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MORPHOMETRIC ANCESTRAL ANALYSIS OF INFRAORBITAL FORAMEN AND MAXILLO-FACIAL LANDMARKS OF ADULT NORTH AMERICAN SKULLS USING X-RAY AND COMPUTED TOMOGRAPHY SCANS

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By

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Morphometric Ancestral Analysis of Infraorbital Foramen and Maxillo-Facial Landmarks of Adult North American Skulls Using X-Ray and Computed Tomography Scans

Chairperson: Randall Skelton

Abstract

Skeletal remains provide a variety of information about a species population and the sub populations within that species. The infraorbital foramen has previously been used to understand dietary niches, paleoecology, the nervous system, and the effect of the nervous system on other bone functions in the facial region in humans and other mammals. In medicine, the precise location of the infraorbital foramen has been studied to aid and guide maxillo-facial procedures and surgeries. In this research project, the null hypothesis states that the placement and location of the infraorbital foramen in relation to other facial landmarks were the same between modern North American populations in three ancestral categories: Native Americans, White, and Black.

The collection, stated above, was chosen due the abundance of well-preserved facial and maxillo-skeletal documentation via computed tomography scans and x-rays. This project took note of previous researchers and developed new identification of twelve maxillo-facial landmarks in relation to the infraorbital foramen to ascertain an explicit location of the infraorbital foramen in 199 modern human individuals.

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Above all I would like to thank my family and friends for guiding me through one of the worst years of my life, while I struggled to complete my degree despite a cancer diagnosis and chemotherapy treatments. I extend a thanks most importantly to my mother, who held my hand through the pain, calmed my anxieties, and listened to endless rants about human bones, despite having no idea what I was talking about. Also, thank you to Emily Owens and Samantha Hofland, for spending so many nights with me in the lab while I worked on my thesis.

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Introduction

The infraorbital foramen is a vital landmark of the human maxillae that allows the passage of the infraorbital nerve and blood vessels to travel into the palpebral, labial, and nasal branches that supply the blood to the skin of the lower eyelid, lateral surface and ala of the nose, upper lip, premolar teeth, and the conjunctiva. The infraorbital nerves are the continuation of the maxillary nerve that branches out to vital areas of the maxillo-facial region. Anthropologists also use the infraorbital foramen to identify the maxilla (Bass 1992). The study of the infraorbital foramen in humans and other animal species have led to interesting questions about the evolution of humans and other mammals (Spriggs, Muchlinski, and Gordon 2016). The infraorbital foramen has been used to understand dietary niches, paleoecology, the nervous system, and the effect of the nervous system on other bone functions in the facial region (Muchlinski et al. 2011).

However, the study of the infraorbital foramen in humans is most researched for clinical or medical purposes to aid in maxillo-facial surgeries and procedures. In many instances the infraorbital foramen is the pathway in which surgeons apply infraorbital nerve blockers to administer regional anesthesia to the maxillo-facial region (Rochette 2005; Kaçar et al. 2020; Lynch et al. 1994). The most common situations for the application of infraorbital nerve blockers are in cases of zygomatic complex fractures, pain management after surgical operations of the complex sinuses, or cleft lips in children (Shin et al. 2020; Nanayakkara et al. 2016). In these cases, the knowledge of the precise location of the infraorbital foramen is important to diminish the chances of the anesthetic difficulties or complications such as injuring the neurovascular bundles that pass through this foramen (Shin, Shin, and Lee 2020). Despite the surgical significance of this landmark there was previously very little information regarding its precise morphology and location. This has changed in recent years, with more clinical researchers searching for a way to precisely identify the IOF and discover the clinical relevance of the IOF's

size and shape in relation to a patient's gender or age. However, there are still very little data using broader ancestral groups as an avenue for understanding the morphology of the IOF, which is the purpose of this research study.

1.1 Purpose of Research

In recent years many doctors and researchers have completed research on the infraorbital foramen to reduce the risks and help surgeons and doctors use more precise location methods of the infraorbital foramen (IOF) in situations where on-site imaging is unavailable to discourage anesthetic complications (Shin et al. 2020; Nanayakkara et al. 2016). The medical necessity of this and similar research has been proven by other disciplines, researchers, and medical professionals. However, this research will strive to understand if an anthropological study of the location of the infraorbital foramen could provide insight on ancestral variation in the human skull, as well as expand on previous research using different ancestral groups. The goal is to expand the understanding of the infraorbital foramen in multiple ancestral groups found in North America using CT and X-ray scans to measure the infraorbital foramen in relation to distinct maxillo-facial landmarks. In pursuit of this purpose two null hypotheses will be examined in this study:

- ***Hypothesis 1*** *(Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen between males and females IOF measurements.*
- ***Hypothesis 2*** *(Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen when comparing all ancestral groups with each other.*

1.2 Use of Human Remains and Ancestry in Scientific Research

The human skeleton has been a vehicle for scientific research for thousands of years. Information gathered from skeletal remains helps scientists to understand things such as the human body, medicine, and a variety of other information about human culture and variation. However, that only scratches the surface of what scientists have discovered using the human skeleton as a source of information and body of research. While most researchers agree that the human skeleton is an important tool to be used in the pursuit of scientific inquiry, many struggle with the ethical dilemma that is presented when using human remains. The problem lies with the direct informed consent, which is often not granted by the individuals that are studied, and in archeology and anthropology it is often not possible to get the consent of family members or relatives. In many instances there is a definite expression against research on human remains given by relatives, tribal members, and communities. In studies, such as the research conducted in this paper, which use Native American remains and artifacts this dilemma is at the forefront of problems to be solved before the continuation of research. For these reasons, the current study uses x-ray scans and CT images taken from recently deceased individuals at the time of their final examination by a medical examiner that were collected by the New Mexico Decedent Imaging Database. The sampling, measurement, and data collection techniques used in this study minimized invasive handling of the human remains. As a result, no human remains were damaged in the pursuit of this research study.

1.3 Problems with Ancestral Studies

The study of ancestry in the field of anthropology in the past has presented many issues on the path for scientific inquiry. Many times, the study of ancestry was used to oppress minorities using forms of pseudoscience to justify prejudice. Because of this, many anthropologists are hesitant about using ancestry determination in modern practices. However,

with new scientific discoveries about biodiversity and the human genome the blending of ancestries in modern populations may be an ample field for further research. In medicinal practices, such as the procedures that inspired this study, ancestral variation can mean more precise patient care. The fears of using ancestry in anthropology and medicine still exist, especially in the study of cranial variation due to ancestry, because of the misuse of anthropological techniques to justify inequality. It is only right that there is a certain level of skepticism on the topic of reintroducing ancestry into scientific practice, but it may be important to understand the vital interplay between nature and nurture in medical and anthropological research. In forensic contexts, the determination of geographic ancestry is usually an important consideration despite the concept of "race" being considered a counter-productive difficulty within the scope of osteology(Bass 1992). These difficulties are more notable in individuals of mixed ancestry when clear determination is not probable and other issues within the context of self-described ancestry that can lead to discrepancy in the identification of individuals. Despite these difficulties, ancestral determination is still a vital aspect of identification in forensic cases, and it becomes necessary for forensic practices to adapt to these changes in modern populations.

