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ANTHROPOMETRIC ANALYSIS OF THE MANDIBLE USING COMPUTED TOMOGRAPHY AS A DETERMINANT OF SEXUAL DIMORPHISM: AN ALTERNATIVE IN FORENSIC DENTISTRY

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ABSTRACT
The process of human identification in the forensic area is fundamental in several circumstances, especially mass accidents and tragedies. Forensic dentistry plays an important role in this environment, with the use of modern technologies such as cone beam computed tomography for the investigation of determining parameters in the identification of sex. The objective of this article was to analyze whether it is possible to identify the sex of patients from the mandible, analyzing morphological and morphometric patterns predominant in males and females. This study used a sample of 100 cone beam computed tomography (CBCT) scans, 50 male and 50 female. CBCT scans were analyzed using the RadiAnt DICOM® software in the 3D tool, visualizing three morphological patterns and nine morphometric patterns. With results of almost 100% accuracy, this study reveals that it is possible to identify sexual dimorphism through mandibles. The morphological patterns of chin shape, muscle marking, and gonial reflex revealed a marked sexual dimorphism. Morphometric analyses of the mandible measured at different sites and their combinations

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revealed satisfactory results and can be used to identify sexual dimorphism. Thus, the results of this work may be a useful tool in the forensic practice in diagnoses and recognition of the individual's sex in the forensic area.

Keywords: Forensic Dentistry. Cone Beam Computed Tomography.

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INTRODUCTION

Forensic science is a great ally of the judicial system, being characterized as the practice that supports the investigations of crimes and legal matters using scientific and technical knowledge that involves a large interdisciplinary area [1]. Forensic dentistry has significant importance in the performance of methods of recognizing people and their characteristics, such as gender, age, height, ethnic groups, skin color or even in defining the cause and time of death, among other functions [3]. The identification of corpses can be carried out through the use of various techniques, which will initially depend on the stage of conservation of the victim found [4]. In dentistry, this area is constantly being updated and has a series of resources and tools that did not exist before, such as computed tomography, analysis of DNA obtained by the dental pulp and oral cells, electron microscopy in the analysis of dental materials present in the oral cavity and individual characteristics of the dental structure, such as enamel, conventional and digital radiographs, software that helps in the collection, classification and comparison of dental records and virtual autopsy [2]. One of the most important aspects in forensic science is related to finding specific characteristics detected in the dead body, through data recorded during the individual's life that serve as individualization factors such as fractures or bone pathologies, fingerprint analysis and anthropological methods. There are significant differences between men and women, such as hormonal and skeletal physiology, distinct characteristics that correspond to what is known as sexual dimorphism [7]. In this sense, radiographic methods are also used to facilitate identification, obtaining numerous radiological techniques. The use of cone beam computed tomography (CBCT) is also a very useful and accurate tool, as it has numerous advantages over traditional radiographic projection. Firstly, because it is free from the problem of superposition of structures beyond the plane of interest and also because it allows the visualization of small differences in density. [17]. CBCT can be used to assist in human identification, including the determination of gender, ethnic group and, especially, age [5]. Since the estimate of age and height depend on the correct determination of sex. [6]. The diagnosis is based on the analysis of physical characteristics in several anatomical regions, markedly distinct for each sex. For this, forensic dentistry can act in this process from the beginning, where general identifications such as sex, age, height, ethnicity occur until the recognition of the person [8]. The analysis of certain populations or groups is also taken into account, as these people have skeletal characteristics that can be used to differentiate them from

