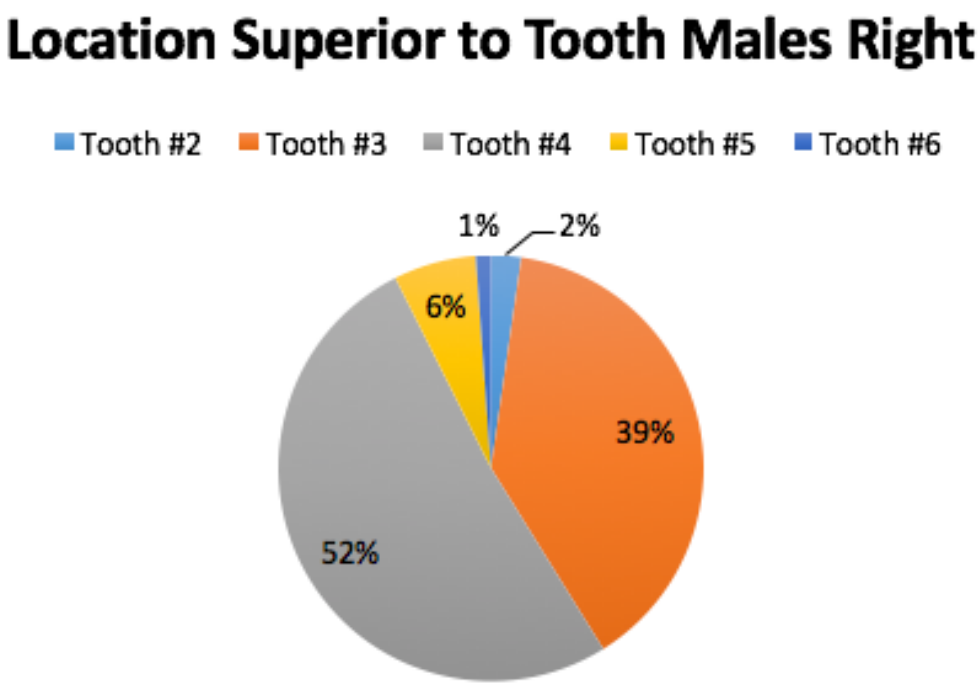

Figure 9: Pie chart of percentage of occurrences above right maxillary tooth for male population.

Location Superior to Left Tooth Total Males	
Tooth #11	2
Tooth #12	16
Tooth #13	82
Tooth #14	69
Tooth #15	6
Total	175

Table 6: Occurrences of foramen above teeth on left side for male population.

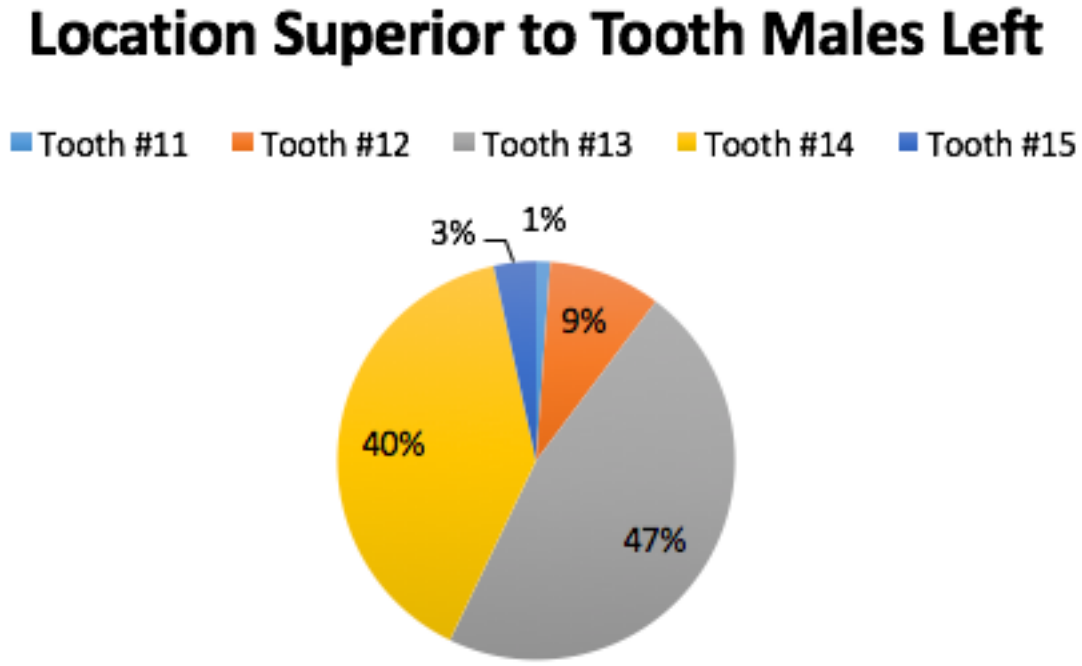

Figure 10: Pie chart of percentage of occurrences above left maxillary tooth for male population.

The total female population on the right side showed 1% above tooth #2 with 2 occurrences, 48% above tooth #3 with 108 occurrences, 42% above tooth #4 with 96 occurrences, 8% above tooth #5 with 19 occurrences and 1% above tooth #6 with 3 occurrences (Table 7, Figure 11). The left side of the total female population showed 1% above tooth #11 with 2 occurrences, 10% above tooth #12 with 22 occurrences, 47% above tooth #13 with 108 occurrences, 40% above tooth #14 with 91 occurrences and 2% above tooth #15 with 5 occurrences as seen in Table 8 and Figure 12.

Location Superior to Tooth Total Females Right	
Tooth #2	2
Tooth #3	108
Tooth #4	96
Tooth #5	19
Tooth #6	3
Total	228

Table 7: Occurrences of foramen above teeth on right side for female population.

