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Archaeology and Dental Forensic: What's the relationship?

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## ABSTRACT

Archaeology is a science combining numerous skills in a multidisciplinary approach. In the presence of human remains, its objectives are the recovery, identification, and analysis on an anthropological purpose to reconstruct the context of the individual's past lives. One of these approaches is in the forensic medicine sciences whose main purpose is the identification of human bodies through bones and teeth in deteriorated corpses. Archaeology and forensic medicine are therefore two intertwined sciences.

The goal of this bibliographical review is to summarize the first steps to reconstruct the biological profile of a person using teeth as an object of study. Beginning by explaining the preservation and the type of the tooth sample, then by assessing the two most important biological factors being the sex and the age. This study does not cover all the existing tooth forensic aspects, but the most used one and the promising methods for archaeological context.

Keywords: Forensic Archaeology, Bio-archaeology, Tooth diagenesis, Tooth taphonomic, Tooth Archaeology/methods, Sex Determination by teeth, Age Determination by Teeth, Odontometrics.

## RESUMO

A arqueologia é uma ciência que combina uma abordagem multidisciplinar. Na presença de restos cadavéricos, os seus principais objetivos são a recuperação, identificação e análise com o propósito antropológico de reconstruir o contexto das vidas passadas do indivíduo. Uma dessas abordagens relaciona-se com a medicina forense, cujo objetivo principal é a identificação humana através da ossada e dos dentes em cadáveres deteriorados. A arqueologia e a medicina forense são, portanto, duas ciências interligadas.

O objetivo desta revisão bibliográfica é resumir os primeiros passos para a reconstrução do perfil biológico de uma pessoa, utilizando as peças dentárias como objeto de estudo, começando por explicar a preservação e o tipo da amostra dentária e avaliando dois fatores biológicos, tais como o sexo e a idade. Este estudo não abrange todos os aspetos forenses dentários existentes, mas os métodos mais utilizados e os métodos mais promissores para o contexto arqueológico.

Palavras-chave: Arqueologia Forense, Bio-arqueologia, Diagénese Dentária, Taphonómica Dentária, Arqueologia/Métodos Dentários, Determinação do sexo por dentes, Determinação da idade por dentes, Odontometria.

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**ABBREVIATION**

AMEL X – Amelogenin X-Linked, chromosome X

AMEL Y – Amelogenin Y-Linked, chromosome Y

BCE – Before Common Era

CE – Common Era, « a year in our time », begins with the year 1 in our calendar

CRA – Canine Radiological Age estimation

DNA – DesoxyriboNucleic Acid

FDI– Fédération Dentaire Internationale, World Dental Federation

NGS – Next Generation Sequencing

PCR – Polymerase Chain Reaction, permits the analysis of any short sequence of DNA

## **I. INTRODUCTION**

Since the 1970s, forensic medicine sciences have been enriched by a new branch of the discipline called Forensic Archaeology. Forensic archaeology uses and adapts traditional archaeological methods to locate, document and recover human remains and associated evidence. Forensic anthropologist recognized that the field methods used in archaeology could and should provide an invaluable contribution to the skeletal analysis of human remains and decomposing bodies, in law enforcement and death investigations.

The two disciplines, Forensic medicine, and Archaeology have different aims: the former implies the work in the medico-legal context, whereas the latter implies traditional archaeology works on an anthropological paradigm to reconstruct broad patterns of human behaviour. However, archaeology and forensic medicine share the same primary goal: the reconstruction of the past based on evidence found in an altered context (Schultz, 2015; Dirkmaat and Cabo, 2016).

One of the branches of archaeology used for forensic medicine investigations is called under the term of Bioarchaeology. First introduced in 1977 by the American anthropologist Jane Buikstra, Bioarchaeology is the study of human remains withdrawn from archaeological settings. Bioarchaeology is based on the study of the mortuary archaeological site combined with human biology, to interpret the human skeletal in social, cultural and behavioural contexts, and thus to understand past populations using new and innovative tools and perspectives. Bio-archaeology attaches importance to skeletal and dental tissues growth and development (Larsen, 2018).