1.4 Benefits of Ancestral Study of Infraorbital Foramen

Previous research has been conducted to analyze the infraorbital foramen, and successfully compared gender, age, difference between the left and right sides, size, and location of the infraorbital foramen in singular ancestral populations (Gibelli et al. 2019; Kazkayasi et al. 2001; Shin et al. 2020; Dudzik 2019; Nanayakkara et al. 2016). However, research regarding the determination of ancestral differences in the placement and location of the infraorbital foramen and context from an anthropological perspective have not been formed, leaving a large gap in our understanding of the infraorbital foramen, despite many researchers hypothesizing that ancestry

might be an important factor for variation (Singh 2011; Tewari et al. 2018; Gupta, Nirala, and Gupta 2018; Saheb Shaik et al. 2012; Marx n.d.). Another gap is the limited number of ancestries that have been researched using the infraorbital foramen. Notably, most of the research of infraorbital foramen has been conducted using the dry skulls of adult Indian populations (Singh 2011; Tewari et al. 2018; Gupta, Nirala, and Gupta 2018).

Sadly, the most common problem to plague research, lack of an adequate sample, is also seen in the study of infraorbital foramen, as most research is conducted on sample sizes of less than one hundred individuals. The human skeleton is outstandingly variable, even in populations from the same ancestral group, so sample sizes of 60-100 are not always serviceable for application in clinical or anthropological settings. The use of dry skulls has also been a limitation for many researchers that focus on the infraorbital foramen, because of the use of certain landmarks on bone which are not visible or palpable through soft tissue (Ercikti, Apaydin, and Kirici 2017). The few studies that have been conducted using computed tomography (CT) or cone-beam computed tomography (CBCT) scans (Dagistan et al. 2017; de Oliveira et al. 2016; Thilakumara et al. 2021; Gupta, Nirala, and Gupta 2018; Tewari et al. 2018) have also been limited by niche ancestral populations to determine clinical significance in certain areas of the world.

The present study uses CT scans and X-rays of recently deceased individuals, which are commonly available, to increase the sample size and allow for a non-invasive measurement procedure to be conducted. An example of research using CBCT was conducted by Dagistan et. al. (2017), that examined morphometric traits of the IOF in 125 living adult patients from India (Dagistan et al. 2017). Cone-beam computed tomography (CBCT) is like a traditional CT except that is uses low power medical fluoroscopy tubes that allows for imaging throughout the entire

scan, as opposed to a high-power rotating x-ray tube. As a result, the imaging in a CBCT scan can often be of lower visual quality. As previously stated, Dagistan's research does not focus on ancestry as an avenue for study and does not compare more than one ancestral group to the other. Research using human skeletal remains from niche populations lead to results for niche populations. Having information on these populations is never an issue, but there is an obvious gap in the research of broader ancestries. Another issue that is seen in the previous research is the use of invalid measurements and landmarks. Recently a study found that much of the previous research had been using the facial midline (FM) as a measuring point, and while much of the research can be a jumping off point, this method was not useful in clinical or anthropological practice because of facial asymmetry as well as the fact that the IOF can be located anywhere in relation to the FM (Ercikti, Apaydin, and Kirici 2017).

1.5 Ancestry and the Skull

The human skull is amazingly variable, and in many instances patterns in this variability are used by forensic anthropologists to ascertain the possible geographic or ancestral background of individuals. While it is unlikely that any two individuals will have the same skeletal features, certain ancestral and sexual dimorphic traits are present in the skull (Bass 1992). Some common nonmetric traits used to access ancestry in the skull are the zygomatic arches, the shape of the eye orbits and nasal passages, the complexity of the skeletal sutures and many others. Some anthropologists prefer to use metric traits when determining ancestry. So, when studying the human skull, anthropologists will often take a set of measurements from the skull using landmarks as a guide and compare those measurements using computer software that is programed with other skeletal databases. However, it is just as common for anthropologists to use the nonmetric traits for determining ancestry in their observations as well.

The measurements that were adapted for this study used the nonmetric traits, such as the nasal profile, shape of the nasal spine, shape of the nasal aperture and nasal bones, as well as the shape of the eye orbits to determine which measurements might show ancestral variances in the sample (Bass 1992; Katherine Spradley and Jantz 2016).

1.5 a Native American/ American Indian

Nonmetric traits that are useful in the determination of Native American ancestry could include shovel-shaped incisors, robust and flaring zygomatic arches, and elliptical palate(Bass 1992). Individuals of Native American/ American Indian ancestry will also often present with a convex nasal profile, low and tented nasal bones, and a tilted nasal spine (Katherine Spradley and Jantz 2016; Bass 1992).

1.5b European/White

Nonmetric trait that are useful in the determination of European/White ancestry could include small retreating zygomatic arches, parabolic palate, and simple cranial sutures (Bass 1992). Individuals of European/White ancestry will often present with a straight nasal profile, arched nasal bones, and a long and large nasal spine (Bass 1992; White and Folkens 2005).

1.5c African/Black

Nonmetric traits that are commonly present in individuals of African/Black ancestry could include alveolar and facial prognathism, a hyperbolic palate, and blade-form incisors (Bass 1992). Individuals of African/Black ancestry will often present with low and flat nasal bones, a wide nasal aperture, and small nasal spine (Bass 1992; White and Folkens 2005).

1.6 Organization of Thesis

The following sections are organized to present the research as clearly as possible. The materials and methods I chose to implement are outlined in section two. This section outlines the

sample collection and measurement techniques, equipment, and software, which analysis would be run, and how the results would be interpreted. Section three presents the results of the analysis. This section includes the output tables for the compare means, independent t-tests, and ANOVA one way analysis. The Discussion (Section four) and Conclusion (Section five) interpret the results of the analysis and present the arguments as to why the results occurred. Suggestions for future research are also given in the conclusion section of the thesis.

Materials and Methods

2.1 Collection used for research

The collection used for this research was the New Mexico Decedent Image Database compiled by the University of New Mexico (UNM) in conjunction with the National Institute of Justice (NIJ). The foremost reason this collection was chosen was for the abundance of well documented images of recently deceased individuals of multiple ancestral backgrounds to include Native American, Black, and White.

2.2 NMDID

Permission to use the NMDID collection was granted by Dr. Shamsi Berry, an assistant professor within the Western Michigan University's Biomedicine Informatics Department. Data was collected from January 8 through December 1, 2021, with supervision from the University of Montana, Department of Anthropology.