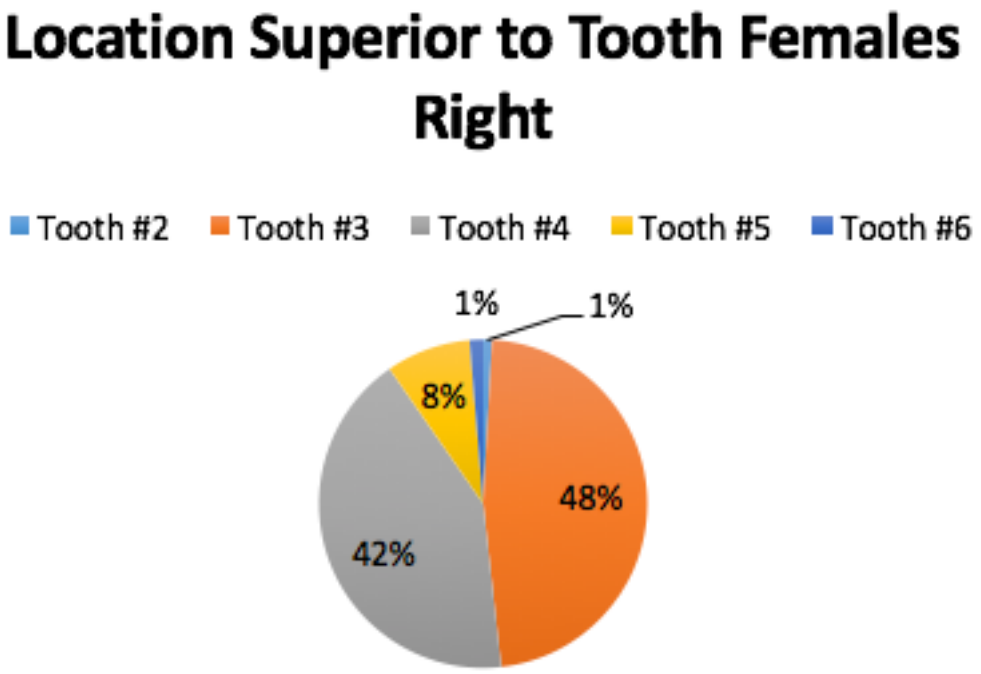

Figure 11: Pie chart of percentage of occurrences above right maxillary tooth for female population.

Location Superior to Tooth Total Females Left	
Tooth #11	2
Tooth #12	22
Tooth #13	108
Tooth #14	91
Tooth #15	5
Total	228

Table 8: Occurrences of foramen above teeth on left side for female population.

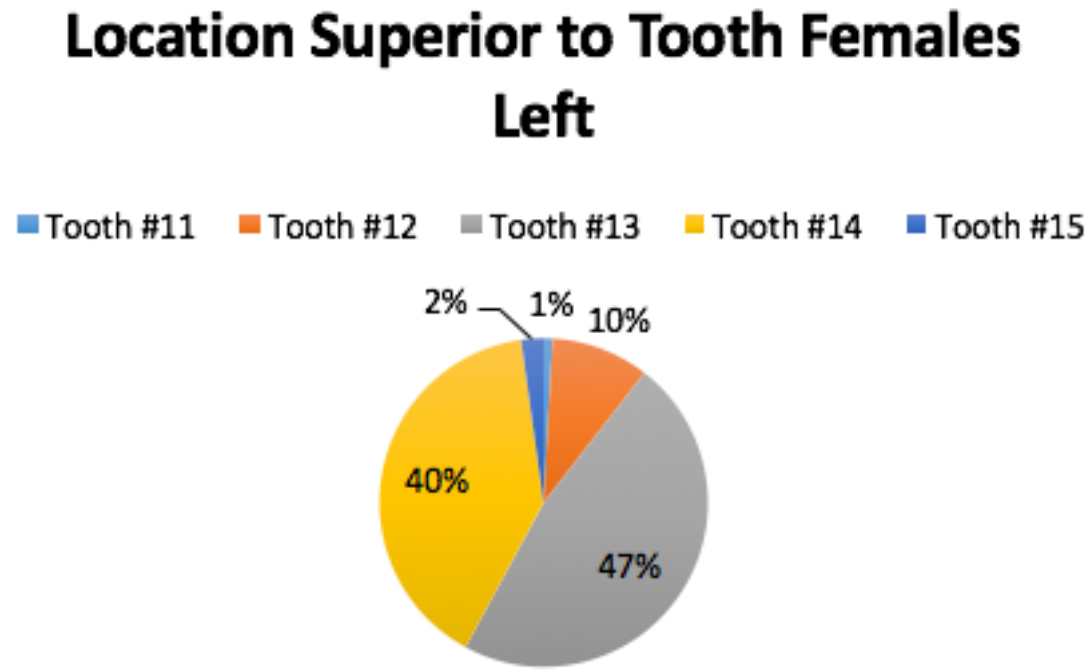

Figure 12: Pie chart of percentage of occurrences above left maxillary tooth for female population.

The total Caucasian population on the right side showed 1% above tooth #2 with 2 occurrences, 43% above tooth #3 with 113 occurrences, 48% above tooth #4 with 127 occurrences, 7% above tooth #5 with 19 occurrences and 1% above tooth #6 with 3 occurrences (Table 9, Figure 13). Additionally, the total Caucasian population on the left side showed 1% above tooth #11 with 2 occurrences, 11% above tooth #12 with 29 occurrences, 47% above tooth #13 with 125 occurrences, 38% above tooth #14 with 101 occurrences and 3% above tooth #15 with 7 occurrences (Table 10, Figure 14).

Location Superior to Tooth Caucasians Right	
Tooth #2	2
Tooth #3	113
Tooth #4	127
Tooth #5	19
Tooth #6	3
Total	264

Table 9: Occurrences of foramen above teeth on right side for Caucasian population.