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another group or population. [8] Research carried out in forensic dentistry searches for anatomical structures that establish reliable data about possible measurements of sexual differentiation. These analyses occur through measurements in skulls, mandibles or two-dimensional images, limiting the evaluations and subject to superposition of important bone structures [9-16]. There are considerable differences between men and women, particularities that correspond to what is known as sexual dimorphism. The bones that have the most particularities for the analysis of sexual dimorphism are the skull, pelvis and femur [18]. Among the bones of the face, the mandible is the largest and strongest, consisting of the coronoid and condylar processes, the body and the ramus of the mandible. This bone plays a key role when the skull is not found intact in sex determination, possessing high accuracy. A few studies have used quantitative and qualitative methods to differentiate sex, age, and ethnicity, evaluating mandible morphology and size [19]. However, these evidences used local samples, and there are not many studies in the Brazilian population, because the ideal discriminant functions for sex differentiation are obtained through specific studies by the standards of each population [20]. This research is of great importance for the analysis of the anthropological patterns of the Brazilian population because it uses different patterns and techniques for this analysis of sexual dimorphism. Therefore, this article aims to describe the anthropometric analysis of the mandible using CBCT to determine sexual dimorphism in a Brazilian sample.

MATERIALS AND METHODS

The project was submitted to the Committee of the Institute for Ethics in Research with Human Beings. Care was taken in the study respecting the research standards involving human beings (Res. CNS 466/12) of the National Health Council. CT scans that presented high image definition were selected for a better analysis of bone structures, including CT scans of patients over 18 years of age, 50 men aged 19 to 74 years and 50 women aged 18 to 60 years, as they already have developed bones and cartilage. After the sample size calculation, 100 cone beam CT scans of the whole skull using the I- CAT CLASSIC (Imaging Sciences International, Hatfield, Pennsylvania, USA) CT scanner were used in this study, 50 males and 50 females were systematically randomized. Patients with any dental or craniofacial anomaly, who had craniofacial trauma, who had syndromes or CBCT exams with artifacts that made it difficult to read the image were excluded. CBCT scans were used from a database performed with dental indication. The methodology was

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based on the study done by Aspalilah et al (2018) [21], who analyzed sex determination in jaws of a Malaysian population. Thus, morphological and morphometric patterns of the mandible were evaluated. This research consists of a descriptive, retrospective, qualitative and quantitative study. The analysis of the images was performed by 02 previously trained dental evaluators, in isolation from each other, without access to the patient's data. Each evaluator received the sample with 100 CT scans, 50 of which were for each sex. These CT scans were previously randomized, and the evaluators and the statistician were blinded, thus avoiding interventions or privileges with the samples. For the evaluation of the CT scans, the RadiAnt DICOM® software (Poznan, Poland), version 5.0.2, was used, and the CT scans were observed on a 17-inch LCD monitor, with a resolution of 1280 x 1024 pixels, in a dark room for better analysis.

MORPHOLOGICAL PATTERNS

First, morphological patterns were analyzed, such as chin shape, gonial reflex and markings of insertions of the muscles: masseter, buccinator, mental, orbicularis oris oris, depressor of the lower lip, depressor angle of the mouth and depressor of the nasal septum. For the analysis of the muscle marking, the depth of muscle insertion and its locations were evaluated. The DICOM file was used in the Radiant software, using the 3D tool for the analyses. (Table 1)

MORPHOMETRIC PATTERNS

Next, nine morphometric patterns were analyzed: maximum and minimum width of the ramus of the mandible, height of the ramus, height of the condyle, coronoid height, height of the mandibular body, height of the symphysis, bicondylar and bigonal width. (Table 2)

The zygomatic bone was removed in the 3D image to perform measurements of the height of the coronoid process and the condyle height of the mandible. To make the measurements of the bicondylar width and bigonal width, a part of the skullcap and skull was removed in a coronal section allowing the observation of the goni and condyles in a posterior view of the head.

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Table 1: The three morphological patterns