Among the human remains, bones and teeth are the most valuables; especially the teeth which are often one of the only remains to endure through time and preserve a great wealth of information about the individual of whom they were once part of (Guatelli-Steinberg, 2011).

### **1.1 Materials and Methods**

For this bibliographical review, the electronic searches included articles from the databases of PubMed, Wiley Online Library, Science Direct, Nature Research, Research Gate.

Using the search terms: Forensic Archaeology, Bioarchaeology, Tooth diagenesis, Tooth taphonomy, Tooth Archaeology/methods, Sex Determination by teeth, Age Determination by Teeth, Odontometrics. References are from books, scientific articles, and journals. The inclusion criteria were related to the human species, hominids, relevant to human teeth study, or bones comparison with teeth, about adult teeth, articles available in English or French. The exclusion criteria were archaeology and forensic on animals. There is no restriction for the search for scientific papers by a publication period. Of the 112 articles initially selected, 47 references were used based on the relevance of their content to the topic and the inclusion criteria.

## **II. DEVELOPMENT**

### **2.1 Interest of the teeth**

#### **2.1.1 Properties, durability**

Pierre Fauchard, a surgeon dentist from the XVIII<sup>th</sup> century, specifies in the first-ever odontology treaty written, that the tooth is considered the hardest and most compact tissue of the human bodies. The hardness equals that of the rocks, resist to the sharpness of steel and cannot be burned or turned to ashes like the rest of our bodies bones (Fauchard P, 1746). For these criteria already assessed three hundred years ago, teeth are a widely studied fossil.

Teeth are the most mineralized hard tissue in the human body with its hardest structure, enamel, mineralized with 96% hydroxyapatite (almost pure) with negligible organic content; dentine with 70% and 20% organic (collagen) and bone-like cementum with a higher content of collagen. As a result, the enamel is inert to changes brought about by time, the environment and presents the best resistance to diagenesis (Guatelli-Steinberg, 2011; Porto et al., 2011).

Firstly, teeth conserve very well due to their anatomical position, isolated from the external environment within bone protection (jaw bone, cranial bones, hyoid, and cervical) and the firm attach in the maxillaries (Turner-Walker, 2008; Hollund et al., 2013).

The tooth is subject to taphonomical factors, which determine the composition and structure of the conserved elements from the production to the actual state: biological, chemical, and physical factors of the local environment (Fernandez-Lopez, 1995).

The mineral predominance of enamel makes them less susceptible to biological decay (contaminating agents): Soil bacteria can use (bone) collagen as a substrate which initiates the decomposition (Balzer, 1997), so, only the cementum and the dentine are prone to organic deterioration. However, in the tooth, the enamel is protecting the inner part, the cemento-dentinal junction act as a barrier to bacterial preservation due to an enamel-like hyper mineralized zone (Cherian, 2011). The low porosity of the teeth also enhances protection. Besides, the furthest an element is in the human body to the guts, the better it seems to preserve (Child, 1995). Bacteria in the gut are involved in eroding the skeleton. Finally, a study comparing human femurs to teeth from the Middle Ages to modern times on bodies buried in cemeteries showed that overall, in terms of histological integrity and collagen preservation, teeth are better than bones and keep better, which is also true for other biomolecules such as collagen and DesoxyriboNucleic Acid (DNA) (Hollund et al., 2013). The enclosure provided by the tough enamel offers improved DNA protection (Adler et al., 2011).