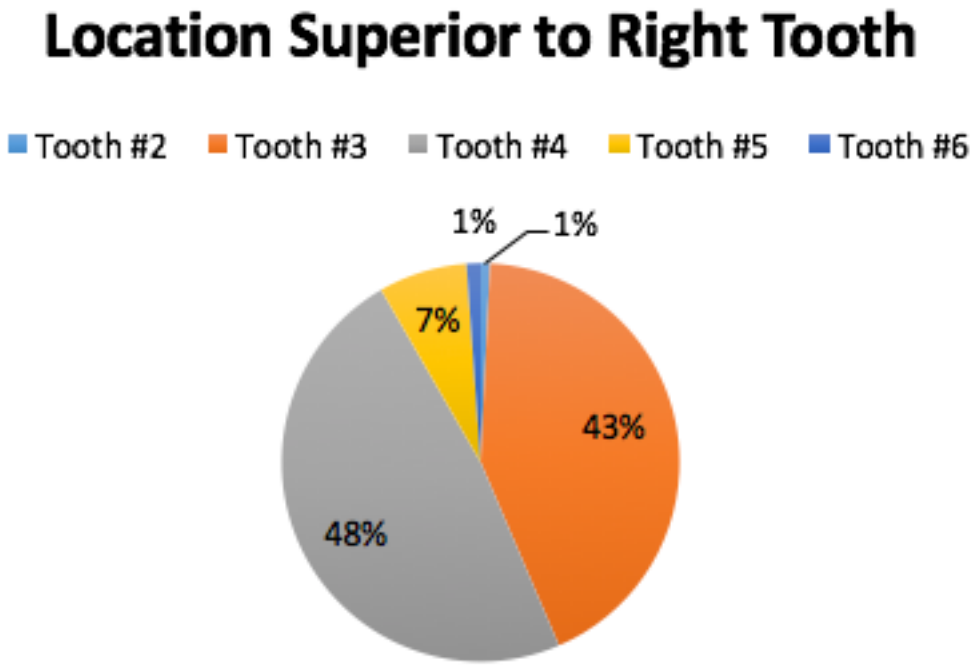

Figure 13: Pie chart displaying percentage of occurrences above right maxillary teeth in Caucasian population.

Location Superior to Tooth Caucasians Left	
Tooth #11	2
Tooth #12	29
Tooth #13	125
Tooth #14	101
Tooth #15	7
Total	264

Table 10: Occurrences of foramen above teeth on left side for Caucasian population.

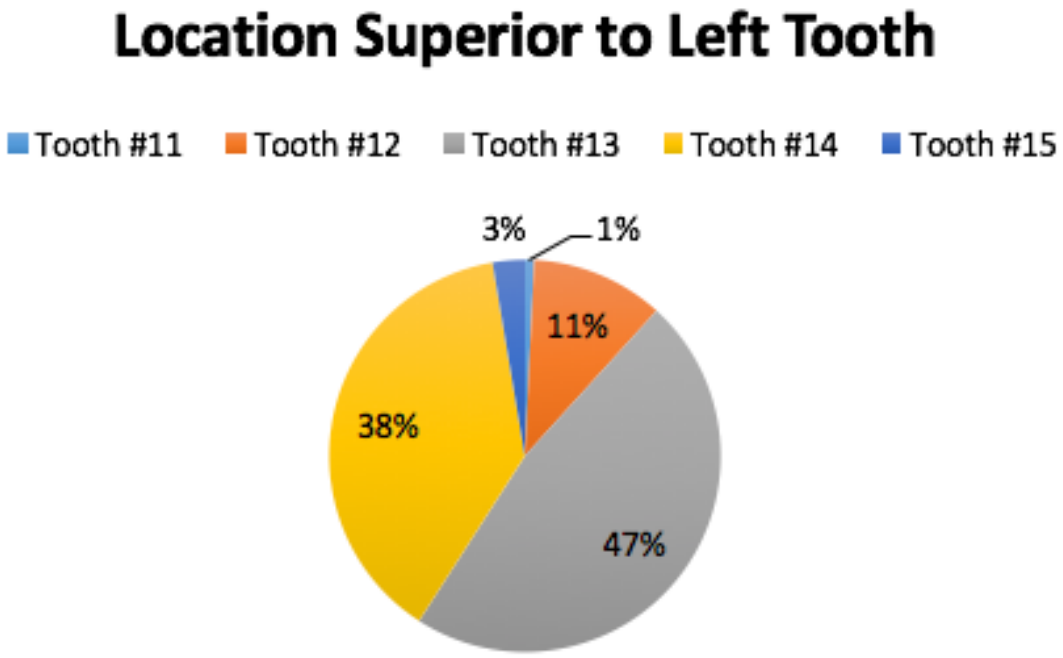

Figure 14: Pie chart displaying percentage of occurrences above left maxillary teeth in Caucasian population.

The total African-American population on the right side showed 4% above tooth #2 with 3 occurrences, 53% above tooth #3 with 41 occurrences, 36% above tooth #4 with 28 occurrences, 6% above tooth #5 with 5 occurrences and 1% above tooth #6 with 1 occurrence (Table 11, Figure 15). Conversely, the total African-American population on the left side showed 1% above tooth #11 with 1 occurrence, 4% above tooth #12 with 3 occurrences, 44% above tooth #13 with 34 occurrences, 47% above tooth #14 with 37 occurrences and 4% above tooth #15 with 3 occurrences (Table 12, Figure 16).

Location Superior to Tooth African-American Right	
Tooth #2	3
Tooth #3	41
Tooth #4	28
Tooth #5	5
Tooth #6	1
Total	78

Table 11: Occurrences of foramen above teeth on right side for African-American population.

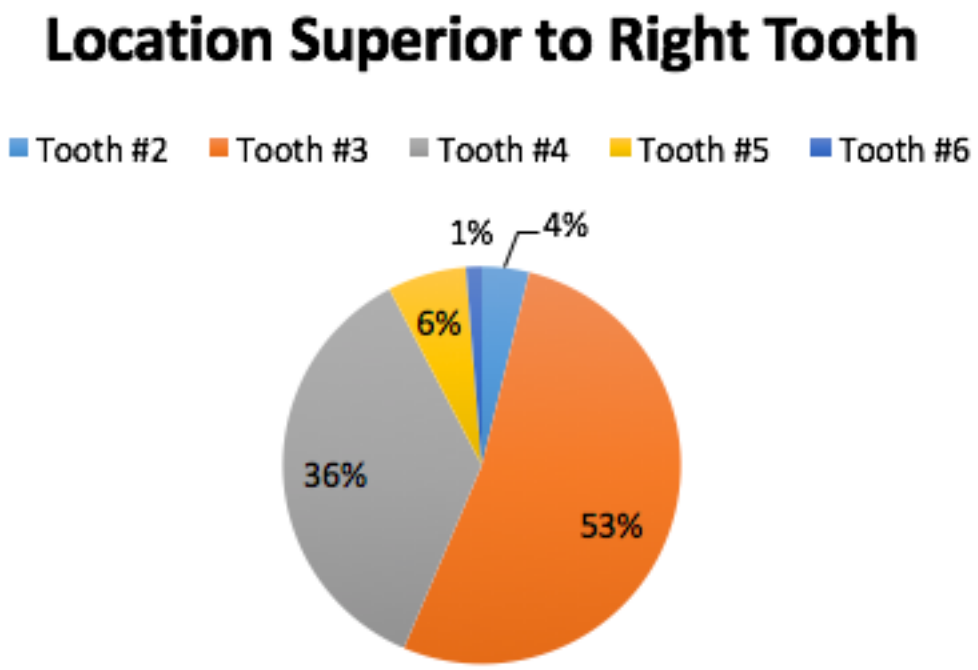

Figure 15: Pie chart displaying percentage of occurrences above right maxillary teeth in African-American population.