The individuals selected for this research study are ages 16-45 years of age at the time of death and can be categorized into the three ancestral groups of Native American, White, or Black. For purposes of this research, only individuals with two easily identifiable infraorbital foramen, one on the right and left sides, and no skull/facial damage, were measured. Within these guidelines, a total of 199 individuals were selected for the final measurement process. The measurements were documented on an excel worksheet.

2.3 Data Collection Techniques

The data collection was divided into three sections. The sections are as follows: 1) Age, and Sex, 2) Ancestry, and 3) Infraorbital Foramen Measurements.

2.3a Records and Demography

The first section of the excel sheet documents the decedent ID number of each individual, the individuals date of birth and date of death, age at death, and ancestral category. The decedent ID numbers are those used by the NMDID to maintain the consistency of the information, allow for a recreation of the study using the same individuals, and make the information available for future research. The demography of each individual in the study was also provided using the information in the NMDID, which was gathered when the decedent was examined by the Medical Examiner, Coroner, or other institution. The determination of ancestry by Medical Examiner can be problematic, as common practice often dictates that the ancestry that is self-identified by the individual be used in the records. It is very common that the ancestry classification that is determinable given the features of the individual and the self-identified classification of ancestry are different (Bass 1992). This should be considered whenever ancestry determination is needed, but it is especially important in forensic contexts when self-identification could create a misidentification of individuals. In this instance, which takes a more clinical research approach, the possibility of misidentification of ancestry and admixture are taken into consideration in possible research errors.

2.3b DiCom Software

Images taken from the NMDID include facial X-rays, and full body computed tomography scans. To view these images, two types of software Digital Imaging and Communications in Medicine were used. The x-ray scans were viewed, and measurements were taken using the Windows MicroDicom Viewer available for PC devices. The computed tomography scans (CT) were viewed using the RadiANT DiCom Viewer also available on PC devices (Medixant n.d.).

2.3c Infraorbital Foramen Measurements

The Infraorbital Foramen (IOF) measurements, in millimeters, were taken using the measurement tools within the DiCom Software on the respective scans. The landmark measurements that were taken on the IOF and surrounding areas and measuring procedure for each landmark is described in *Table 1: Description of IOF Measurements* below. For each of the elements, a measurement was taken for both the left infraorbital foramen (LIOF) and right infraorbital foramen (RIOF). A visual representation of the IOF measurements taken on the right side are presented in Figure 1. This was possible for all individuals in the sample due to sampling guidelines. Only individuals with an IOF on the right and left side were used in this study, and no measurements were taken on accessory IOF. Accessory foramen are extra foramen commonly found in the same area as the infraorbital foramen. If the skull or facial bones were damaged in any capacity that individual was not included in the final data used for computation.

This sampling procedure maximized the data's usability to compare both sides of the entire sample with no missing variables. The measurements were adapted from previous researchers, and surgical methods that used the nasal passages and the eye orbits to approximate the location of the infraorbital foramen in living patients and cadavers (Ananya, Sangeetha, and Premavathy 2019; Michalek et al. 2013; Zdilla et al. 2018; Ercikti, Apaydin, and Kirici 2017). These other landmarks were chosen because they adapted ancestry and sex determination landmarks on the skull to determine if the ancestral diversity or sexual dimorphism of these landmarks would correlate with variability in the position and location of the IOF(Bass 1992; White and Folkens 2005; Katzenberg and Saunders 2007).

To avoid measurement error that was commonly seen in similar research, the facial midline was not used as a reference point for measurements. Instead, the IOF were measured in

relation to each other and other bony landmarks that are either visible or palpable through the soft tissues. Researchers such as Marx (2010), sometimes used the infraorbital rim (IOR) or the infraorbital margin (IOM) as a reference point on the IOF, which in dry skulls is a good way to have consistent measuring techniques (Marx n.d. 2010). However, when using a poor-quality x-ray, the IOR and IOM is not easily identifiable unless properly trained. Therefore, to maintain consistent measuring techniques in this study, the center of the IOF was determined and then used as the main point of reference for measurement.

Data	Summary
Ancestry	This study will only be using a sample of individuals that are morphologically of NATIVE AMERICAN, BLACK, OR WHITE ancestries of descent. *Data will be collected using NMDID Collection Database*
Age	This study will only be using a sample of individuals that are in the age range of 16-45 years of age. *Data will be collected using NMDID Collection Database*
Sex	This study will use a sampling of morphological females and males. *Data will be collected using NMDID Collection Database*
Date of Birth and Death	*Data will be collected using NMDID Collection Database*
Distance between both infraorbital foramen (IOF)	The shortest distance from the center of each infraorbital foramen to the other. Annotated as IOF-IOF in the dataset. *Data collected by observation of individual skulls using measuring tool provided in DiCom software in millimeters (mm).*
Distance of each infraorbital foramen from the alveolar process of the first premolar (PM).	Measurement was collected on both the RIOF and LIOF. Annotated as RIOF-PM and LIOF-PM respectively in the dataset. *Data collected by observation of individual skulls using measuring tool provided in DiCom software in millimeters (mm).*
Distance of each infraorbital foramen from the lateral edge of the perpendicular plate of the ethmoid bone as it meets the vomer bone (MPPEB).	Measurement was collected on both the RIOF and LIOF. Annotated as RIOF-MPPEB and LIOF- MPPEB respectively in the dataset. *Data collected by observation of individual skulls using measuring tool provided in DiCom software in millimeters (mm).*
Distance of each infraorbital foramen from the apex of the nasal aperture (NA).	Measurement was collected on both the RIOF and LIOF. Annotated as RIOF-NA and LIOF-NA respectively in the dataset. *Data collected by observation of individual skulls using measuring tool provided in DiCom software in millimeters (mm).*
Distance of each infraorbital foramen from the inferior margin of the eye orbit (EO) at its most lateral point.	Measurement was collected on both the RIOF and LIOF, and each IOF was also measured in relation to the opposite eye at the same point. Annotated as RIOF-REO, RIOF-LEO, LIOF-REO and LIOF-LEO respectively in the dataset. *Data collected by observation of individual skulls using measuring tool provided in DiCom software in millimeters (mm).*
Distance of each infraorbital foramen from the most lateral portion of the nasal spine (NS).	Measurement was collected on both the RIOF and LIOF. Annotated as RIOF-NS and LIOF-NS respectively in the dataset. *Data collected by observation of individual skulls using measuring tool provided in DiCom software in millimeters (mm).*