Teeth are resistant to non-biological decay (weathering, fire and mainly physical):

The environment is critical for the potential of preservation, depending on the fluctuation of water within the soil. The bones minerals are sensitive to dissolution in soil water. In environments with a restricted level of water like arid deserts, frozen and iced fields, isolated places (caves), the survival of mineral and organic content is insured. In deposits or sediments like clays, impeding the movement of water, the preservation is optimal. In drained soil, the mineral phase is very susceptible to degradation. Furthermore, in normal soil, the protein and mineral association found in the hard tissue mineralized collagen is stabilizing the chemicals and microbial degradation (Turner-Walker, 2008).

The intact upper fourth premolar of *Graecopithecus sp.* dated at 7,24 Million years old discovered in 2017 in Bulgaria, is the oldest tooth fossil ever discovered of a potential hominid related to us (Fuss et al., 2017).

Cremation funeral rites are frequent through history; when reacting to heat, the less organic composition of the enamel (1%) than the bones (20%), makes it less inclined to

permanent plastic deformation, Gejvall 1969 (cited in Schwartz, 2010). With heat, multi-directional cracking can occur due to the presence of water boiling in the dental tubule. Cracks occur from the internal structure (pulp) to the outer surface of the dentino-enamel junction and are stopped by the strength of this junction. Surface cracks that do not penetrate the internal structure are a likely sign of trauma over a lifetime (Byers, 2008).

The part of the tooth to be sampled for archaeometric analysis can be established after assessing the overall conservation and the major decay agents involved (Hollund et al., 2014).

### **2.1.2 The tooth, an individual marker**

Although the teeth are well insulated in the oral cavity by bones and muscles, they are the only part of the skeleton interacting directly with the external environment (White, 2011a), predominantly for the alimentation (solid, liquids). This continuous interaction causes an alteration of the tooth structure, associated with the age, which permits to study one individual. The alteration of the structure is mainly related to the enamel. Enamel is an almost inorganic mineral without cells in its mature form; it cannot grow back like bone tissue. It is, therefore, a marker in the life of an individual because it preserves the morphological characteristics and wears.

Teeth contain a record of their growth with progressive development and layered growth of enamel and dentine, like "tree rings" but over shorter periods. Cementum is also produced throughout life with an annual growth cycle deposit (Guatelli-Steinberg, 2011).

New insights are emerging with the possibility to extract specific and complete enamel proteins as proteins best survive at longer times. Using a whole crown etching method followed by a mass spectrometry analysis of molars from 800 Common Era(CE) to 1100 CE, amelogenin peptides were successfully identified (Porto et al., 2011). Lots of potential uses of the tooth proteome exist, it offers the ability to investigate health status and diet of ancient populations but also to sex the individuals. The tooth proteome contains amelogenin peptides specific to the sexual chromosomes: Amelogenin X-Linked (AMELX) and Amelogenin Y-Linked (AMELY). It is now possible to characterize peptides showing sex-specificity and phenotype information. At least 1500 proteins have been identified using a sample of eleven 5000 years old tooth from the Neolithic period (Froment et al., 2020).

Teeth are used for genetic recovery, using DNA from the whole tooth or the roots. A recent technique, the Next Generation Sequencing (NGS) permits to obtain in one study, hundreds of thousands of ancient DNA's short sequences, it is now considered more reliable than previous methods such as the Polymerase Chain Reaction (PCR). Older DNA analysis is used to identify sex when current identification methods are not possible, as well as the origin, family relationships and population movements (Forshaw, 2019). When comparing the recovery of ancient DNA in dentine and cementum from German Neolithic samples, the cementum offered a higher concentration of DNA and so is a better source of ancient DNA in the tooth (Adler et al., 2011). Moreover, teeth are proven to be more refractory to exogenous DNA contamination caused by direct handling and washing by the archaeologist on excavated skeletal remains, enhancing their choice as a material for ancient DNA studies (Pilli et al., 2013).

Everything in the tooth can be studied; every dentition is unique. The over-represented status of teeth as organs (2 successive sets of teeth), combined with their integrity over time better than that of bones, their growth pattern and their function throughout an individual life, make teeth a valuable object of study for an anthropologist, a palaeontologist, an archaeologist and a forensic scientist (Marado and Silva, 2017).