Location Superior to Tooth African-American Left	
Tooth #11	1
Tooth #12	3
Tooth #13	34
Tooth #14	37
Tooth #15	3
Total	78

Table 12: Occurrences of foramen above teeth on left side for African-American population.

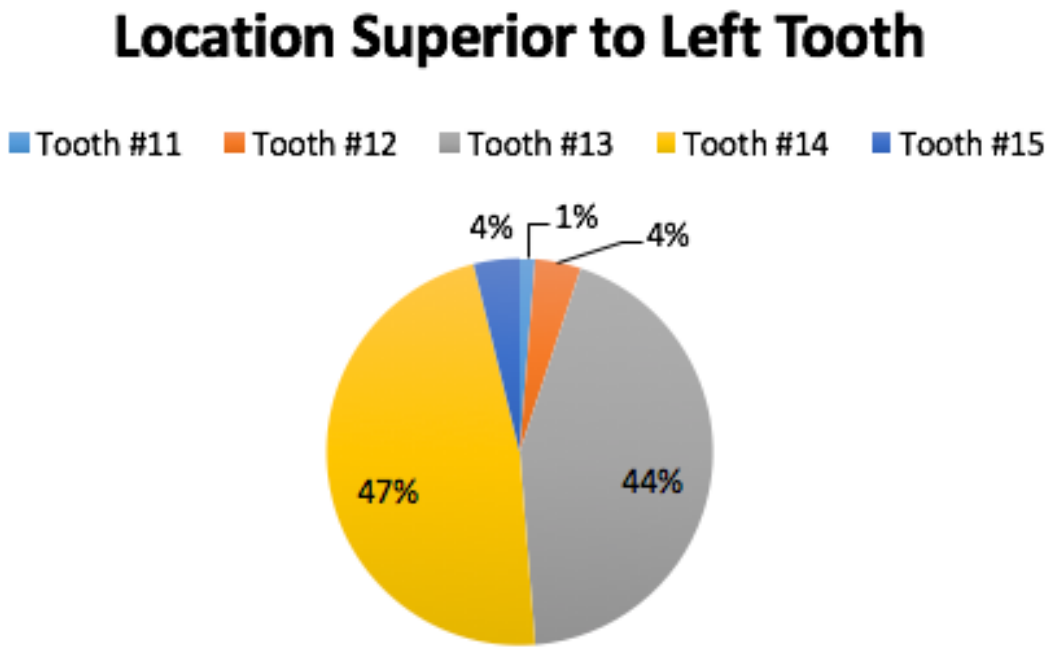

Figure 16: Pie chart displaying percentage of occurrences above left maxillary teeth in African-American population.

The total Asian population on the right side showed 3% above tooth #2 with 1 occurrence, 33% above tooth #3 with 13 occurrences, 51% above tooth #4 with 20

occurrences, 10% above tooth #5 with 4 occurrences and 3% above tooth #6 with 1 occurrence (Table 13, Figure 17). On the contralateral, or left side in the Asian population, 2% above tooth #11 with 1 occurrence, 13% above tooth #12 with 5 occurrences, 49% above tooth #13 with 19 occurrences, 33% above tooth #14 with 13 occurrences and 3% above tooth #15 with 1 occurrence as seen in Table 14 and Figure 18.

Location Superior to Tooth Asians Right	
Tooth #2	1
Tooth #3	13
Tooth #4	20
Tooth #5	4
Tooth #6	1
Total	39

Table 13: Occurrences of foramen above teeth on right side for Asian population.

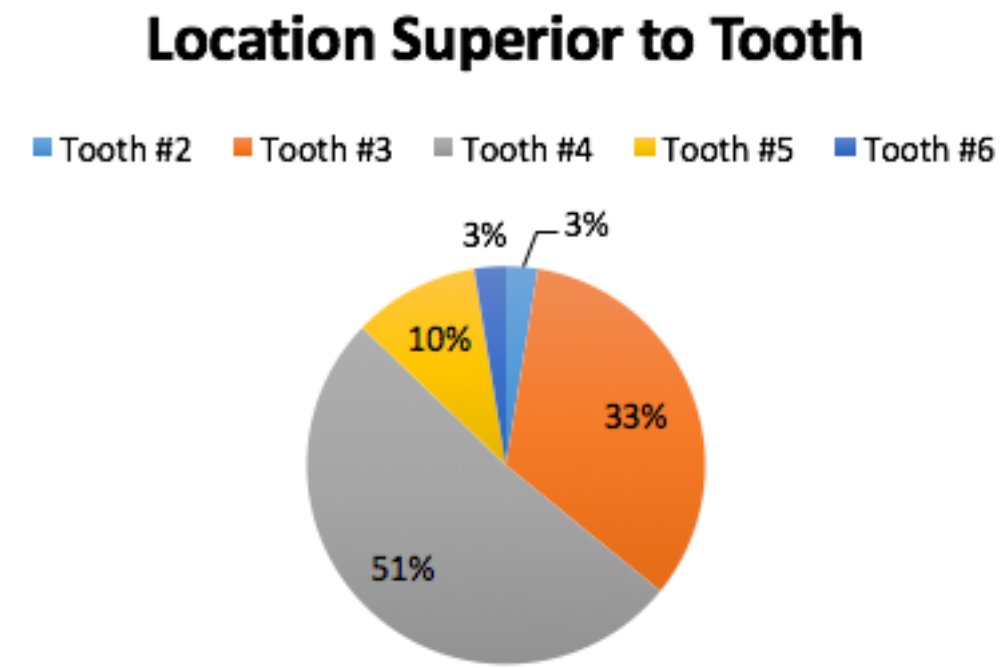

Figure 17: Pie chart displaying percentage of occurrences above right maxillary teeth in Asian population.

Location Superior to Tooth Asians Left	
Tooth #11	1
Tooth #12	5
Tooth #13	19
Tooth #14	13
Tooth #15	1
Total	39

Table 14: Occurrences of foramen above teeth on left side for Asian population.

