SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 1.1, (2026), pp. 1155-1169
Open Access. Online & Print

DOI: 10.5281/zenodo.11425186

VALIDATION OF THE DECISION TREE METHOD FOR NON-METRIC SEXUAL IDENTIFICATION OF THE SKULL USING TOMOGRAPHIC IMAGES IN A CONTEMPORARY SAMPLE FROM CHACHAPOYAS, AMAZONAS, PERU

Héctor Miguel Manriquez Zapata[1], Kattia Enith Guerrero Tamariz[2], Wilfredo Amaro Cáceres[3], Hitler Adolfo Vela Zuta[4]

[1]Toribio Rodríguez de Mendoza of Amazonas National University, Chachapoyas, Peru, hector.manriquez@untrm.edu.pe, ORCID: https://orcid.or/0000-0001-5947-9050
[2]Toribio Rodríguez of Mendoza of Amazonas National University, Chachapoyas, Peru, kaenguta@gmail.com ORCID: https://orcid.or/0000-0003-2422-0692
[3]Toribio Rodríguez of Mendoza of Amazonas National University, Chachapoyas, Peru wilfredo.amaro@untrm.edu.pe, ORCID: https://orcid.or/0000-0001-6601-1835
[4]Toribio Rodríguez of Mendoza of Amazonas National University, Chachapoyas, Peru, hitler.vela@untrm.edu.pe, ORCID: https://orcid.or/0000-0002-0363-6173

Received: 10/10/2025
Accepted: 10/11/2025

Corresponding Author: Héctor Miguel Manriquez Zapata (hector.manriquez@untrm.edu.pe)

ABSTRACT

The main objective of the study was to analyze the relationship between the Decision Tree method and Langley's Non-Metric Sex Assessment, with the aim of identifying biological sex in a contemporary digital sample from the Province of Chachapoyas, Amazonas Region, Peru, in 2023. Therefore, a quantitative research study was conducted, using morphological dimensions of the skull to quantify its characteristics. These measurements were then subjected to statistical analysis in order to validate their effectiveness according to the parameters established in Langley's method (2018). The sample analyzed consisted of 80 digital images of human skulls, corresponding to individuals between the ages of 30 and 50, selected according to the guidelines of forensic techniques used for sex determination based on bone structures. The technique applied was a detailed analysis of the skulls, focusing on the identification of observable sexual characteristics in specific structures such as the glabella, zygomatic extension, and mastoid process. The degree of agreement between observers was assessed using the linear Kappa test. Observers 1 and 3 obtained values of 0.90 and 0.92, respectively, indicating almost perfect agreement (0.81 < k < 1). Observer 2 obtained a value of 0.775, corresponding to substantial agreement (0.61 < k < 0.80). Regarding the accuracy of Langley's method, it was found to be significantly high for sex determination, provided that the evaluators have the necessary experience. Accuracy ranged from 95% to 96.25% among the most experienced observers, while the least experienced observer achieved 88.75%. The statistical results revealed a highly significant relationship (p = 0.000 < 0.01) between the Decision Tree method and Langley's Non-Metric Sex Assessment, confirming its effectiveness in determining actual sex in the sample analyzed in Chachapoyas.

KEYWORDS: Measure of the Skull, Langley's Method, Glabella, Zygomatic Extension, Mastoid, Sex Determination, Forensic Anthropology, Kappa Coefficient.

1. INTRODUCTION

Sex assessment by means of non-metrical skull typologies us a meritorious procedure for Criminal Anthropology and the matching of mortal skeletons. However, its use has not yet been widely studied in specific contemporary populations. Therefore, the purpose of this study is to ratify a Decision Tree pilot by means of sex assessment from non-metrical physiognomies in a sample of contemporary male and female skulls collected electronically in Chachapoyas, Amazonas – Peru.

Nowadays, the purpose of Criminal Anthropology is to cooperate with Forensic Medicine in the positive typification of individuals, in the solution of the crimes and in the investigation of alleged cases of infringement of fundamental rights, terrorism and others forms of physical abuse and mistreatment. It also involves the participation of expertise in situations of large – scale catastrophes, based on Archaeology and Social Anthropology (Rodríguez, 2023).

Whenever the discover of the remains of a subject is explores, numerous questions arise. **Human remains can be categorized in many ways** skeletonized, in an advanced degree of decomposition, mutilation, charring, mummification. All these characterizations can be addressed form the approach of Forensic Anthropology (Chavez, 2019). The discovery of remnants of unidentified individuals, either in an advanced degree of decay or in a skeletal stage, are common in the judicial sector as well as the police forces, and often non-specialized collaborators in the collection, analysis, and characterization of the remain (Nasti, 2023). The Decision Tree method is an approach frequently employed in Forensic Anthropology research to determine sex base on non-metric cranial features. The recognition of unidentified individuals is considered a challenge in Forensic Anthropology and contributes to the solution of criminal cases and the identification of human remains. Furthermore, it is important to note that there is no local research related to the issue, also, the national studies about this topic are limited, therefore, a thorough study on whether the Decision Tree in the non-metrical analysis was adjustable in the Chachapoyas test has not been conducted. It is significant that these instruments are in our argument since they are not available, even in the field of the technological instruments of advanced Forensic Anthropology equipment to determine sexual identity in skulls.

2. THEORETICAL FRAMEWORK

2.1. Forensic Anthropology

It is a discipline of Physical Anthropology, whose objective is to recognize skeletal remains or possible genetic inheritance (Stewart cited by Rodríguez, 2004). In the field of Criminal Anthropology, sex can be determined by testing certain areas of the human skeleton, including skulls, using the Decision Tree system suggested by Langley. Physical Anthropology and Criminal Anthropology should focus on the study of dead bones, since these do not disintegrate easily and, in most situations, become the only evidence of the existence of an individual or group of individuals. Sex diagnosis is not only a crucial component of osteobiography, but it is often the first aspect of evaluation, given that, in most situations, determining age or height is based on the sex of the individual (Izasa, 2015).

Forensic anthropologists are highly skilled and trained to investigate, recover, and test the bones of individuals in medical law. Over the years, Forensic Anthropology has become technically effective, distinguishing itself from other branches of Anthropology. Criminal Anthropology should be seen as a branch with a unique knowledge base, distinct from other similar forms of Anthropology. Criminal anthropologists have unparalleled expertise, making them the only category of anthropologist trained to carry out medico-legal analysis of bones (Passalacqua et al., 2021). The evolution of Forensic Anthropology occurred in parallel with Forensic Medicine. European influence on the school of thought in Latin America was notable, particularly through the British Association for the Advancement of Science - Anthropology Section, etc. (Calmon, 2019).