## **2.2 Identification process in archaeology**

### **2.2.1 Dental formula**

The first step to follow when dental fossils are discovered is to assess the completeness of the remains and record them correctly. In archaeological studies, teeth are often found individually outside the maxillaries, so their identification is of paramount importance. The identification of individual teeth is dependent on various morphological details/ traits of the crowns and roots (Lease, 2016).

The osteologist Timothy D. White (2011a) states five identification criteria usable in unworn or worn teeth. Since the variation between categories of teeth has "homogenized" in humans throughout evolution, the criteria can be used to identify human teeth as well as those of human parents, but also to differentiate between other species. Every osteologist must have a partial or complete comparative dentition.

1- The category of the tooth: distinguishing anterior tooth, Incisors and Canines from the posterior ones, Premolars and Molars; Using the known morphological anatomy and function of each tooth. Identification using the anatomy of the crown: Incisors are flat and blade-like, the canines are conical, the premolars are round with a lower height than the canines and smaller than the molars, the molars are larger and more square with more cusps than the other tooth.

2- The dentition: identifying tooth from permanent and deciduous dentition. Deciduous tooth got a more bulbous crown, thinner enamel; roots are finer, shorter, and often resorbed.

3- The upper or lower position:

- For anterior teeth, the mesiodistal length and the crown height must be registered; if the crown height is twice the length, the tooth must be lower.

- For molars, measure the mesiodistal axis and locate the largest cusp of the molar on the mesial side. If this cusp faces the buccal (cheek) side, the molar will be lower and the cusp named protoconid; if it is on the lingual side, the molar will be higher, and the cusp named protocone. Concerning the mesiodistal axis; on the upper molars, the cusps are placed asymmetrically. Finally, the upper molars have more roots, usually three.

4- The relative position in the arcade and among teeth of the same category

5- The side, right or left; The observation of the tooth is made in labial view by orientating the tooth as it would be in the dentition, with the occlusal surface placed horizontally. The root axis angles posterolateral and distally relative to the vertical axis of the crown for all teeth. For molars, the distinction must be made concerning the protocone/conid and the hypocone, the smallest cusp. The hypocone is on the lingual and distal side for upper molars. The occlusal wear pattern can also be used: for inferior Incisive, the occlusal wear is often distal and inferior relative to the vertical axis of the crown.

The most widely used labelling system for dental inventory in publications is the use of numbers and letters. This system adapted to the study of primates is widely used by osteologists and palaeontologists. Tooth quadrants are identified by a «U» for upper, maxilla; «L» for lower, mandibular. Right and left are noted as «R» and «L»; an example would be UR3 for the permanent upper right canine; the abbreviation «dec» is added before for

deciduous teeth. Initials are used for the tooth with I for Incisive (I<sub>1</sub>, I<sub>2</sub>); C, canines; P, premolars (P<sub>1</sub>, P<sub>2</sub> or P<sub>3</sub>, P<sub>4</sub>); the notation P<sub>3/4</sub> indicates that these are homologous to the third and fourth premolars of ancestral primates, the first and second lost phylogenetically; M, molars (M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub>). The arcade is noted with the position of the teeth as a superscript for maxillary (M<sup>3</sup>), or a subscript for mandibular (M<sub>3</sub>) (Gentry Steele and Bramblett, 1988; White, 2011a; Antoine, 2017).

Odontometrics (measurements) established for the identification of teeth are used for forensic and anthropological investigations into the sex, age, origin, and classification of a living being (taxonomy). The measurements are the diameter (or length) of the mesiodistal crown, the diameter (width) of the buccolingual crown, the height of the crown and the length of the root. Each of these should be registered using a thin, pointed caliper. The non-metric element is also recorded (White, 2011a).