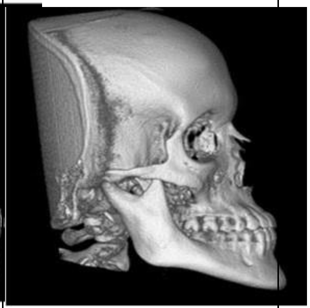
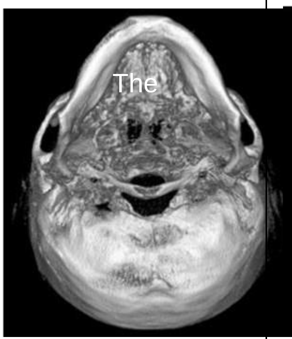
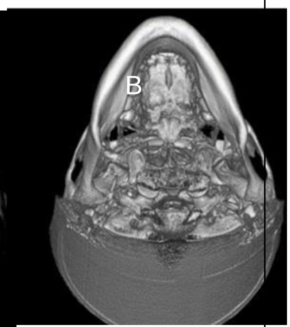
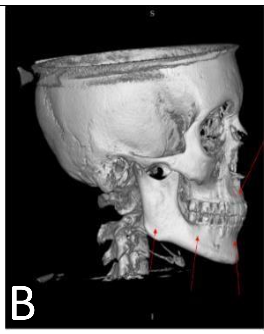
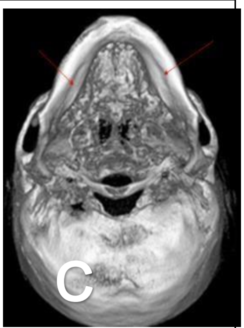
Morphological patterns					
1- Chin shape	Square A	Face in coronal plane;			
	Pontiagudo B	Face in the sagittal plane on the right side of the face			
2- Reflexo gonial	Inverted To	Axial plane - observed from the lower plane to The superior			
	Not reversed B				
3- Markings of muscle inserts	Proeminente:A,C Not prominent : B	Coronal flat face; plan sagital; Axial plane			

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Table 2: The nine morphometric patterns.