2.2. Decision Tree Method

It is a branching diagram of a set of linked decisions. This tree will make it easier for an individual or a company to compare possible actions based on cost, possibility, and benefit. They are used in the informal exchange of ideas or to develop an algorithm that mathematically predicts the best alternative. Decision trees usually start with a single node and then branch out toward probable conclusions. The findings generate extra nodes, each of which branches off from another possibility, acquiring a tree-like structure. **There are three types of nodes** probability nodes, decision nodes, and terminal nodes. Probability nodes, symbolized by circles, represent the probability of certain outcomes. The squares that illustrate decision nodes represent the decisions that will be made. Finally, terminal nodes represent the outcome because of the decisions.

Decision trees function as mind maps that start

with fundamental ideas and then expand based on the impacts of the actions taken. Because of its analogy to a tree with multiple branches, it is called a "decision tree." It is used to graphically examine the potential outcome, cost, and impact of a complicated decision (Asana, 2023). Decision tree algorithms have led the ranking of the most widely used algorithms since the early 1980s. It is important to emphasize the challenge that has impacted decision tree algorithms, which lies in their lack of effectiveness, or lack of proximity to effectiveness: decision tree algorithms tend to be greedy or inefficient, and sometimes generate models that are undoubtedly suboptimal. The complexity of optimizing the decision tree represents both a theoretical and practical barrier (Xiyang et al., 2019).

2.3. Sex Identification in Skull Sample

The cranial structure is divided into two parts the cranial vault (neurocranium) and the facial skeleton (splanchnocranium). The facial skeleton is designed biometrically, allowing it to withstand the pressure generated by the muscles when chewing, thus protecting the sensory organs. These arch experiences minimal stress during chewing, although the development of the nuchal lines can be affected by shoulder movement. For this reason, craniometry is an area of Biological Anthropology that analyzes the philological differences of the skull and its constituents, seeking to unravel the cranial vault in terms of width, height, and projected extensions (Rodríguez, 2004). As mentioned previously, globally there are different methods for determining the sex of corpses through morphological and metric characteristics observed in various skeletal structures, noting that the skull is considered the most reliable part of the skeletal body for sex identification, according to theory.

In fact, the cranial vault is the part that best presents excellent markers for determining the sex of the person being evaluated. For this reason, it has been argued in much of the doctrine that it could be placed in second position after the pelvic girdle. In other words, the estimation of sex through the skull is since, being male, it has a higher consistency, that is, it is considerably stronger. However, it should be noted that the male skull has certain characteristics that distinguish it from the female skull. Nevertheless, this has not proven adequate for accurate identification, as there are female skulls that share the same characteristics as the male cranial vault. **For this reason, this research uses skulls, although only the following parts of the skull are considered** the mastoid process, the zygomatic extension, and the glabella.

Determining gender from a body's skeleton is a fundamental objective in the field of Forensic Medicine. This process is based on the variations in size and shape that exist between the male and female sexes. The skull is the second most reliable bone structure for determining gender in adults, behind only the pelvis, as it allows for a correct estimate in 80% to 92% of cases. However, it is crucial to consider the specific measurements of the morphological complexion of the group to which the person belongs, since sexual dimorphism varies among different human populations and is not constant over time. These characterizations are most accurate when the bone structure and characteristics of the sample in question are understood, in addition to considering variables related to its mutability (Buchi, 2016).

Determining gender based on cranial structure is essential for identifying bone structures. In the field of Forensic Anthropology, this process is mainly carried out through visual inspection of the external shape and morphometric analysis of the cranial structure. The first technique is based on the notable sexual differences present in all or parts of the skull (Imaizumi et al., 2020). By combining the ergonomic discernment of bones and molars with metric analysis, a highly accurate diagnosis of sex can be achieved at a reduced cost. In the absence of the pelvic bone, the skull shows significant sexual differences (Thamires, 2021). Integrating all the characteristics used to determine sex into an estimate that considers several traits produces a correct classification rate of over 90% (Bertsatos, 2020).

2.4. Non-metrical Sex Assessment Proposed by Langley

In the field of Criminal Anthropology, the non-metric technique for determining sex refers to a methodology based on the investigation and evaluation of qualitative features of human skeletal remains to establish biological sex. In contrast to the metric method, which uses numerical data from different bone structures and dimensions, the non-metric procedure focuses on non-quantifiable properties.

2.5. Previous Studies

The research identified some previous studies related to the topic under analysis. Previous research on the "Decision Tree for Non-Metric Sex Assessment Based on the Skull" is linked to Forensic Anthropology and the urgent need to develop accurate techniques for determining sex in human

remains during various forensic investigations, with the aim of assisting in the location of missing persons. The research focuses on examining the bone structures of the skull to identify the sex of the deceased individual. It should be remembered that determining sex is crucial for recognizing the individual, and conventional methodologies for this identification rely on the measurement of metric features of the skull. However, these procedures can be restricted by elements such as damage to the cranial vault or the absence of accurate reference information. Therefore, researchers will consider verifying a non-metric methodology to determine sex by means of the cranial vault using a decision tree. The method would facilitate sex determination even when accurate metric measurements are not available. In conclusion, the background of the study is linked to the urgency of implementing accurate, reliable techniques that can identify human remains in criminal investigations or for the recognition of missing persons, as well as the application of machine learning techniques and decision trees in the field of Forensic Anthropology.

Studies conducted by Langley and colleagues in 2018 highlight an analysis based on a decision tree that establishes sex using non-metric skull typologies. This analysis focuses on non-metric cranial features, specifically the glabella, zygomatic extension, and mastoid process, showing that these elements offer greater accuracy. The decision tree developed achieved an accuracy of 93.5%, reaching 94% in a sample that was validated using a cross-validation method, and 96% in a validation sample that was excluded. Likewise, it is noted that the linear Kappa coefficient showed a reasonable level of agreement among the evaluators. Data collection was carried out without bias, as the observers were unaware of the sex and age of the subjects analyzed. An evaluator with less than one year of practice and two observers with more than 10 years of expertise were chosen, using the linear Kappa statistical technique to establish the correlation between observers, to contrast novice and experienced observers and evaluate possible impacts of discrepancies. Similarly, the research by Toneva et al. (2022) argues that sexual dysmorphia can be evidenced in the viscerocranial dimension and formology using geometric morphometric techniques. The research revealed that the facial skeleton differs more in extension than in shape between males and females, and that size is a more effective indicator of sex distinction than morphology. The research also examined gender variations in various viscerocranial areas and found that the nasal area achieved high accuracy based solely on dimension, although the orbital area achieved greater accuracy based on morphology. The study also examines various studies related to the use of craniometric measurements and geometric morphometry to determine sex in human skeletons, addressing the challenges of sex determination, circumscribing the impacts of age, population variability, and sexual dimorphism. In general, the studies show cranial measurements in terms of capacity and geometric morphology to determine sex in Forensic Anthropology. The text presents various findings from a study on sex differences in viscerocranial extension and configuration, using geometric morphometry methods. Among the findings are the size of the facial skeleton in men and women shows more variation than its shape, and size is a better sex separator than shape. The nasal area showed the greatest accuracy when considering size alone, while the orbital area showed the greatest accuracy when considering shape. The research revealed that the viscerocranium of men and women shows significant differences in shape and size in all the facial areas analyzed. The confirmation of sex distinction fluctuated according to the facial area, with the nasal area being the most reliable and the orbital area the least reliable.