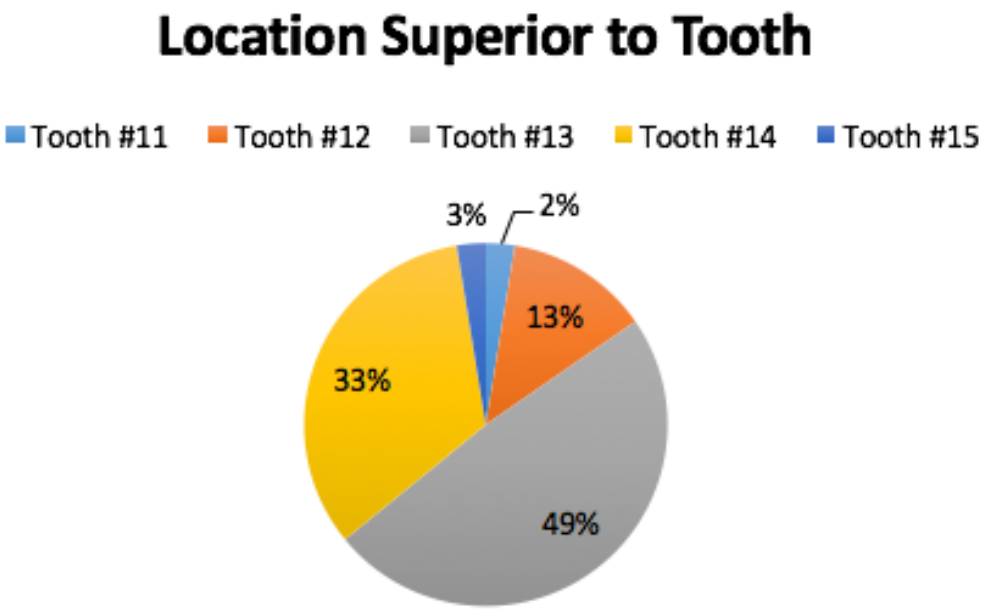

Figure 18: Pie chart displaying percentage of occurrences above left maxillary teeth in Asian population.

The total Hispanic population on the right side showed 0% above tooth #2 with no occurrence, 41% above tooth #3 with 9 occurrences, 50% above tooth #4 with 11 occurrences, 9% above tooth #5 with 2 occurrences and 0% above tooth #6 with no occurrence (Table 15, Figure 19). Moreover, the total Hispanic population on the left side showed 0% above tooth #11 with no occurrence, 5% above tooth #12 with 1 occurrence, 50% above tooth #13 with 11 occurrences, 45% above tooth #14 with 10 occurrences and 0% above tooth #15 with no occurrence (Table 16, Figure 20).

Location Superior to Tooth Hispanic Right	
Tooth #2	0
Tooth #3	9
Tooth #4	11
Tooth #5	2
Tooth #6	0
Total	22

Table 15: Occurrences of foramen above teeth on right side for Hispanic population.

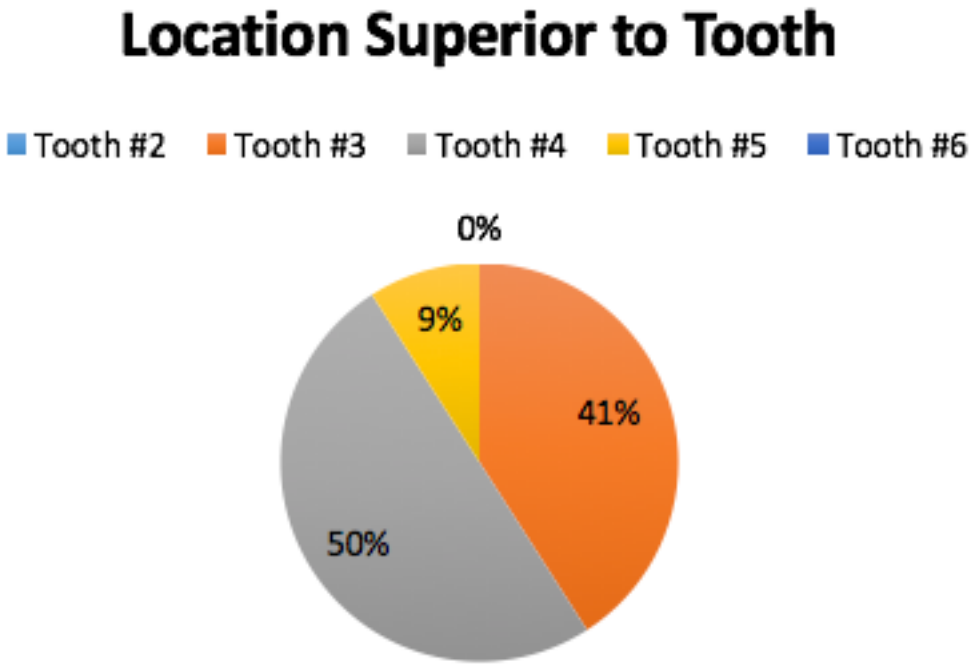

Figure 19: Pie chart displaying percentage of occurrences above right maxillary teeth in Hispanic population.

Location Superior to Tooth Hispanic Left	
Tooth #11	0
Tooth #12	1
Tooth #13	11
Tooth #14	10
Tooth #15	0
Total	22

Table 16: Occurrences of foramen above teeth on left side for Hispanic population.