Table 1: Description of IOF measurements

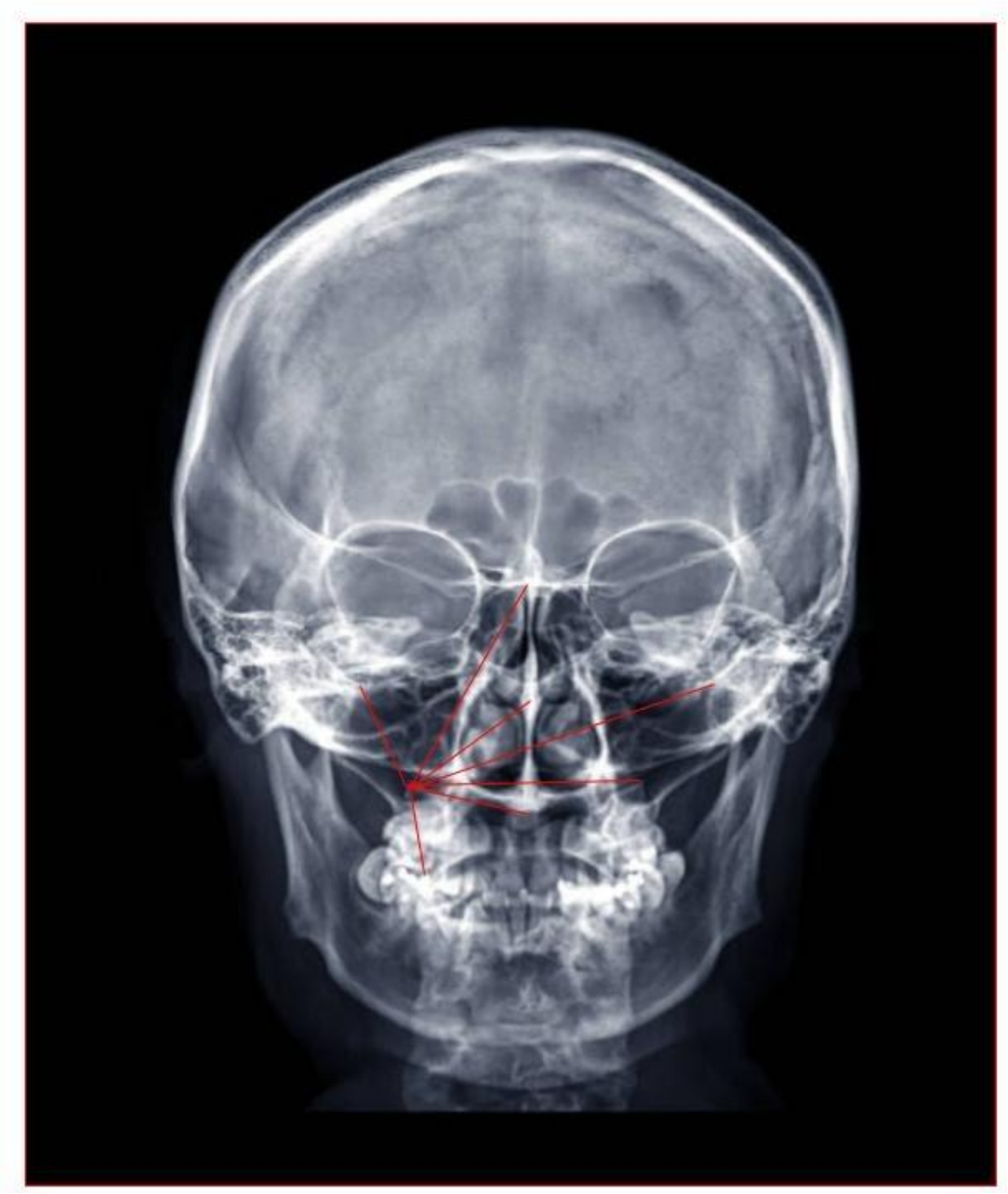

Figure 1: RIOF Measurements example on x-rays

2.4 Computer Analysis Program

The computer program used to analyze the data was the IBM Statistical Package for the Social Sciences (SPSS) software provided by the University of Montana, Social Sciences Department (IBM 2019). For each individual, age, ancestry, sex, and IOF measurements were recorded on a spreadsheet. Within the SPSS program the ordinal data was given a numeric digit so that the categories could be used as factors in the One Way Anova test (to include Post Hoc examination), and Independent Sample T-tests. Before any other suit of statistical analysis, a compare means test will be performed on the sample.

2.5 Compare Means and Independent Sample T-tests

A compare means test compares the means of a variable within one group to the mean of the same variable in one or more other groups. The compare means procedure completed through SPSS automatically summarizes and compares the differences in descriptive statistics across one or more categorical variables or factors(IBM 2019).

An Independent Sample T-test compares the means of two independent groups to determine whether there is statistical evidence that the means of each population are significantly variable (Statistics 2013). Independent T-tests are used on two unrelated groups and usually are performed to test a null hypothesis stating the means of the two groups are equal. This is usually expressed using the equation $\mathbf{H_0: u_1 = u_2}$(Statistics 2013; Laerd Statistics 2018; Laerd Statistics 2016; Choudhary 2018). In this case, the research is looking to reject that null hypothesis and accept the alternative hypothesis $\mathbf{H_a: u_1 \neq u_2}$ and determine the amount of variability, and if that variability is significant in the means between each group (Statistics 2013; Laerd Statistics 2018; Laerd Statistics 2016; Choudhary 2018).

Hypothesis 1 (Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen between males and females IOF measurements.

To address this hypothesis the independent t-tests will examine the variance in infraorbital foramen using gender, and side of individuals to refute that no statistically significant variation is present when comparing these factors. Therefore, an Independent Sample T-test was run to compare the males and females for the entire sample. One independent t-tests were run on the sample for this study. However, further t-tests on this sample could be used to examine the left and right sides between individuals within the sample, and between males and females.

2.6 Anova One Way

Like an Independent t-test, an Analysis of Variance (ANOVA) One Way, tests the variance between groups for a statistically significant variance(Laerd Statistics 2017). How the ANOVA One Way differs from an independent t-test, is in the number of groups that can be compared together when running the statistical analysis (Kim 2017). While an Independent t-test can only compare the means of two groups, an ANOVA test can test the variance of three or more unrelated groups (Yeager 2021; Statistics 2013). Using an ANOVA One Way, all three ancestral groups in the sample can be compared to each other at the same time (Laerd Statistics 2017). This comparison could be done using an independent t-test, but it would require that each ancestry was compared individually with the others. Like the independent t-test, the ANOVA also examines and tests a null hypothesis. This is usually expressed within the equation $\mathbf{H_0: u_1=u_2=u_3=\cdots=u_k}$ (Yeager 2021; Kim 2017; Laerd Statistics 2017). This is demonstrated in the null hypothesis established below.

Hypothesis 2 (Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen when comparing all ancestral groups with each other.

Therefore, an ANOVA One Way procedure will be run on the entire sample using ancestry as the independent factor to test the variance in the IOF measurements and compare the means of all ancestries simultaneously. One aspect that is important to consider is that an ANOVA One Way test is an omnibus test, which is a statistical test that tests if the variance within a dataset is higher than the unexplained variance overall. However, this also means that the ANOVA one way test can only examine if variances exist between at least two groups but cannot tell specifically how which groups were varied. Therefore, if variance is present, an additional post hoc test is necessary to fully understand the results.