A significant study was conducted by Arriarán et al. in 2020, who indicated the effectiveness of two qualitative techniques, Buikstra and Ubelaker, as well as Ferembach, for determining sex in cranial vaults from Ayacucho, Peru. In this research, a sample of 84 adult skulls was examined, revealing that the Buikstra and Ubelaker approach was more efficient than Ferembach's for this estimation. The relevance of applying appropriate methods for sex assessment in diverse populations is highlighted, and the multidisciplinary nature of this type of estimation in skeletal remains is emphasized. In addition, research related to sex determination in bodies through the study of bone morphology in other global areas is analyzed. This work reaffirms the need to use appropriate techniques to estimate sex in different populations and emphasizes the multidisciplinary approach necessary when dealing with skeletal remains. The findings showed that the Buikstra and Ubelaker method had a higher success rate in determining sex in skulls from the Ayacucho region than the Ferembach method. The chi-square test showed that Buikstra and Ubelaker were effective in 52.4% of cases, while Ferembach was not effective. Similarly, it was shown that certain areas of the skull, including the mastoid process and glabella, are more effective for determining sex in skulls.

Similarly, Morlesín and García (2022) address the difficulties associated with identifying sex in archaeological human remains that are incomplete or in poor condition. They introduce metric techniques based on variations in size rather than shape and analyze the differences in populations in terms of the expression of sexual dimorphism. In addition, research is carried out on carpal and metacarpal bones from the archaeological collection located at Lake Salitroso in Argentina, generating logistical functionalities applicable to other Patagonian archaeological collections of physiologically connected groups. The investigation revealed that certain bones offered greater accuracy in identifying sex, using numerical regression equations to determine the sex of seven subjects who had not been previously classified, correctly assigning sex to six of them. The study addresses the difficulties encountered when attempting to determine the sex of fragmented or poorly preserved archaeological human remains and proposes metric methodologies based on size differences rather than shape. The research validates the effectiveness of these bones in sex differentiation and offers relevant conclusions for paleodemographic studies. Binary logistic functions were developed for each bone to achieve a degree of accuracy in correctly classifying sex (female or male), and it was found that certain bones provided a higher level of accuracy in sex identification.

3. METHODOLOGY

Regarding the research method, the Decision Tree procedure for Non-Metric Sexual Evaluation of the skull, created by Langley (2018), was used. This procedure was developed in a group of white people and is still used in Forensic Anthropology today.

The research was quantitative in nature, as anatomical extensions of the skull were used to subsequently measure its features. These were mathematically evaluated for confirmation based on quantifications defined in Langley's method (2018). It is an elementary investigation, with the aim of finding scientific evidence of the effectiveness of a pre-established procedure, in this case, Langley's method (2018) for a contemporary digital sample from Chachapoyas.

Regarding to the sample, this one consisted in 100 digital images of skulls obtained using multi-slice CT from individuals between 30 and 50 years old, who were treated at the imaging unit of the "Virgen de Fátima Regional Hospital" in Chachapoyas during 2023. These images include three-dimensional views: frontal, lateral, and posterior. From this population, 80 digital images were randomly selected as a sample, which decision was based on forensic techniques for sex identification in bone structures. The sample size was obtained using the finite population sampling formula, and the sample was selected by random drawing, discarding 20 images that did not appear in the procedure before mentioned. **Sample:** The sample was simple random probability

$$n = \frac{z^2 Npq}{E^2(N-1) + z^2 pq}$$

$$n = \frac{1.96^2(100)(0.5)(0.5)}{(0.05)^2(100-1) + 1.96^2)(0.5)(0.5)}$$

n=80

Where:

N= Population size

n= Sample size

$z_{95\%}$= Confidence level

p= Sample probability = 0.5

q= 1-p; Non-sample probability = 0.5

E= Marginal error that is acceptable = 5% = 0.05

The study will be conducted on a sample of skulls from a contemporary population in the province of Chachapoyas. The sample will be selected from the helical tomographic images of skulls available in the database (Vitria storage hard drive) of the Toshiba Prime Aquilion multi-slice (160 slices) tomograph, 140 kV power, manufactured in 2016, showed in the Figure 1 located in the imaging department, tomography and radiography service of the "Virgen de Fátima Regional Hospital" in Chachapoyas during the period 2023.

Figure 1: Toshiba Prime Aquilion Multi-Slice (2016).

The data was personally collected at the Diagnostic by images Departure – Image Reading Environment in the "Virgen de Fátima Regional Hospital", that shows in the Figure 2.

Figure 2: Data Obtained.

According to the database, as mentioned above, a total of 80 digital images of skulls were collected, a sample of which is shown from the Figure 3 to the Figure 8.

Figure 1: 33 Year Old Man.

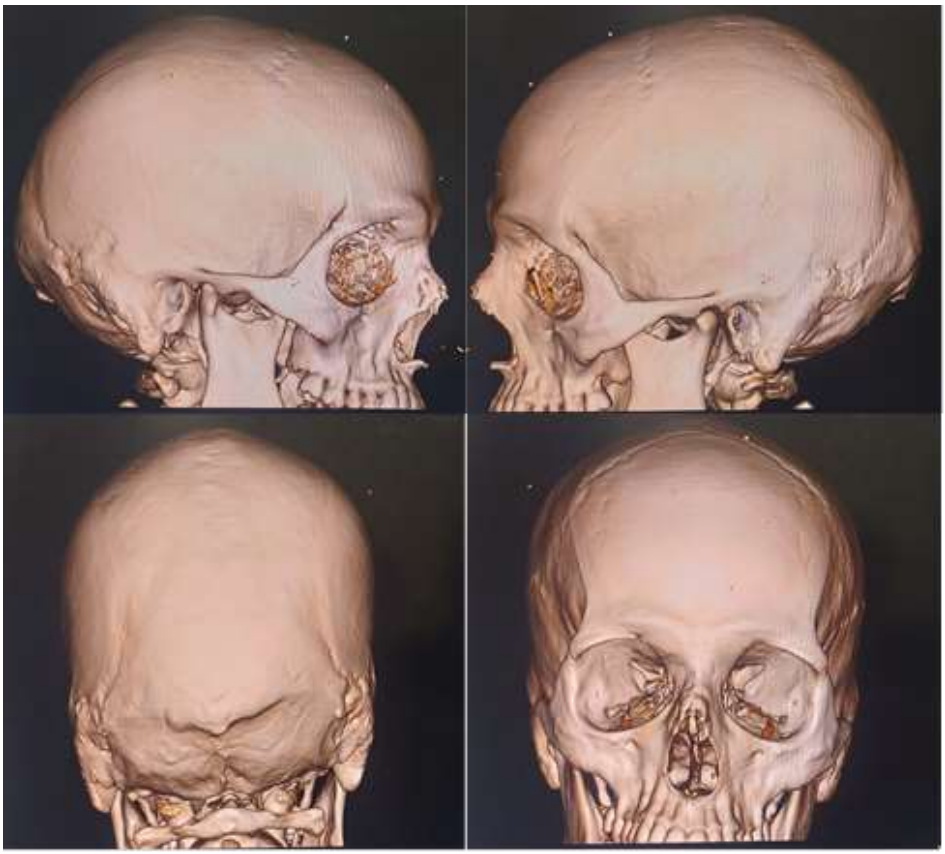

Figure 4: 40-Year-Old Man.