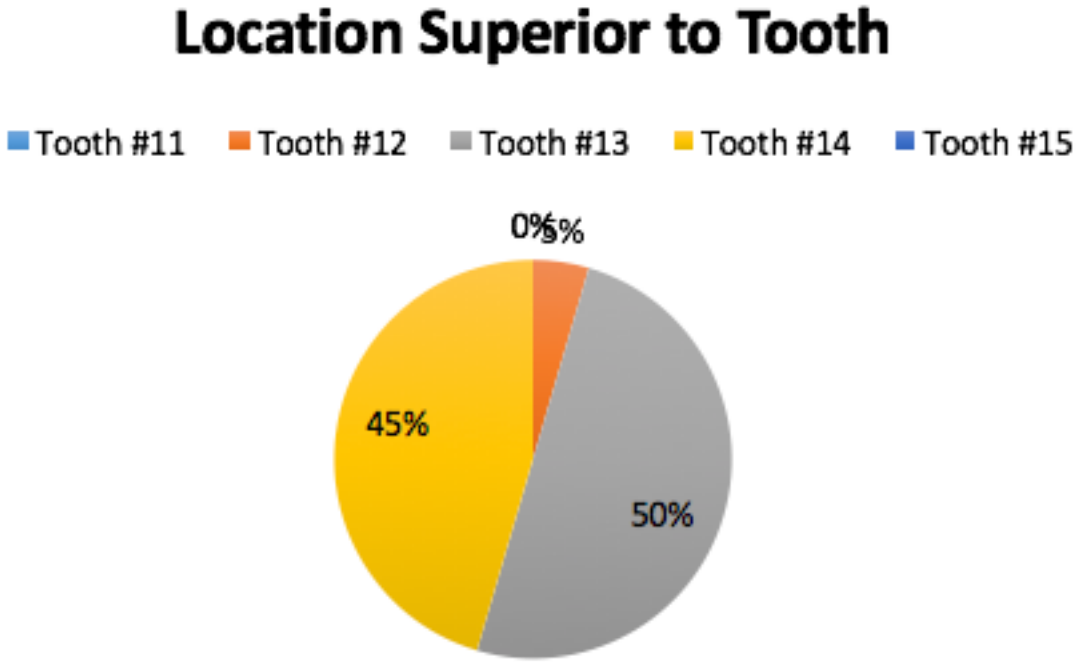

Figure 20: Pie chart displaying percentage of occurrences above left maxillary teeth in Hispanic population.

The average distance between the respective right and left sides of the total population and genders was then determined. The total population showed an average distance of 23.94 mm from the infraorbital foramen to the floor of the maxillary sinus on the right side, and 22.84 mm on the left side. A t-test was performed and a p-value of 0.00000000000151673 was found, indicating statistical significance between the right and left sides (Figure 21).

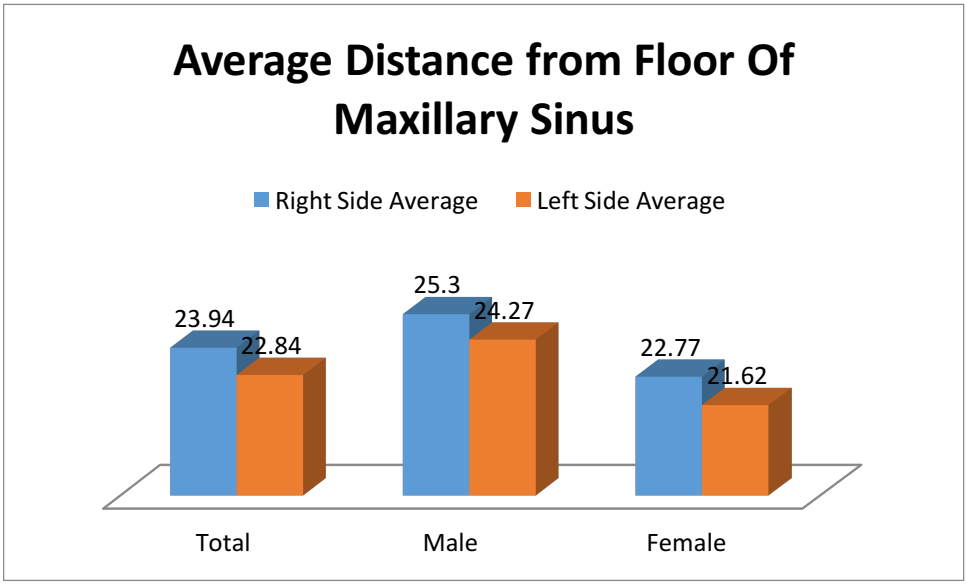

Figure 21: Bar graph showing average distance from the foramen to the floor of the sinus in the total population, male population, and female population.

The two genders were then studied looking for a potential difference between the average distance between the infraorbital foramen and floor of the maxillary sinus. The male population showed an average distance of 25.3 mm from the infraorbital foramen to the floor of the maxillary sinus on the right side and 24.27 mm on the left side. The female population showed 22.77 mm distance on the right side and 21.62 mm on the left side. A t-test was performed yielding a p-value of 0.000000310067, showing statistical

significance between the male and female genders. The males showed a larger overall distance between the foramen and the floor of the sinus.

The total population was broken down by ethnicity and were then studied looking at the mean distance from the infraorbital foramen to the floor of the sinus. The mean for each ethnicity was compared to find a difference occurring between the races. The Caucasians showed an average distance of 23.94 mm from the infraorbital foramen to the floor of the maxillary sinus on the right side, and 22.84 mm on the left side. The African-American population showed an average of 22.83 mm on the right side from the foramen to the floor of the maxillary sinus, and 21.77 mm on the left. Additionally, the Asian population showed a distance of 23.72 mm on the right side when measuring the infraorbital foramen to the floor of the maxillary sinus, and 22.53 mm on the left. Finally, the Hispanic population showed a distance of 21.93 mm on the right side when measuring the infraorbital foramen to the floor of the maxillary sinus and 21.64 mm distance on the left. An analysis of variance (ANOVA) test was used to determine statistical significance. The p-value was 0.833, which showed that there was no statistical significance in the distance from the infraorbital foramen from the floor of the sinus between the different ethnicities (Figure 22, Table 17).