2.6a Post Hoc Tests

An Analysis of Variances (ANOVA) will not pinpoint which groups have means that are different (Chen et al. 2018). An ANOVA will only state that at least two groups have a significant variation but cannot tell you which groups vary and in what way. In order to understand which groups' means are varied, a Post Hoc Test is necessary. **Post Hoc tests are only necessary if variance is present in the One-Way ANOVA.** To examine the results of the ANOVA tests run of the data from this collection, two Post Hoc tests could be run (Rajyaguru and Shingala 2015; Shingala and Rajyaguru 2015). The two Post Hoc tests used on this data were the Duncan's Multiple Range Test (MRT), and the student-Newman Keuls (SNK) DMRT Post Hoc Tests.

Duncan’s Multiple Range Test (DMRT) is a post hoc test that measures the specific differences between pairs of means. A DMRT is like the Fisher's Least Significant Difference

(LSD) test, which is used when the data rejects the null hypothesis, that finds the smallest significant value between the two means. Afterwards, it is possible to make direct comparisons between the two means of two individual groups and see if there is a significant result. Unlike an LSD test, a DMRT is more useful when the amount of data in your table is larger and requires a larger difference between means. Having a larger difference to substantiate a significant variation, guards against a Type I error, which can be an issue when testing a null hypothesis. A Type I error is when a small difference in variation still meets the requirements to reject the null hypothesis but is not significant enough to be a palpable variation. While it is uncertain if a Type I error will occur, it is best, when using data that meets the criteria to err on the side of caution when conducting a post hoc examination.

Student Newman Keuls (SNK) is a variant of the DMRT that assesses which specific pairs of means are different. A SNK post hoc examination is a pairwise comparison among the sample means and is used when there is a need to use a critical value to differentiate among the comparisons based on a basic q statistic (Stephanie 2020). This is usually completed in nonparametric inferential tests that access the significance among two or more matched samples with a dichotomous outcome (Stephanie 2020). A dichotomous outcome is when there are two or more possible values that are intuitively clear variables, in this case male/female or Native American/White/Black (Stephanie 2020). This test will only be run if the ANOVA finds significant variation in at least two groups.

Results

3.1 Results of Analysis

The first analysis run on the sample, before regressions that addressed the null hypotheses, was a compare means test. To compare the means of entire sample both the sex and ancestry were used as dependent variables when comparing the means of all the IOF measurements. This is demonstrated in Tables 2 and 3 respectively. This identified the average location of the IOF in relation to the other landmarks used for measurement.

Compare Means- Sex														
sex		IOF-IOF	RIOF-REO	LIOF-REO	RIOF-LEO	LIOF-LEO	RIOF-MPPEB	LIOF-MPPEB	RIOF-NS	LIOF-NS	RIOF-PM	LIOF-PM	RIOF-NA	LIOF-NA
Female	Mean	49.9690	13.3978	58.5067	58.6276	14.5145	28.1247	27.2824	29.26247	28.6062	23.2147	23.5396	45.8538	46.2274
	N	91	91	91	91	91	91	91	91	91	91	91	91	91
	Std. Deviation	7.59460	5.72296	7.70936	8.92721	5.79662	5.70269	4.56211	4.91542	5.18003	6.91201	7.19543	6.91274	6.44495
Male	Mean	51.9690	14.3881	60.0946	60.8292	15.2967	30.1497	27.8982	30.60694	29.1335	22.5697	22.8245	48.7898	48.1919
	N	108	108	108	108	108	108	108	108	108	108	108	108	108
	Std. Deviation	7.36903	5.67816	6.29733	8.02532	5.44561	5.30799	4.98210	5.130908	4.87699	5.98440	5.52780	6.97298	7.03445
Total	Mean	51.0544	13.9353	59.3685	59.8224	14.9390	29.2237	27.6166	29.99214	28.8924	22.8647	23.1515	47.4472	47.2936
	N	199	199	199	199	199	199	199	199	199	199	199	199	199
	Std. Deviation	7.52066	5.70574	7.00535	8.49936	5.60814	5.57052	4.79255	5.065581	5.01194	6.41666	6.33831	7.08143	6.82527

Table 2: Compare means output with sex as the dependent variable

Compare Means- Ancestry														
race		IOF-IOF	RIOF-REO	LIOF-REO	RIOF-LEO	LIOF-LEO	RIOF-MPPEB	LIOF-MPPEB	RIOF-NS	LIOF-NS	RIOF-PM	LIOF-PM	RIOF-NA	LIOF-NA
White	Mean	50.1363	14.2307	58.8164	59.4087	15.0981	28.9120	27.3569	29.52323	28.4365	22.5353	23.1676	47.3888	47.0239
	N	127	127	127	127	127	127	127	127	127	127	127	127	127
	Std. Deviation	7.27524	5.75252	7.46011	8.99003	5.72704	5.63354	4.81577	5.140730	5.16625	6.80880	6.74660	6.97296	6.31236
Black	Mean	51.2983	12.7792	59.6925	56.9858	13.9358	28.0600	28.8225	29.07333	29.4183	23.5092	23.2017	46.0767	44.9133
	N	12	12	12	12	12	12	12	12	12	12	12	12	12
	Std. Deviation	8.05196	4.88328	4.82919	5.27709	5.11575	4.95414	5.09897	4.190789	5.34795	5.16746	4.28767	7.07219	6.66954
Native American	Mean	52.9490	13.5412	60.4723	61.2653	14.8028	30.1163	27.9253	31.16842	29.7520	23.4330	23.1075	47.8450	48.3405
	N	60	60	60	60	60	60	60	60	60	60	60	60	60
	Std. Deviation	7.69500	5.78969	6.29085	7.77916	5.50866	5.52171	4.70824	4.934528	4.55115	5.79182	5.84689	7.38759	7.77962
Total	Mean	51.0544	13.9353	59.3685	59.8224	14.9390	29.2237	27.6166	29.99214	28.8924	22.8647	23.1515	47.4472	47.2936
	N	199	199	199	199	199	199	199	199	199	199	199	199	199
	Std. Deviation	7.52066	5.70574	7.00535	8.49936	5.60814	5.57052	4.79255	5.065581	5.01194	6.41666	6.33831	7.08143	6.82527

Table 3: Compare means output with ancestry as a dependent variable.

3.1a Individual T-Tests

The output for the independent t-test and One Way ANOVA run through SPSS is presented in a variety of tables (Laerd Statistics 2016; Laerd Statistics 2017). The results of the independent t-test which analyzed hypothesis one; *Hypothesis 1 (Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen between males and females IOF measurements* are shown in Tables 4 and 5. The group statistics (Table 4) analyze the means of each frequency of the measurements of both males and females in the sample.