Figure 5: 50-Year-Old Man.

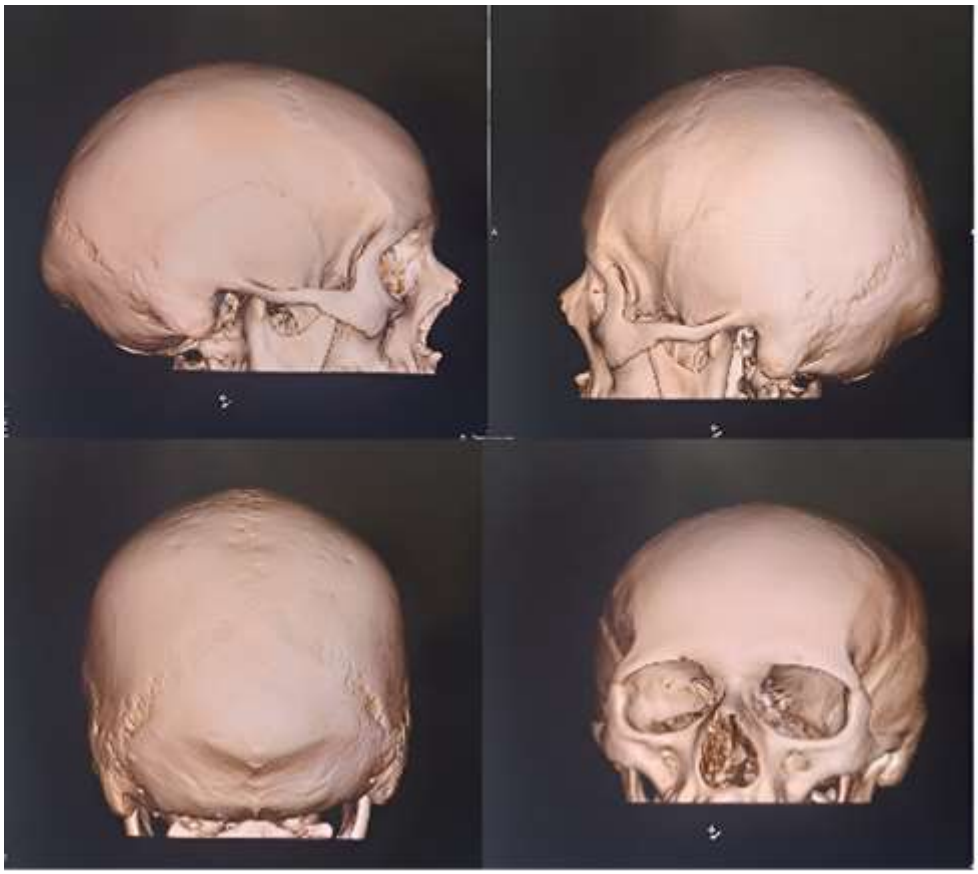

Figure 6: 33-Year Old Woman.

Figure 7: 45-Year Old Woman.

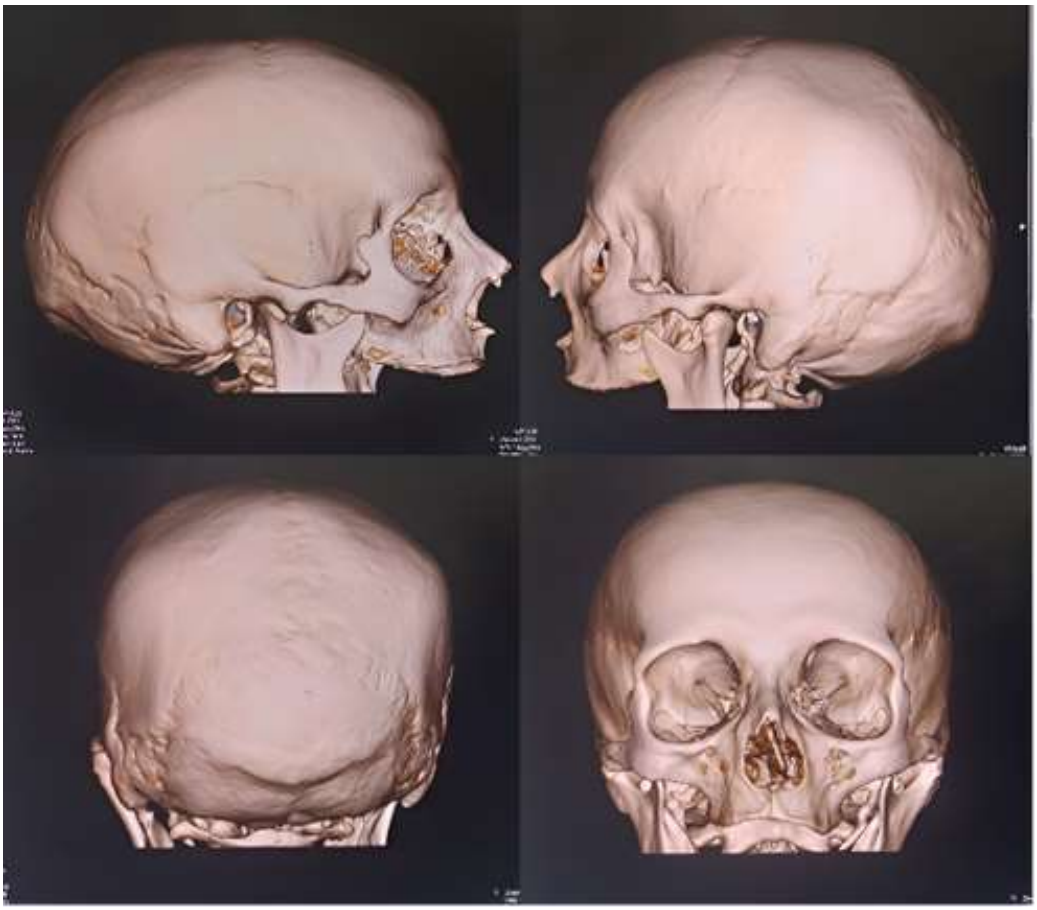

Figure 8: 50-Year Old Woman.