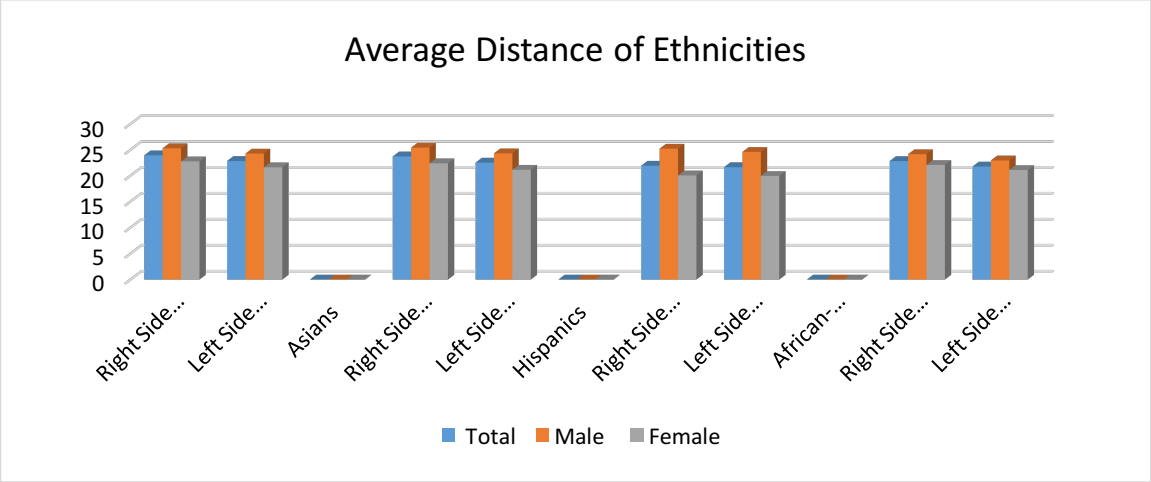

Figure 22: Bar graph showing the average distance from the foramen to the floor of the sinus in all ethnicity groups as a whole, and broken down into males and females.

Anova: Single Factor							
SUMMARY							
Groups	Count	Sum	Average	Variance			
Column 1	264	5936.58	22.48704545	31.56988002			
Column 2	22	479.265	21.78477273	56.48348447			
Column 3	78	1739.365	22.29955128	31.89263064			
Column 4	39	901.76	23.12205128	39.39565094			
ANOVA							
Source of Variation	SS	df	MS	F	P-value	F crit	
Between Groups	29.24824678	3	9.749415593	0.289397004	0.833062175	2.627270479	
Within Groups	13441.79891	399	33.68871908				
Total	13471.04716	402					

Table 17: ANOVA test of the differences in averages between the different ethnicity groups.

The average distance from the infraorbital foramen to the floor of the sinus was also analyzed according to the age groups of the subjects. The age group of 18-35 year olds showed an average distance of 22.11 mm on the right side and 20.61 mm on the left side from the infraorbital foramen to the floor of the maxillary sinus. The age group of 36-53 year olds showed an average distance of 23.73 mm on the right side and 22.53 mm on the left side from the foramen to the floor of the sinus. The next age group comprised of 54-71 year olds, showed an average distance of 23.44 mm on the right side and 22.68

mm on the left side from the infraorbital foramen to the floor of the sinus. Finally, the age group of 72-90 years old showed an average distance of 26.46 mm on the right side and 25.25 mm on the left side from the infraorbital foramen to the floor of the maxillary sinus. These results were analyzed using an ANOVA test to determine statistical significance. A p-value of 0.0265 was found, proving statistical significance between the average distance from the foramen to the floor of the maxillary sinus increases with age (Figure 23, Table 18). A steady increase is shown as age progresses, and the ANOVA tested proved statistical significance.

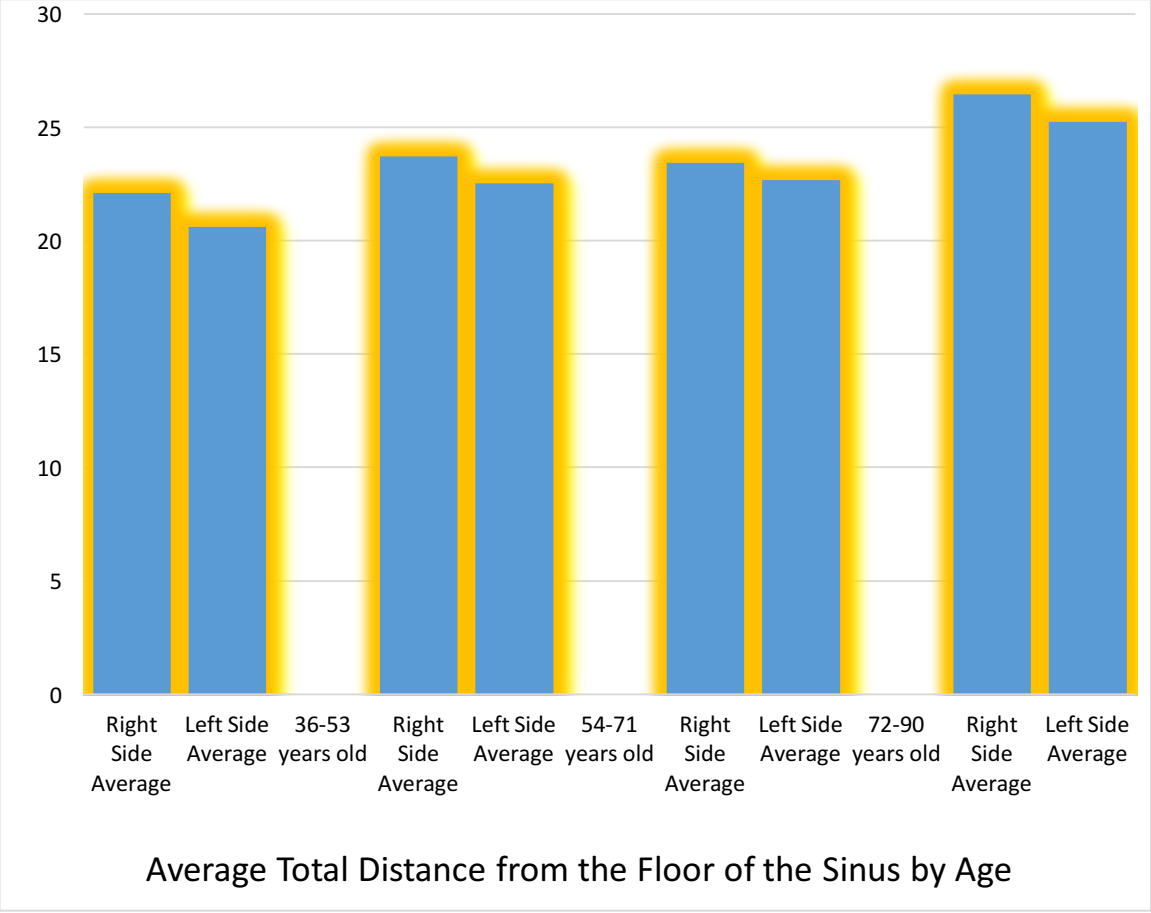

Figure 23: Bar graph of the average distance from the foramen to the floor of the sinus in the different age groups.