Group Statistics

	sex_code	N	Mean	Std. Deviation	Std. Error Mean
IOF-IOF	Female	91	49.9690	7.59460	.79613
	Male	108	51.9690	7.36903	.70909
RIOF-REO	Female	91	13.3978	5.72296	.59993
	Male	108	14.3881	5.67816	.54638
LIOF-REO	Female	91	58.5067	7.70936	.80816
	Male	108	60.0946	6.29733	.60596
RIOF-LEO	Female	91	58.6276	8.92721	.93583
	Male	108	60.8292	8.02532	.77224
LIOF-LEO	Female	91	14.5145	5.79662	.60765
	Male	108	15.2967	5.44561	.52400
RIOF-MPPEB	Female	91	28.1247	5.70269	.59780
	Male	108	30.1497	5.30799	.51076
LIOF-MPPEB	Female	91	27.2824	4.56211	.47824
	Male	108	27.8982	4.98210	.47940
RIOF-NS	Female	91	29.26247	4.915422	.515276
	Male	108	30.60694	5.130908	.493722
LIOF-NS	Female	91	28.6062	5.18003	.54301
	Male	108	29.1335	4.87699	.46929
RIOF-PM	Female	91	23.2147	6.91201	.72458
	Male	108	22.5697	5.98440	.57585
LIOF-PM	Female	91	23.5396	7.19543	.75429
	Male	108	22.8245	5.52780	.53191
RIOF-NA	Female	91	45.8538	6.91274	.72465

	Male	108	48.7898	6.97298	.67098
LIOF-NA	Female	91	46.2274	6.44495	.67561
	Male	108	48.1919	7.03445	.67689

Table 4: Group Statistics of Independent t-test using sex as dependent variable

However, this table alone does not show whether the difference in these means is significant. The second output table, Table 5, uses a Levene's Test to show if the data has met the assumption that the two groups have approximately equal variances. A significant difference in the group means is present when the *Sig.* (2-tailed) value is less than $p=.05$. Given that, and that equal variances were assumed when comparing male and females within the sample, the independent t-test show no significant variation. This study found that most mean measurements of distance in the IOF are slightly larger in males than females within the sample, but the difference is not statistically significant, except for two measurements.

According to the independent t-test there was a significant difference in the distance between the RIOF (Right Infraorbital Foramen) and the MPPEB (Distance of each infraorbital foramen from the lateral edge of the perpendicular plate of the ethmoid bone as it meets the vomer bone). The t-test found that male participants has statistically larger distance from the RIOF-MPPEB (30.15±5.3 mm) when compared to females (28.12±5.7 mm), t (197) =-2.591, p=.010. The study also identified that there was a significant variation in the RIOF-NA measurement. Males had a statistically larger difference from the RIOF- NA (48.8±7mm) when compared to females in the sample (45.9± 6.9 mm), t (197) =-2.97, p=.003.

Independent Samples Test									
	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper

IOF-IOF	Equal variances assumed	.013	.909	-1.881	197	.061	-1.99997	1.06337	-4.09702	.09708
	Equal variances not assumed			-1.876	189.253	.062	-1.99997	1.06613	-4.10299	.10305
RIOF-REO	Equal variances assumed	.002	.965	-1.221	197	.223	-.99035	.81090	-2.58951	.60881
	Equal variances not assumed			-1.220	190.805	.224	-.99035	.81145	-2.59091	.61021
LIOF-REO	Equal variances assumed	6.937	.009	-1.599	197	.111	-1.58793	.99294	-3.54608	.37023
	Equal variances not assumed			-1.572	173.514	.118	-1.58793	1.01011	-3.58160	.40575
RIOF-LEO	Equal variances assumed	1.486	.224	-1.831	197	.069	-2.20158	1.20231	-4.57263	.16946
	Equal variances not assumed			-1.815	182.949	.071	-2.20158	1.21331	-4.59546	.19229
LIOF-LEO	Equal variances assumed	.597	.441	-.980	197	.328	-.78216	.79810	-2.35607	.79175
	Equal variances not assumed			-.975	186.757	.331	-.78216	.80238	-2.36506	.80074
RIOF-MPPEB	Equal variances assumed	.025	.874	-2.591	197	.010	-2.02500	.78147	-3.56611	-.48388
	Equal variances not assumed			-2.575	185.992	.011	-2.02500	.78629	-3.57618	-.47381
LIOF-MPPEB	Equal variances assumed	.455	.501	-.903	197	.368	-.61582	.68228	-1.96134	.72969
	Equal variances not assumed			-.909	195.614	.364	-.61582	.67716	-1.95129	.71964
RIOF-NS	Equal variances assumed	.027	.870	-1.877	197	.062	-1.344472	.716264	-2.757002	.068058
	Equal variances not assumed			-1.884	193.752	.061	-1.344472	.713632	-2.751957	.063013
LIOF-NS	Equal variances assumed	.266	.606	-.739	197	.461	-.52736	.71400	-1.93543	.88070
	Equal variances not assumed			-.735	186.934	.463	-.52736	.71770	-1.94320	.88847
RIOF-PM	Equal variances assumed	.491	.484	.706	197	.481	.64500	.91423	-1.15793	2.44793

	Equal variances not assumed			.697	179.397	.487	.64500	.92553	-1.18133	2.47133
LIOF-PM	Equal variances assumed	2.747	.099	.792	197	.429	.71502	.90277	-1.06531	2.49535
	Equal variances not assumed			.775	167.026	.440	.71502	.92297	-1.10717	2.53722
RIOF-NA	Equal variances assumed	.048	.827	-2.971	197	.003	-2.93597	.98832	-4.88502	-.98692
	Equal variances not assumed			-2.973	191.858	.003	-2.93597	.98759	-4.88389	-.98805
LIOF-NA	Equal variances assumed	.213	.645	-2.039	197	.043	-1.96458	.96356	-3.86480	-.06436
	Equal variances not assumed			-2.054	195.596	.041	-1.96458	.95637	-3.85069	-.07847

Table 5: independent t-test output using sex as dependent variable

3.1b Anova One Way

The output for the Anova One Way regression is outlined in a descriptive table, Table 6, that summarizes each independent grouping with the size of each group, the respective means, and standard deviations. A significant difference in the variation of means is present if the Sig. value is less than p=.05. As shown below in Table 6, the results of the Anova One Way show no significant difference in the means of the IOF measurements when using the three ancestral groups, Native American, Black, and White as the dependent variables.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
IOF-IOF	Between Groups	323.134	2	161.567	2.912	.057
	Within Groups	10875.802	196	55.489		
	Total	11198.936	198			
RIOF-REO	Between Groups	36.443	2	18.222	.557	.574
	Within Groups	6409.541	196	32.702		
	Total	6445.984	198			
LIOF-REO	Between Groups	113.081	2	56.541	1.154	.318
	Within Groups	9603.765	196	48.999		
	Total	9716.846	198			
RIOF-LEO	Between Groups	243.208	2	121.604	1.695	.186