The instruments used were

1. Data collection form: digital iconography was added to several groups of collaborators to analyze sex determination by applying the reasoning defined by the decision tree methodology. To carry out the data collection and subsequent study, the grading indicated in Langley's methodology (2018) was used as a basis.
2. **Observation protocol** a protocol was used to examine the characteristics evaluated (glabella, zygomatic extension, and mastoid process) of the digitized skull specimens, which had been analyzed to establish sex as defined by Langley. The grading used for the evaluation was a Likert progression from 1 to 5 to measure whether the distribution presents a low or high expression according to the reference quantifications established in the method (DOC PICTURE).

Statistical analysis applications were used to manage and examine the information (SPSS V.20). The ordinal scores of the non-metric characteristics were examined through statistical parameters. This method verifies a Decision Tree model to estimate the variables under study, in this case, the effectiveness in identifying sex considering cranial dimensions. Regarding the specific analysis evaluation, the Kappa coefficient was used to assess the correlation of the observations, and subsequently classification trees were used.

In any research, it is crucial to consider the ethical issues involved in the collection and use of data. For the analysis of digital images of skulls, it is crucial to consider the authorizations granted by the institution for this type of information, bearing in mind that it belongs to people treated at the hospital and whose information must be protected. **Regarding privacy and confidentiality** the data and images of the skulls were treated confidentially for research purposes with the work team.

Regarding cultural sensitivity it was considered essential to consider the cultural and religious ideologies of the community to which the iconography of the skulls corresponds and to ensure that they are treated with the necessary responsibility. About the ethical use of information: the data collected was used exclusively for research purposes and was not used for any other purpose without the permission of the database owner.

4. RESULTS

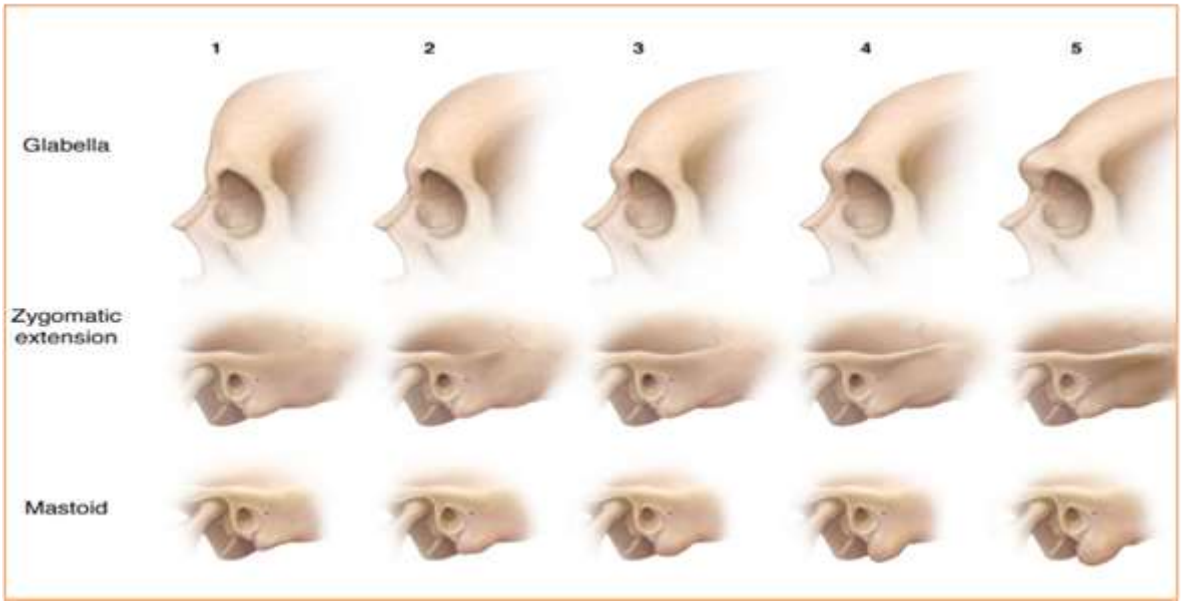

Figure 9: Non-Metric Skull Assessment to Determine Sex by Langley (Glabella, Zygomatic Extension, and Mastoid Process).

The Figure 9 shows the scoring scale for cranial structures (glabella, zygomatic extension, and mastoid process) according to Langley's method (2018), which served as a parameter for the numerical assessment of the structures under study.

Table 1: Effectiveness of the Decision Tree Technique and Langley's Non-Metric Sex Assessment in Identifying the Actual Sex in a Sample from Chachapoyas.

Observers of the sample	Sample (n)	Measurement based on actual gender data	Approximate significance	Interval confidence (IC 95%)
Observer 01	*80*	*Kappa: 0.900*	*0.000*	*0.805 – 0.995*
Observer 02	*80*	*Kappa: 0.775*	*0.000*	*0.663 – 0.911*
Observer 03	*80*	*Kappa: 0.925*	*0.000*	*0.842 – 1.008*
Approx. measure relative		*Kappa 0.866*		

Regarding to the Table 1, the average agreement between the observers' assessment and the true sex of the specimen analyzed in Kappa was 0.866, which implies almost perfect agreement according to the factor used. This suggests that there is a high degree of correspondence between the actual sex of the sample and the perceptions of the three observers. Likewise, the agreement of the first observer was 0.900 (almost perfect), the second observer 0.775 (substantial agreement), and the third observer 0.925 (almost perfect).

Table 2: Interobserver Agreement Measured by Weighted Linear Kappa-Chachapoyas Sample.

Observers	Glabella (n=80)		Zygomatic extension (n=80)		Mastoid process (n=80)	
	Kappa	IC 95%	Kappa	IC 95%	Kappa	IC 95%
Observer 1 y Observer 2	*0.631*	*0.545-0.717*	*0.605*	*0.534-0.676*	*0.969*	*0.934-1.004*
Observer 1 y Observer 3	*0.906*	*0.848-0.963*	*0.971*	*0.940-1.003*	*0.889*	*0.827-0.951*
Observer 2 y Observer 3	*0.609*	*0.506-0.712*	*0.625*	*0.549-0.700*	*0.858*	*0.789-0.928*

Table 2 shows the agreement index between observers on the evaluation of the bone structures under study (glabella, zygomatic extension, and mastoid process).

There is evidence of regular to almost perfect agreement according to Kappa. The agreement

between observers 1 and 3 is greater than the agreement between observer 2 and the other observers (1 and 3).

Table 3: Analysis of Concordance between the Decision Tree Method for the Non-Metric Sex Assessment Proposed by Langley Using Kappa.