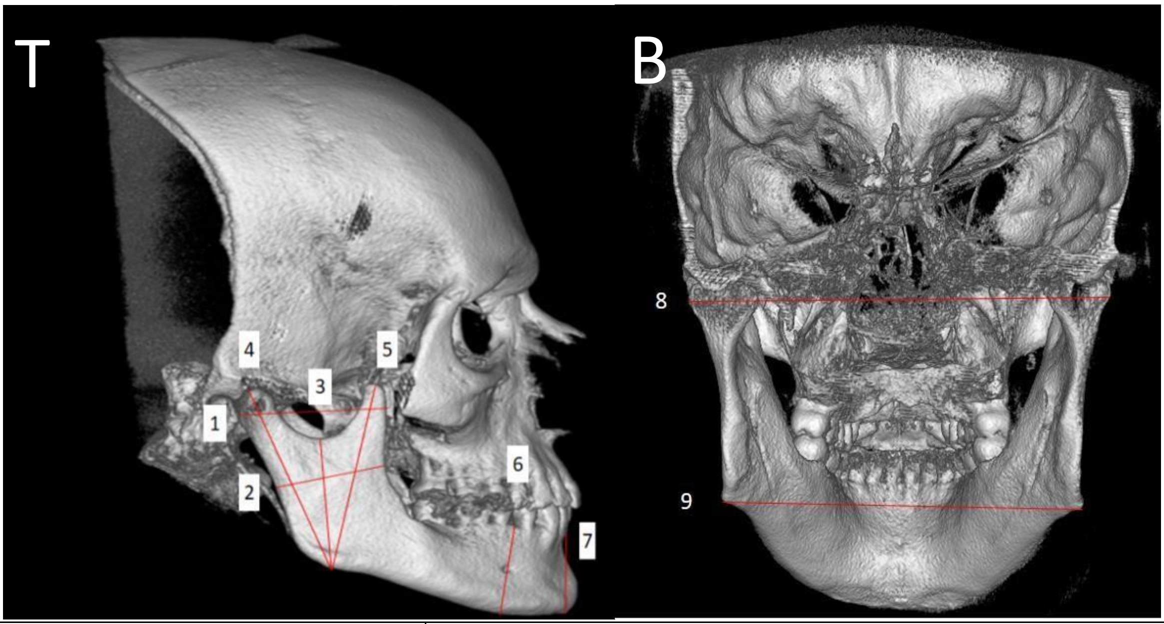

Image A	Morphometric patterns
1-Maximum width of the branch:	The distance between the most anterior point of the mandibular ramus and a line connecting the most posterior point in the condyle
2- Minimum branch width	Smaller anterior-posterior diameter of the branch
3-Maximum height of the branch	The distance between the midpoint of the notch and the angle of the jaw
4-Condyle height	Height of the ramus of the mandible from the uppermost point of the condyle mandibular to the tubercle, or portion most protruding from the lower border of the ramus
5-Coronoid height	Projective distance between the coronary part and the lower wall of the bone
6-Height of the mandibular body	The direct distance between the alveolar process to the lower edge of the mandible perpendicular to the base at the level of the mental foramen
7-Height to Symphyse	The direct distance between the alveolar process to the lower edge of the mandible perpendicular to the base, at the level of the chin symphysis
Image B	Morphometric patterns
8-Largure bicons	The straight distance between the most lateral points at the two condyles
9-Largura bigonal	The right distance between two gonios

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STATISTICAL ANALYSIS

The data obtained were tabulated in Excel spreadsheets (Microsoft, USA) and the statistics were evaluated according to the normality of the data collected, using tests for parametric data, with Bioestat 5.3 software (Belém, Pará, Brazil). The alpha level adopted is 5% as statistically significant. The Blend-Altman test was used to evaluate the agreement between methods, Kappa and Lin weighted test was applied to analyze the inter-rater agreement, while the chi-square test was applied to evaluate the association between the morphological variation of the mandible and sex, the linear discriminant function, logistic regression and the CART classification tree algorithm to obtain the accuracies of the variables in relation to sexual dimorphism.

RESULTS

MORPHOMETRIC PATTERN

Lin's correlation coefficient of agreement indicated good agreement between the pairs of evaluations in all measurements. The continuous quantitative variables were measured on a ratio scale, where each individual was evaluated twice, and the arithmetic mean of the two evaluations was assigned. The variables LMaxR, LMinR, AMaxR, ACond, APCor, LBigo, LBico, ACMand and Asinf, showed significant differences in the means of the male and female groups, the sample data corroborate the statement that the mandible measurements in the male and female sexes are different, and these measurements are higher in the male population. Using the logistic regression method, we can observe the following results in the anthropometric analysis of the mandible observed in CBCT for the determination of sexual dimorphism in a Brazilian sample. It was possible to obtain accuracy of the variables in relation to sexual dimorphism, analyzed individually, of 88% for males and 80% for females, confirming that there is an important difference between males and females, where the characteristics in males are more prominent. It was also possible to observe sexual dimorphism when both sexes were included, a satisfactory result for differentiating men and women with 84% accuracy. (Table 3)

MORPHOLOGICAL PATTERN

Chin shape is a categorical qualitative variable, which can assume two values: square or pointed. The sample kappa coefficient is 90%, indicating that there was almost perfect agreement between the evaluators. Most female individuals (88%) had their chin shape classified as pointed. In turn, the majority of male individuals (88%) had their chin shape classified as square. This difference is statistically significant (p< 0.0001 in the chi-square test). Gonial reflex is a categorical (nominal) qualitative variable, which can assume two values: inverted or non-inverted. The sample kappa coefficient was approximately equal to 90%, 9 indicating that there was almost perfect agreement between the evaluators. Most female individuals (74%) had their gonial reflex classified as inverted, while most male individuals (70%) had their gonial reflex classified as non-inverted. This difference is statistically significant (chi-square test p< 0.0001). In the morphological analyses using the logistic regression method, it was possible to obtain a result with almost 100% accuracy for sexual dimorphism in males with an accuracy of 96%, for females of 88% and including both sexes of 92%. These results confirm that it is possible to differentiate between men and women in CT scans and to assist in the forensic area. (Table 4)

Table 3: Analysis of sexual dimorphism by logistic regression, accuracy only with morphometric variables.

Group	Number of individuals	Correct classification	Misclassification
Male	50	44 (88%)	6 (12%)
Female	50	40 (80%)	10 (20%)
Total	100	84 (84%)	16 (16%)

Table 4: Analysis of sexual dimorphism through logistic regression, accuracy only with morphological variables.