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	2	42.72	21.36	1.125		
Column 2	2	46.26	23.13	0.72		
Column 3	2	46.12	23.06	0.2888		
Column 4	2	51.71	25.855	0.73205		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20.7352375	3	6.911745833	9.647044798	0.026500918	6.591382116
Within Groups	2.86585	4	0.7164625			
Total	23.6010875	7				

Table 18: ANOVA test of the differences in averages between the different age groups.

CHAPTER 4
DISCUSSION

This study further examines the CBCT study of the same Temple University Kornberg School of Dentistry population looking for sinus pathology (Hsiao, 2014). Although the same population was examined, the current research focused on studying the location of the infraorbital foramen, and how it can affect surgical and anesthetic techniques. Knowing the location above the respected tooth and approximate distance from the floor of the sinus can be used as an aid to avoid surgical complications and achieve more profound local anesthesia. There is some variance with the location of the infraorbital foramen depending on each individual patient. CBCT scans can provide the exact location for each patient. One study found that there was a minimum distance of 3 mm between the infraorbital foramen and margin and a maximum distance of 12 mm (Lokanayaki, 2013). This shows that there can be large differences between patients. These findings can be utilized in everyday practice to help practitioners with treatment planning and to avoid potential complications.

There were 403 patients included in this study and a similarity of location was noticed. The data was analyzed based on right and left sides and compared as a whole also. The distance and location above inferior maxillary tooth was recorded for each patient. The infraorbital foramen was found to be located above the second premolar most often then followed by the first molar. This varies from other studies and differs from the common accepted area where local anesthesia is administered. One study found the majority to be above the second premolar, but then the next most common location

was between the two premolars (Varshney et al., 2013). Another study found the same results, showing less prevalence above the first molar, with the majority above the second premolar (Ilayperuma et al., 2010). Both studies were performed on cadaver skulls and both differed from the present study as the second most common location was the first molar. The results obtained varied from the common techniques taught for the infraorbital nerve block. Typically, the tooth landmark to give the infraorbital block injection is the canine or first premolar (Malamed, 2004). Judging from this data, if a dentist is having difficulty achieving profound anesthesia with the infraorbital or anterior superior alveolar nerve block, performing injection in a more distal site may be a more efficient technique. Any aid in anesthesia for the dental profession becomes helpful, especially as more surgical procedures are done every year since the advent of implant dentistry.

The distances when compared between the right and left side were analyzed for differences as well. Statistical significance was found between the right and left sides, and this was in agreement with other studies. In study by Macedo et al. (2009), the distance was measured between the infraorbital foramen and the infraorbital margin and piriform aperture respectively. Using a t-test, that study also yielded statistical significance in the difference between the right and left side location of the infraorbital foramen (Macedo et al., 2009). The distance between the sides of the foramen to the alveolar crest was observed in CBCT study and found to be statistically significant as well (Sheikhi et al., 2013).

The different genders were compared based on the mean distance as well and a statistical significant difference was observed. The males showed a larger overall mean distance when compared to the females, which can be attributed to average size difference in general between the respective genders. Males and females were compared using CBCT in the Sheikhi et al. (2013) study, observing the distance from the foramen to the alveolar crest. In this study the distance was different between the sexes as well with males having a greater distance (Sheikhi et al., 2013). In another study on the crania of two hundred forty-two Brazilians, the crania showed statistically significant differences between the height of the foramen and distance to the anterior nasal spine (de Oliveira et al., 2016). All measurements were larger amongst the males in this study as well (de Oliveira et al., 2016). The Ilayperuma et al. (2010) study on Sri Lankan skulls analyzed the mean distance between the infraorbital foramen to the maxillary midline, infraorbital rim and supraorbital foramen. All distances were significantly longer in the males than females, and this variation can be useful information when treating patients of different genders (Ilayperuma et al., 2010).

Intriguingly, when comparing the ethnicities, no statistical significance was found. This could be attributed to having a smaller sample size amongst some of the groups or to there truly being no difference between the different ethnicities studied. The previous studies referenced only examined patients of the same race, so differences could not be drawn from previous data either.

Finally, age groups were studied looking for a statistical difference between the mean distances. A statistical significant difference was noted, showing that the distance

from the foramen to the floor of the sinus increased with age. There are a few factors that can account for this difference. As the patients lose maxillary teeth, the sinus pneumatizes, which could cause the distance to increase. Additionally, if the patients were to lose mandibular teeth, the maxillary teeth could supraerupt, causing the sinus to become larger as well. As patients age, the total number of lost teeth tends to increase. Therefore, a correlation can be attributed to the loss of maxillary and mandibular teeth. An additional study on the increase in the size of the maxillary sinus with age could be beneficial. The missing teeth on the mandible and maxilla could be taken into account to determine their effect on the sinus as well.

CHAPTER 5
CONCLUSIONS

This CBCT study broke down the patients from Temple University Kornberg School of dentistry into groups based on age, gender and ethnicity. The location of the infraorbital foramen was recorded with respect to the floor of the maxillary sinus and the tooth directly inferior in the maxillary arch. The data was analyzed and tested for statistical significance.

As a patient ages, the distance between the foramen and the floor of the sinus increases. This can be attributed to the loss of teeth in both arches and pneumatization of the sinus. An increase of 4-5 mm was seen between the 18-35 year old group and the 72-90 year old group. An ANOVA test was performed and statistical significance was found.

With the data collected, and divided by gender, statistical significant differences were noted through use of a t-test. Males had a longer distance from the floor of the sinus to the foramen. Males showed a distance of 25.3 mm on the right side and 24.27 mm on the left side, whereas females showed 22.77 mm on the right and 21.62 mm on the left sides.

The right and left sides also showed statistically significant differences when analyzed using a t-test. The right side had an average value of 23.94 mm and the left side was 22.84 mm, demonstrating variance between the right and left side of individuals.

There was no statistically significant difference exhibited between ethnicities using the ANOVA test.

Interestingly, the location correlated with the inferior maxillary tooth was found to be different than in previous studies. The location was most often superior to the second premolar followed by the first molar. Almost 90% of the time the foramen was located above these two teeth.

With this new data, anesthetic techniques can be modified to achieve better local anesthesia delivery. The location can also be avoided to prevent any unwanted injury or complications in surgical procedures. Knowing the location of the infraorbital foramen

will act as an aid to increase efficacy and safety for the dental professional when performing complex or routine procedures.

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