		Value	Asymptotic standard error	T approximate	Approximate significance
Kappa	**Observer 1**	0.900	0.049	8.060	0.000
	Observer 2	0.775	0.070	7.040	0.000
	Observer 3	0.925	0.042	8.276	0.000
	N° Valid cases	80			

According to the Table 3, in result to the statistical of Kappa, the observers 1 and 3 has values of 0.90 and 0.92, respectively, falling within the range of 0.81<k<1, which indicates almost perfect agreement. In the case of the observer 2, the value obtained was 0.775, within the range of 0.61<k<0.80, which corresponds to substantial agreement.

Table 4: Accuracy Analysis Using the Decision Tree Method: Chachapoyas, Amazonas, Peru.

Sample	True sex	Observer 1		Observer 2		Observer 3	
		Sex	Success	Sex	Success	Sex	Success
1	1	1	TRUE	1	TRUE	1	TRUE
2	1	1	TRUE	1	TRUE	1	TRUE
3	1	1	TRUE	2	FALSE	1	TRUE
4	1	1	TRUE	1	TRUE	1	TRUE
5	1	1	TRUE	1	TRUE	1	TRUE
6	1	1	TRUE	1	TRUE	1	TRUE
7	1	1	TRUE	1	TRUE	1	TRUE
8	1	1	TRUE	1	TRUE	1	TRUE
9	1	2	FALSE	2	FALSE	2	FALSE
10	1	1	TRUE	1	TRUE	1	TRUE
11	1	2	FALSE	2	FALSE	1	TRUE
12	1	1	TRUE	2	FALSE	1	TRUE
13	1	1	TRUE	1	TRUE	1	TRUE
14	1	1	TRUE	1	TRUE	1	TRUE
15	1	1	TRUE	1	TRUE	1	TRUE
16	1	1	TRUE	1	TRUE	1	TRUE
17	1	1	TRUE	2	FALSE	1	TRUE
18	1	1	TRUE	1	TRUE	1	TRUE
19	1	1	TRUE	2	FALSE	1	TRUE
20	1	1	TRUE	1	TRUE	1	TRUE
21	1	2	FALSE	2	FALSE	2	FALSE
22	1	1	TRUE	1	TRUE	1	TRUE
23	1	1	TRUE	1	TRUE	1	TRUE
24	1	1	TRUE	1	TRUE	1	TRUE
25	1	1	TRUE	1	TRUE	1	TRUE
26	1	1	TRUE	1	TRUE	1	TRUE
27	1	1	TRUE	1	TRUE	1	TRUE
28	1	1	TRUE	1	TRUE	1	TRUE
29	1	1	TRUE	1	TRUE	1	TRUE
30	1	1	TRUE	1	TRUE	1	TRUE
31	1	1	TRUE	1	TRUE	1	TRUE
32	1	1	TRUE	1	TRUE	1	TRUE
33	1	1	TRUE	1	TRUE	1	TRUE
34	1	1	TRUE	1	TRUE	1	TRUE
35	1	1	TRUE	1	TRUE	1	TRUE
36	1	1	TRUE	1	TRUE	1	TRUE
37	1	1	TRUE	2	FALSE	1	TRUE
38	1	1	TRUE	1	TRUE	1	TRUE
39	1	1	TRUE	1	TRUE	1	TRUE
40	1	1	TRUE	1	TRUE	1	TRUE
41	2	1	FALSE	1	FALSE	1	FALSE
42	2	2	TRUE	2	TRUE	2	TRUE

43	2	2	TRUE	2	TRUE	2	TRUE
44	2	2	TRUE	2	TRUE	2	TRUE
45	2	2	TRUE	2	TRUE	2	TRUE
46	2	2	TRUE	2	TRUE	2	TRUE
47	2	2	TRUE	2	TRUE	2	TRUE
48	2	2	TRUE	2	TRUE	2	TRUE
49	2	2	TRUE	2	TRUE	2	TRUE
50	2	2	TRUE	2	TRUE	2	TRUE
51	2	2	TRUE	2	TRUE	2	TRUE
52	2	2	TRUE	2	TRUE	2	TRUE
53	2	2	TRUE	2	TRUE	2	TRUE
54	2	2	TRUE	2	TRUE	2	TRUE
55	2	2	TRUE	2	TRUE	2	TRUE
56	2	2	TRUE	2	TRUE	2	TRUE
57	2	2	TRUE	2	TRUE	2	TRUE
58	2	2	TRUE	2	TRUE	2	TRUE
59	2	2	TRUE	2	TRUE	2	TRUE
60	2	2	TRUE	2	TRUE	2	TRUE
61	2	2	TRUE	2	TRUE	2	TRUE
62	2	2	TRUE	2	TRUE	2	TRUE
63	2	2	TRUE	2	TRUE	2	TRUE
64	2	2	TRUE	2	TRUE	2	TRUE
65	2	2	TRUE	2	TRUE	2	TRUE
66	2	2	TRUE	2	TRUE	2	TRUE
67	2	2	TRUE	2	TRUE	2	TRUE
68	2	2	TRUE	2	TRUE	2	TRUE
69	2	2	TRUE	2	TRUE	2	TRUE
70	2	2	TRUE	2	TRUE	2	TRUE
71	2	2	TRUE	2	TRUE	2	TRUE
72	2	2	TRUE	2	TRUE	2	TRUE
73	2	2	TRUE	2	TRUE	2	TRUE
74	2	2	TRUE	2	TRUE	2	TRUE
75	2	2	TRUE	2	TRUE	2	TRUE
76	2	2	TRUE	2	TRUE	2	TRUE
77	2	2	TRUE	2	TRUE	2	TRUE
78	2	2	TRUE	2	TRUE	2	TRUE
79	2	2	TRUE	2	TRUE	2	TRUE
80	2	2	TRUE	2	TRUE	2	TRUE
Success			76		71		77
Failures			4		9		3
Total			80		80		80
Precision (Success/Total)			95.00%		88.75%		96.25%

According to the Table 3 from the accuracy calculation results, an accuracy of between 95% and 96.25% is determined for the most experienced observers (Observers 1 and 3) and 88.75% for the least experienced observer (Observer 2).