	Within Groups	14060.141	196	71.735		
	Total	14303.349	198			
LIOF-LEO	Between Groups	16.404	2	8.202	.259	.772
	Within Groups	6210.930	196	31.688		
	Total	6227.334	198			
RIOF-MPPEB	Between Groups	76.399	2	38.200	1.234	.293
	Within Groups	6067.677	196	30.958		
	Total	6144.076	198			
LIOF-MPPEB	Between Groups	31.738	2	15.869	.689	.503
	Within Groups	4516.030	196	23.041		
	Total	4547.768	198			
RIOF-NS	Between Groups	121.073	2	60.536	2.392	.094
	Within Groups	4959.629	196	25.304		
	Total	5080.701	198			
LIOF-NS	Between Groups	74.046	2	37.023	1.481	.230
	Within Groups	4899.627	196	24.998		
	Total	4973.673	198			
RIOF-PM	Between Groups	38.144	2	19.072	.461	.632
	Within Groups	8114.219	196	41.399		
	Total	8152.363	198			
LIOF-PM	Between Groups	.179	2	.090	.002	.998
	Within Groups	7954.300	196	40.583		
	Total	7954.479	198			
RIOF-NA	Between Groups	32.468	2	16.234	.322	.725
	Within Groups	9896.579	196	50.493		
	Total	9929.047	198			
LIOF-NA	Between Groups	142.989	2	71.494	1.543	.216
	Within Groups	9080.716	196	46.330		
	Total	9223.704	198			

Table 6:Anova One Way output using multiple ancestries as dependent variables

3.1c Post Hoc Tests

Given the results of the Anova One Way, which showed no statistically significant variances in any group within the sample, post hoc examinations were not required.

Discussion

4.1 Discussion of Analysis

This section attempts to interpret the results of the independent t-tests and Anova one-way regressions and provide explanations for the acceptance of the null hypothesis. The analysis of all measurements shows no statistically significant variability within the sample due to sex or ancestry regarding the location of the IOF.

4.2 Interpretation of Results

When comparing males and females in the sample, the independent t-test shows a significant variation in two of the IOF measurements; the RIOF-MPPEB and the RIOF-RNA. The means of this measurements are statistically significant at the 95% significance interval. However, the effect size of these measurements is too small to be determinative. The effect size is a measure of the strength of the relationship between two variables and tests the practical applications of the significance (Coe 2002). Effect size will quantify the size of the difference between two groups and find the true measure of significance. In statistics, the significance is the likelihood that the difference between two groups could be an accident because of sampling, usually calculated using a p-value that analyzes the probability of chance while effect size will analyze a true measure of practicality that will take these accidents into account (Coe 2002). In this instance, despite the statistical significance shown in the completion of the analysis, the effect size is not tangible. The significance is also not present in other measurements using the independent t-test; therefore, it is concluded that *Hypothesis 1 (Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen between males and females IOF measurements* is accepted.

The Anova one way examination also concluded that there was no statistically significant variation in the means of the IOF measurements when comparing ancestry. Therefore, the *Hypothesis 2 (Null Hypothesis): No statistically significant variation in the anatomical location of the infraorbital foramen will be seen when comparing all ancestral groups with each other* is accepted.

The results of both examinations reject variation in the location of the IOF due to sex and ancestry. These results could have come to be by virtue of the techniques used to assemble the sample of individuals, and as a consequence of the adaptations of methodology and measurements present in another research. Previous research used a variation of the landmarks and techniques, such as measuring from the facial midline, which was not used in the methodology of this study. Sampling error may have occurred given the utilization of a sample strictly from the NMDID, in which all individuals are from the same region, and given the exclusion of individuals with facial/neck/head trauma. This may also be due to the qualities that were being searched for in individuals within the sample, such as the limited age range and necessestity for two IOF, which were selected for to allow for more information about the IOF on both sides and eliminate variation due to skull size because of age.

Conclusion

5.1 Effect of Results on Hypothesis

The results of the ANOVA One Way and Independent T-test show no signs of significant variation due to ancestry. This outcome accepts the null hypothesis and concludes that there is no significant variation in the location of the IOF in the three ancestral groups or between males and females in the sample. Therefore, the location of the IOF is not determined or explained through ancestral variation in the skull, and variation in the IOF is more likely determined by age, which does conflict with results formulated in previous research studies.

5.2 Implications for Issues in Anthropology

This research explored techniques and methods of analyzing human remains that do not require invasive procedures that are damaging to the subjects of study. Advancing technology in the world of digital imaging can allow for precise research to be conducted on human remains and other sensitive artifacts. These techniques cannot yet replace hands on study of human remains, and certain research questions cannot yet be answered without a certain level of invasive techniques being imposed. Yet, it is clear these advances can allow for other questions to be answered reliably.

While the alternative hypothesis was rejected in this research, the infraorbital foramen and its evolutionary implication in humans is a fascinating landmark to be used in future medical and anthropological research.

5.3 Future Research

There are many implications for future research on the infraorbital foramen. While this study accepted the null hypothesis, and no variation when comparing ancestry was found, further research could explore if variation is found in groups of people of the same ancestry groups. Further research could also be conducted on the evolution of the infraorbital foramen in humans

and the way that environment and ecology could have affected the location and morphology of the landmark, as well as if/how these aspects of the IOF have changed over time.

5.4 Future goals

One goal for the continuation of this research is too increase the sampling size, by adding more ancestries, ages, regions, and time periods into consideration in the studies of the IOF and other maxillo-facial features. While this study held no statistically significant variation in the IOF location when comparing the three ancestral groups, that could be due to the sampling techniques implemented.

References

Ananya, Bathala, S. Sangeetha, and Dinesh Premavathy

2019 Morphometric Study of the Infraorbital Foramen in Local Anesthesia. Drug Invention Today 12(6).

Bass, William M.

1992 Human Osteology. Tim D. White . The Quarterly Review of Biology 67(3).

Chen, Tian, Manfei Xu, Justin Tu, Hongyue Wang, and Xiaohui Niu

2018 Relationship between Omnibus and Post-Hoc Tests: An Investigation of Performance of the F Test in ANOVA. Shanghai Archives of Psychiatry 30(1).

Choudhary, Rajeev

2018 Application of "Independent t-Test" by Using SPSS for Conducting Physical Education Researches. Physical Education, Sports and Health 5(1).

Coe, Robert

2002 It's the Effect Size, Stupid - What Effect Size Is and Why It Is Important. Annual Conference of the Briditsh Education Research Association. University of Exeter.

Dagistan, S., Milolu, O. Altun, and E. K. Umar

2017 Retrospective Morphometric Analysis of the Infraorbital Foramen with Cone Beam Computed Tomography. Nigerian Journal of Clinical Practice 20(9).

Dudzik, Beatrix

2019 Examining Cranial Morphology of Asian and Hispanic Populations Using Geometric Morphometrics for Ancestry Estimation. Forensic Anthropology 2(4). University Press of Florida.