Group	Number of individuals	Correct classification	Misclassification
Male	50	48 (96%)	2 (4%)
Female	50	44 (88%)	6 (12%)
Total	100	92 (92%)	8 (8%)

MORPHOMETRIC AND MORPHOLOGICAL PATTERNS

This study also analyzed the morphometric and morphological variables together in the logistic regression method and obtained as a result accuracy for sexual dimorphism again of almost 100%, with males being 96%, 98% in females and total including both sexes 97%. (Table 5)

Table 5: Analysis of sexual dimorphism through logistic regression, accuracy with all variables.

Group	Number of individuals	Correct classification	Misclassification
Male	50	48 (96%)	2 (4%)
Female	50	49 (98%)	1 (2%)
Total	100	97 (97%)	3 (3%)

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The CART method becomes an interesting tool to analyze morphometric and morphological variables because this method has an accuracy of 90%, in this data set the classification tree demonstrated that the muscle marking and the chin shape were the variables that most responded to sexual dimorphism, since the interpretation must be made through the observation of the data that the tree shows. Because if the muscle marking is non-prominent, the chances of being female are greater and if the muscle marking is prominent, the shape of the chin, pointed or square, should be observed to know if it is female or male. It can be observed in these results that with non-prominent muscle marking, the result was 43 women and 5 men. When the muscle marking is prominent and the square chin shape the result was 40 men and 0 women, and pointed chin the result was 7 women and 5 men. (Figure 1).

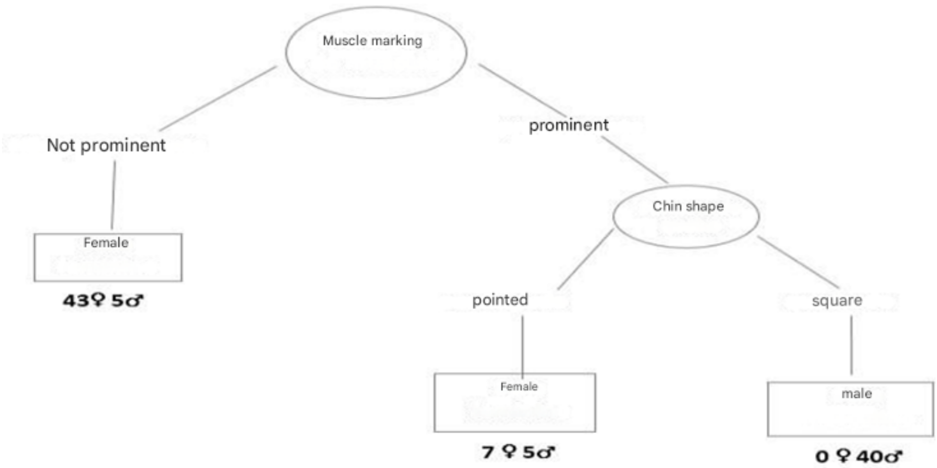

Figure 1: CART Algorithm Classification Tree

The linear discriminant analysis (ADL) method found the combination in relation to sexual dimorphism in the morphometric variables and their combinations. And it can be observed that the accuracy between these combinations had a satisfactory result for the identification of dimorphism between men and women with a minimum value of 62% accuracy and a maximum of 84% accuracy. (Table 6 and 7)

Table 6 - Linear discriminant analysis (ADL) method

VARIABLES	METHOD	METHOD
LMaxR	ADL	62%
APCOR+LBIGO+ACMAND	ADL	84%

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Table 7 - Table: Means and respective standard deviations of morphometric parameters in men and women.

LMaxR	Women	Men
Mean	3.95	4.16
SD	0.33	0.37
LMinR		
Mean	2.83	3.08
SD	0.30	0,31
AMaxR		
Mean	4.38	4.89
SD	0.46	0.46
ACond		
Mean	6.18	6.75
SD	0.52	0.59
APCor		
Mean	5.68	6.30
SD	0.47	0.53
ACMand		
Mean	2.82	3.15
SD	0.30	0.34
Asinf		
Mean	2.96	3.26
SD	0.30	0.42
LBico		
Mean	11.48	11.99
SD	0.56	0.68
LBigo		
Mean	9.19	9.80
SD	0.54	0.55