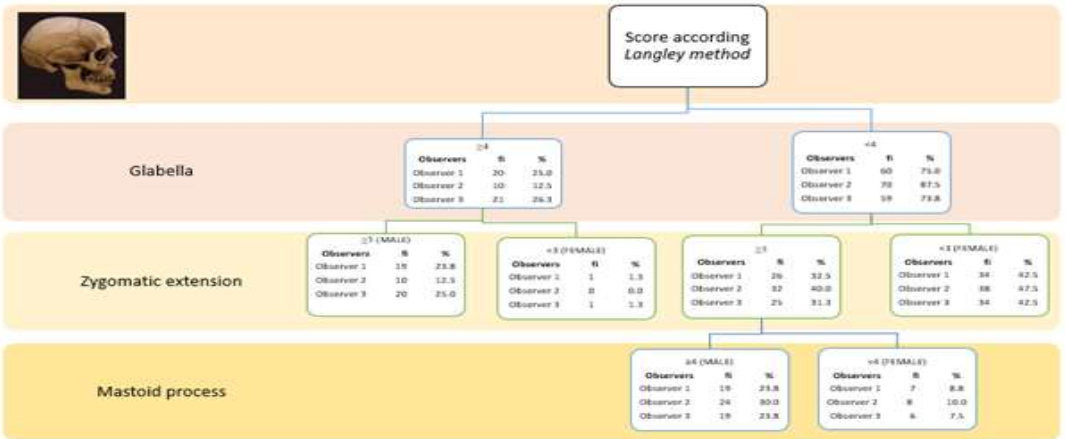

Figure 10: Decision Tree for Non-Metric Sex Assessment to Establish the Actual Sex-Chachapoyas Sample.

Figure 10 shows the method for identifying the sex of the specimen using the decision tree suggested by Langley based on the data provided by the evaluators. Thus, in the measurement of the glabella, figures of ≥4 were recorded in evaluator 1, with 20 people (25%), in evaluator 2, with 10 people (12.5%), and in evaluator 3, with 21 people (26.3%). Similarly, glabella measurements of <4 were found in evaluator 1, with 60 individuals (75%), in evaluator 2, with 70 individuals (87.5%), and in evaluator 3, with 59 individuals (73.8%).

5. DISCUSSION

The study found that the Langley (2018) procedure is effective for determining the sex of skull specimens in Chachapoyas, considering the assessment of the bone structures of the glabella, zygomatic extension, and mastoid process. This is demonstrated by the statistical tests applied ($p<0.05$). There is more than 90% agreement in general, provided that the observers have the necessary experience to adequately assess the parts under study.

In this regard, Toneva et al. (2022) indicate that research supports the use of skull measurements and geometric morphometry to infer sex in forensic anthropology. Similarly, Arriarán et al., (2020) highlight the effectiveness of two qualitative approaches in estimating sex in skulls from the Ayacucho area, adding that some cranial regions, such as the mastoid process and glabella, are more efficient in identifying the sex of skulls.

In another line of research, Morlesín (2022) observed that certain skeletons showed a higher degree of accuracy in sex identification, using numerical regression algorithms to classify the sex of seven individuals without a prior assignment, correctly defining the sex in six of them. Similarly, Isaza (2015) point to contemporary techniques for determining sex based on skull shape, which include the analysis of typologies such as the glabella, the occipital crest, and the morphology of the mandible, which are often effective.

Another study conducted by Kellin (2020) indicates that the application of morphometric and iconographic techniques, such as computed tomography and magnetic resonance imaging, could be beneficial, as they would increase the accuracy of sex determination in people of Hispanic origin. Similarly, Vargas (2021) indicate that gender identification using mastoid bones may be relevant for recognizing fundamental differences in the anatomy of male and female mastoid bones. Similarly, Rojas (2019) found in his study a notable opposition between his findings and the actual sex of a sample of cranial vaults with a value of $p = 0.004$, concluding that there are concordances in establishing the sex of the skulls evaluated.

Other procedures were discovered that demonstrated their effectiveness in the non-metric sexual assessment of the cranial vault, **as reflected in the following research** Oneto (2019) in Spain using machine learning, Muñoz (2023) in Ecuador using the technique of morphological and metric analysis of the skull, and Larico (2022) in Lima using the cheiloscopic method of Suzuki, Tsuchihashi, and Renaud in Lima. Similarly, Gómez et al. (2021) in Colombia using various techniques, Escalante (2019) in Lima through the morphometric study of palatal vaults, Maldonado (2020) in Ecuador through a cranio-dento-facial study, and Acosta et al. (2021) in Colombia through a study of mesio-distal diameter symmetry. Likewise, Sevillano (2022) in Lima using the opisthion bimastoideal triangle area technique and Llaguno (2020) also in Lima using the mandibular canine index of patients.

As can be seen, the results of the study confirm the usefulness and effectiveness of qualitative methodologies for determining sex based on the assessment of certain cranial structures, in this case the glabella, zygomatic extension, and mastoid process, provided that the evaluators have sufficient practice for an effective assessment. Furthermore, current technology poses a challenge to these methods, as digital images are now used in this type of assessment. In addition, health and legal services are already implementing modern equipment for digital assessment. Perhaps, over time, this equipment will be able to determine sex from images using software that allows for assessment and conclusion of the sex of a skull.

6. CONCLUSIONS

a. The relationship between the Decision Tree method and the Non-Metric Sex Assessment developed by Langley was analyzed, with the aim of identifying the actual sex in a contemporary digital sample from the Province of Chachapoyas, Amazonas Region, Peru, in 2023. The results showed a highly significant relationship ($p=0.000<0.01$) for the accurate determination of sex in this sample.
b. The concordance between the Decision Tree method and the Non-Metric Sex Assessment proposed by Langley was evaluated, with the aim of comparing their similarity with a previous study carried out in the Province of Chachapoyas, Amazonas Region – Peru 2023,

using a sample of digital skulls. An acceptable level of agreement between observers (linear Kappa index) was obtained in the measurements of the glabella, zygomatic extension, and mastoid process. The values obtained by observers 1 and 3 were 0.90 and 0.92, respectively, falling within the range of $0.81<k<1$, which indicates almost perfect agreement. Observer 2 obtained a value of 0.775, within the range of $0.61<k<0.80$, which corresponds to substantial agreement.

c. The accuracy of the Decision Tree method applied to the Non-Metric Sexual Assessment of the skull, developed by Langley, was evaluated in order to validate its effectiveness in a contemporary digital sample from the Province of Chachapoyas, Amazonas Region, Peru, in 2023. The results indicate that this method is significantly accurate in determining actual sex in cranial samples, provided that the evaluators have sufficient experience. Among observers with the highest level of experience, accuracy ranged from 95% to 96.25%, while the observer with the least experience recorded an accuracy of 88.75%.

Acknowledgements: This investigation will contribute to increase the scientific evidence about the sex determination based on non-metrical cranial features in a specific sample, in this case, in a contemporary sample of Chachapoyas. It´s important to mention the existence of a knowledge gap about the application of sexual estimation methods, using diverse techniques in the population of the region Amazonas, therefore, the present investigation through his results will decrease that gap, also, will be very helpful to the Criminalistic Science with located dates. It´s necessary to mention, that the validation of the Langley´s method of identification will contribute to the exactitude and precision of the non-metrical technique to determinate the sex from tomographic 3D pictures of the skull, helping with a scientific base more elaborate for his application in forensic and judicial contexts.

REFERENCES

Acosta, et al. (2021). Proporción del diámetro mesio-distal de los dientes anterosuperiores, como factor dimórfico sexual en un grupo de individuos mestizos colombianos. Estudio exploratorio. http://repositorio.uan.edu.co/handle/123456789/5089.