Ercikti, Nurcan, Nihal Apaydin, and Yalcin Kirici

2017 Location of the Infraorbital Foramen with Reference to Soft Tissue Landmarks. Surgical and Radiologic Anatomy 39(1). Springer-Verlag France: 11–15.

Gibelli, Daniele, Alessia Borlando, Luisa Barni, et al.

2019 Anatomy of Infraorbital Foramen: Influence of Sex, Side, and Cranium Size. Journal of Craniofacial Surgery 30(4).

Gupta, Amrita, Kamta P Nirala, and Subhash Gupta

2018 Morphometric Study of Accessory Infraorbital Foramen in Northern Indian Human Skull. International Journal of Advanced and Integrated Medical Sciences 3(1).

IBM

2019 SPSS Software | IBM. IBM Website.

Kaçar, Cem Kıvılcım, Osman Uzundere, Fikret Salık, et al.

2020 Effects of Adding a Combined Infraorbital and Infratrochlear Nerve Block to General Anaesthesia in Septorhinoplasty. Journal of Pain Research 13.

Katherine Spradley, M., and Richard L. Jantz

2016 Ancestry Estimation in Forensic Anthropology: Geometric Morphometric versus Standard and Nonstandard Interlandmark Distances. Journal of Forensic Sciences 61(4). Blackwell Publishing Inc.: 892–897.

Katzenberg, M. Anne, and Shelley R. Saunders

2007 Biological Anthropology of the Human Skeleton: Second Edition. Biological Anthropology of the Human Skeleton: Second Edition.

Kazkayasi, Mustafa, Ahmet Ergin, ; Mehmet, et al.

2001 Certain Anatomical Relations and the Precise Morphometry of the Infraorbital Foramen-Canal and Groove: An Anatomical and Cephalometric Study.

Kim, Tae Kyun

2017 Understanding One-Way Anova Using Conceptual Figures. Korean Journal of Anesthesiology 70(1).

Laerd Statistics

2016 Independent T-Test - An Introduction to When to Use This Test and What Are the Variables Required | Laerd Statistics. Laerd Statistics.

2017 One-Way ANOVA in SPSS Statistics. Laerd Statistics.

2018 Independent T-Test for Two Samples. Lund Research Ltd.

Lynch, Michael T., Scott A. Syverud, Robert A. Schwab, J. Matthew Jenkins, and Richard Edlich

1994 Comparison of Intraoral and Percutaneous Approaches for Infraorbital Nerve Block. Academic Emergency Medicine 1(6).

Marx, Chakravarthy S

N.d. Anthropometric Analysis of the Infraorbital Foramen in a South Indian Population.

Medixant

N.d. RadiAnt DICOM Viewer [Software].

Michalek, Pavel, William Donaldson, Francis McAleavey, Paul Johnston, and Rostislav Kiska

2013 Ultrasound Imaging of the Infraorbital Foramen and Simulation of the Ultrasound-Guided Infraorbital Nerve Block Using a Skull Model. Surgical and Radiologic Anatomy 35(4).

Muchlinski, Magdalena N., Laurie R. Godfrey, Kathleen M. Muldoon, and Lydia Tongasoa

2011 Evidence for Dietary Niche Separation Based on Infraorbital Foramen Size Variation among Subfossil Lemurs. Folia Primatologica 81(6).

Nanayakkara, Deepthi, Roshan Peiris, Navini Mannapperuma, and Amal Vadysinghe

2016 Morphometric Analysis of the Infraorbital Foramen: The Clinical Relevance. Anatomy Research International 2016. Hindawi Limited: 1–8.

de Oliveira, Laís Carolina Santos Cisneiros, Maria Paula Mendonça Silveira, Erasmo de Almeida, Francisco Prado Reis, and José Aderval Aragão

2016 Morphometric Study on the Infraorbital Foramen in Relation to Sex and Side of the Cranium in Northeastern Brazil. Anatomy and Cell Biology 49(1).

Rajyaguru, Arti, and Mital C. Shingala

2015 Comparison of Post Hoc Tests for Unequal Variance. International Journal of New Technologies in Science and Engineering 2(5).

Rochette, Judy

2005 Regional Anesthesia and Analgesia for Oral and Dental Procedures. Veterinary Clinics of North America - Small Animal Practice.

Saheb Shaik, Hussain, Muralidhar P Shepur, SD Desai, ST Thomas, and GF Maavishettar

2012 Morphometric Analysis of Infra Orbital Foramen Position in South Indian Skulls. Innovations Dev. http://iseeadyar.org/ijid.html.

Shin, Kang Jae, Shin Hyo Lee, Min Gyu Park, Hyun Jin Shin, and Andrew G. Lee

2020 Location of the Accessory Infraorbital Foramen with Reference to External Landmarks and Its Clinical Implications. Scientific Reports 10(1). Nature Research.

Shin, Kang Jae, Hyun Jin Shin, and Shin Hyo Lee

2020 Location of the Infraorbital Foramen with Reference to Soft Tissue Landmarks for Regional Nerve Blocks during Midface Surgery. Clinical Anatomy 33(8). John Wiley and Sons Inc: 1159–1163.

Shingala, Mital C., and Arti Rajyaguru

2015 Comparison of Post Hoc Tests for Unequal Variance. International Journal of New Technologies in Science and Engineering 2(5).

Singh, Rajani

2011 Morphometric Analysis of Infraorbital Foramen in Indian Dry Skulls. Anatomy & Cell Biology 44(1). Korean Association of Anatomists: 79.

Spriggs, Amanda N., Magdalena N. Muchlinski, and Adam D. Gordon

2016 Does the Primate Pattern Hold up? Testing the Functional Significance of Infraorbital Foramen Size Variation among Marsupials. American Journal of Physical Anthropology 160(1).

Statistics, Laerd

2013 Independent T-Test - An Introduction to When to Use This Test and What Are the Variables Required. Laerd Statistcs.

Tewari, Siddharth, Chandni Gupta, Vikram Palimar, and Sneha Guruprasad Kathur

2018 Morphometric Analysis of Infraorbital Foramen in South Indian Dry Skulls. Bangladesh Journal of Medical Science 17(4).

Thilakumara, I. P., P. V.K.S. Hettiarachchi, R. M. Jayasinghe, et al.

2021 Morphometric Analysis of Infraorbital Foramen Using Cone Beam Computed Tomography in a Cohort of Sri Lankan Adults. International Journal of Morphology 39(2).

White, Tim, and Pieter Folkens

2005 The Human Bone Manual. The Human Bone Manual.

Yeager, Kristin

2021 SPSS Tutorials: One-Way ANOVA. Kent State Univeristy.

Zdilla, Matthew J., Aaron W. Koons, Michelle L. Russell, Kelsey R. Mangus, and Kaitlyn N. Bliss

2018 The Infraorbital Foramen Is Located Midway between the Nasospinale and Jugale: Considerations for Infraorbital Nerve Block and Maxillofacial Surgery. Journal of Craniofacial Surgery 29(2).