DISCUSSION

The skeletal structure becomes a very important part of sexual differentiation [22]. This study used several analyses on the mandible in order to evaluate its effectiveness in determining sex, since the mandible is the most resistant and durable bone of the skull [23]. The observations were divided into two standards in which we have the morphological standard and the morphometric standard, showing excellent agreement between the evaluators, demonstrating good accuracy in the measurements and indicating that this methodology can be reproducible [24]. In this research, all three morphological analyses studied (chin shape, muscle marking, and gonial reflex) revealed a marked sexual dimorphism(P>0.0001), These observations were also found in the study by Aspalilah et al (2018) [21]. Our research used the CART algorithm classification tree with 90% accuracy, and it was observed that muscle marking and chin shape were the most dimorphic variables. This tool becomes very important and directs to the variables that most responded to sexual dimorphism. In this method, the root divides creating two nodes at the next level of the tree, it prunes some of its branches at the end of the process and we have the result with almost 100% accuracy. Morphological analyses were considered more

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objective and reproducible, and have low inter-examiner error, however, they can be influenced by eating habits, lifestyle, and environment. Some authors also cite that the morphological characteristics as well as morphometric parameters of the human jaw are useful in determining sex [25]. Our study reveals that measurements in jaws show higher values in men. Gillet et al (2020) [26], using a multislice CT scan to study, found higher values for men than women. These researchers concluded that the mandible is not the most dimorphic structure among other cephalic structures, but a useful tool when only this structure is available and not the entire skull, Whereas, the jaw is the largest and hardest facial bone and holds its shape better than other bones in the skull. Another Brazilian study by Lopez et al (2018), reveals that mandibular measurements provide a simple and reliable method for sex discrimination in Brazilian adults due to the sexual dimorphism revealed by the analysis of morphometric variables and the satisfactory results demonstrated by discriminant formulas [27]. The nine morphometric patterns, studied by our research group, followed the diagram adapted from Saini et al (2011), which estimates sex through metric characteristics in the mandible [28]. These morphometric analyses were obtained through linear discriminant analysis and their combinations obtained accuracy between 62% and 84%, further confirming that it is possible to identify sexual dimorphism. The combinations between the variables performed by the ADL can also be used to identify the sex even in damaged jaws or part of them, as there are several parameters that can be observed, such as the combination of the variables APCor+LBigo+ACMand and can reach an accuracy of up to 84%. Researchers around the world have studied the metric characteristics of the mandible and its reliability in determining sex, with accuracy results ranging from 60 to 90% accuracy for sexual dimorphism [29].

Our study used the logistic regression model to estimate sex, grouped all variables with an accuracy of 97%, and can be used as an essential method in estimating sex, as it has almost 100% accuracy, especially when professionals in the area receive for analysis only parts of the human body or isolated bones, they need a very safe method to determine the sex of the individual. Through the results obtained in this study, it is suggested that the estimation of sex through the mandible contributes significantly, when added to other analyses in the identification of the human body for forensic purposes in diagnoses and recognition of the individual's sex in the forensic area. Therefore, it provides the coroner with a more accurate result in their reports. The small amount of research in the Brazilian population implies the limitation of determining standards in this area, as there are still few

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literatures that deal with the proposed theme [30]. Therefore, it is important that the proposed methodology be followed in other studies in order to analyze its efficacy in other populations in different parts of the world.

CONCLUSION

The present study demonstrated through the results obtained in a Brazilian sample that the mandibular morphology analyzed by CBCT and the methods to achieve results such as linear discriminant analysis, logistic regression and classification tree CART algorithm obtained extremely satisfactory results, with high accuracy rates, which can be used to determine sexual dimorphism in adults. The morphological patterns chin shape, muscle marking, and gonial reflex revealed a marked sexual dimorphism, with muscle marking and chin shape being the variables that most presented favorable results for sexual dimorphism. It can be observed that these morphometric and morphological analyses obtained very satisfactory results in isolation and, when associated, obtained an accuracy of almost 100%, revealing that these parameters are a very useful tool in forensic science for the analysis of sexual dimorphism in mandibles. The mandible proved to be an essential bone in sex determination, aiding in human identification, with great importance for the forensic area and for the scientific community.

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