Arriarán, L. Vigo C y Velezmoro, I. (2020). Eficacia de los métodos de Buikstra & Ubelaker y Ferembach, en la estimación del sexo en cráneos humanos procedentes del departamento de Ayacucho, Perú; revista mexicana de medicina forense, pp. 24-35. https://www.medigraphic.com/pdfs/forense/mmf-2020/mmf204c.pdf

Asana, T. (2023). ¿Qué es un árbol de decisiones? Un análisis de 5 pasos para tomar mejores decisiones. https://asana.com/es/resources/decision-tree-analysis.

Bertsatos A. (2020). Advanced procedures for skull sex estimation using sexually dimorphic morphometric features. Volume 134, pages 1927–1937. https://link.springer.com/article/10.1007/s00414-020-02334-9.

Buchi, A. (2016). El Dimorfismo Sexual en Distintas Relaciones Cráneo-Mandibulares. Int. J. Morphol., 34(1):365-370, 2016. Scielo. https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0717-95022016000100052.

Calmon, M. (2019). Forensic anthropology and missing persons: A Brazilian perspective. https://www.sciencedirect.com/science/article/abs/pii/S0379073819301100.

Chavez, A. (2019). Antropología forense asociada a la escena del crimen y la investigación criminal. Unidad de Antropología Física forense. [PDF file]. https://www.mpfn.gob.pe/escuela/contenido/actividades/docs/3970_antrop_forense_asoc_a_esc_crimen_aidde_chavez_r.pdf.

Escalante, K. (2019). Precisión del dimorfismo sexual a través del análisis morfométrico de bóvedas palatinas en cráneos de una población peruana. https://repositorio.cientifica.edu.pe/bitstream/handle/20.500.12805/846/TE-Escalante%20K.pdf?sequence=1&isAllowed=y.

Imaizumi K., Bermejo, E., Taniguchi, K. Ogawa, Y., Kaga, K. (2020). Development of a sex estimation method for skulls using machine learning on three-dimensional shapes of skulls and skull parts. https://www.sciencedirect.com/science/article/abs/pii/S2666225620300427.

Isaza, J. (2015). La Antropología Física y el diagnóstico del sexo en el esqueleto a partir del cráneo: métodos

actuales y futuras perspectiva. Boletín de Antropología. Universidad de Antioquia, Medellín, vol. 30, N°50, pp. 94-126. [PDF file]. https://www.redalyc.org/pdf/557/55743108006.pdf

Kellin J. (2020). The faults in the methods: problems with current sex estimation methods for hispanic individuals and potential solutions. [PDF file]. file:///D:/TESIS%20articulo%20problemas%20en%20estimacion%20del%20sexo.pdf

Langley, N. (2018). Un Árbol de Decisión para la Evaluación Sexual no Métrica del Cráneo, Edit. Academia Americana de Ciencias forenses, Vol. 63, N°1. [PDF file]. file:///D:/Langley_et_al-2018-Journal_of_Forensic_Sciences%20(1).pdf

Larico, Y. (2022). Eficacia de los métodos queiloscópicos de Suzuki y Tsuchihashi y Renaud en la determinación del sexo. https://cybertesis.unmsm.edu.pe/bitstream/handle/20.500.12672/18535/Larico_ay.pdf?sequence=5&isAllowed=y.

Maldonado, C. (2020). Detalles anatómicos cráneo-dento-facial para la identificación y exploración de cadáveres. https://repositorio.ug.edu.ec/items/6d1b4256-45ca-4480-bb27-e4f20896c076.

Morlesín, M. & García S. (2022). Determinación del sexo a partir de carpos y metacarpos de la colección arqueológica del lago Salitroso (Santa Cruz, Argentina). Revista Intersecciones en Antropología, volumen: 67-79. [PDF file]. https://interseccionesantro.soc.unicen.edu.ar/archivospdf/volespecial/05morlesin.pdf.

Muñoz, A. Utilidad de la antropología forense para la identificación del sexo en cadáveres mediante el análisis morfológico y métrico del cráneo. https://dspace.ucacue.edu.ec/items/c3d2b110-4b66-4ea7-abe8-cce861f5a4e8.

Nasti, A. (2023). Análisis antropológico forense de restos humanos recuperados en Santa Cruz. Revista argentina de antropología biológica, vol. 25, núm. 1, e059, 2023. Asociación de Antropología Biológica Argentina. https://www.redalyc.org/journal/3822/382274300004/html/.

Oneto, M. (2019). Uso de datos craneométricos para la estimación del perfil biológico mediante machine learning. https://openaccess.uoc.edu/handle/10609/96708.

Passalacqua, N. Pilloud, M. y Congram, D. (2021). Forensic anthropology as a discipline. Biología 2021, 10 (8), 691; https://doi.org/10.3390/biology10080691.

Rodríguez, C. (2023). Antropología forense hoy. https://www.museosdetenerife.org/blog/articulo-de-divulgacion-antropologia-forense-hoy-por-conrado-rodriguez-maffiotte/.

Rodríguez, J. (2004). La antropología forense en la identificación humana. Editora Guadalupe Ltda, Bogotá: Colombia.

Rojas, C. (2019). Determinación del sexo en restos óseos craneales a través de la apófisis mastoides y el triángulo inión-opistocranium-asterium en el laboratorio de ciencias morfológicas de la Universidad de Huánuco 2018. http://repositorio.udh.edu.pe/handle/123456789/1703;jsessionid=30170FFD7A6DCF87DCF12438C0228D13.

Sevillano, M. (2022). Valores del área del triángulo opistion bimastoideo en tomografías computarizadas "Cone beam" en el dimorfismo sexual de pacientes de la Facultad de Odontología de la UNMSM. http://38.43.142.130/handle/20.500.12672/19229.

Thamires, M. y Souza, V. (2021). Contributions of Anatomy to Forensic Sex Estimation: Focus on Head and Neck Bones. Forensic Sciences Research, Volume 7, Issue 1, March 2022, Pages 11–23. https://doi.org/10.1080/20961790.2021.1889136.

Toneva, D. et al. (2022). A Geometric Morphometric Study on Sexual Dimorphism in Viscerocranium. Biology, N°11. file:///D:/TESIS%20art%C3%ADculo%202022.pdf

Vargas, D. (2021). Determinación del sexo según la apófisis mastoides en una muestra de población colombiana. Morfolia – Vol. 13 - No. 1 – 2021. https://repository.udca.edu.co/handle/11158/4307.

Xiyang, H.; Rudin, C. y Seltzer, M. (2019). Optimal Sparse Decision Trees. Advances in Neural Information Processing Systems 32 (NeurIPS 2019). https://proceedings.neurips.cc/paper_files/paper/2019/hash/ac52c626afc10d4075708ac4c778ddfc-Abstract.html.