Metrics and Non-metric traits allow establishing phylogenetic affiliation. Each hominid species got its proper identifiable features. An example lies between *Homo sapiens* (modern humans) and *Neanderthal* species which shared a common ancestor. The teeth traits permitted to assess that an adult left hemi-maxilla with a complete dentition discovered in Israel's Misliya cave, aligns more to that of *Homo Sapiens* species; The Incisive and Canines, as opposed to *Neanderthal*, have no lingual tubercle. The premolars of *Neanderthal* are featuring a lower and broader crown with a compressed occlusal area. The metric analysis of the buccolingual size ratio of I<sub>2</sub> to M<sub>1</sub> and of the tooth root size is near the range of modern humans. The identification and the dating permitted to assess the possibility that *Homo Sapiens* dispersed out of Africa around 177 000 to 194 000 years ago, before what was previously established at 220 000 years ago (Hershkovitz et al., 2018).

### **2.2.2 Sex determination**

The need for sex assessment is fundamental when assessing a biological profile in an archaeological and forensic context. It is necessary to reconstruct past societies for demography, identity and epidemiological settings (Stewart et al., 2017).

#### **2.2.2.1 Sexual dimorphism between male and female**

Sexual dimorphism is normally assessed by the study of morphology and metrics of the cranial skeleton, the skull, mandible, the postcranial skeleton and mostly traits on the pelvis. In archaeology, if the skeleton is often missing or fragmented, teeth are always present due to their durable states. The most used methods for sexing the teeth are using the morphological features of the crown or the root. The accuracy of sexing the unknown using tooth metrics is between 60 to 90 per cent (White, 2011b).

When sexing the teeth, the most common dimensions are the Mesio-Distal and Bucco-lingual crown diameters. The same cervical dimensions of the crown are also recorded. The Mesio/Buccal-Disto/Lingual and Mesio/Lingual-Disto/Buccal diameters of the molar tooth are completing the last ones. Research led by Viciano et al, published in 2011 studies the sex assessment for a sample of dentition from 117 individuals of whom 87 adults, who died during the Vesuvius eruption in Herculaneum 79 CE. It reveals that out of 76 measurements taken from everyone, 65 have a significantly higher value in males than females. With statistical analysis, an increase in tooth dimension is associated with the male group pattern, a decrease with the female pattern. The canines are the most sexually dimorphic tooth followed by the central maxillary incisor.

Another study of 149 individuals from Italy's Samnites population (III to V centuries Before Common Era (BCE)) using the same measurements also shows that tooth dimensions are more pronounced in men than in women for the maxilla and mandible. The mandibular canines also have a more significant sexual dimorphism followed by both the first and second molar. On this sample, the sex determination is very accurate and complete other methods used before for 143 out of 149 individuals at 95,97% success (Viciano et al., 2015).

#### **2.2.2.2 Recent methods**

One of the promising methods to determine sex apart from the DNA is the use of tooth peptide enamel. Ancient DNA analysis is very accurate with direct results, but this procedure is inconclusive when dealing with large scale archaeological study. The sample's DNA preservation and contamination states provide viable results only in small scale studies.

Peptide enamel permits to determine sex for adults and juvenile in a minimally destructive, cost-effective, and reliable way. The method consists in characterizing amelogenin peptides encoded for X and Y chromosomes, comprising a slight difference in amino-acid sequences. An acid etching of the tooth enamel is performed, followed by mass

spectrometry. A study led on teeth from human remains of the 19th century and from Neolithic to Medieval times archaeological sites, managed to differentiate two dimorphic peptides AMELX-(44-52) and AMELY-(58-64) in the samples. AMELX and Y are present in male; two AMELX in the female. The identification was compared to standard osteological methods and known sex; all cases of the study matched correctly and successfully with the results. This method is suitable for sites with poor preservation, in the absence of core skeletal identifiers. The possibility to use it for other species is especially interesting as the peptide sequences proved to be identical to apes and so should be present in hominids (Stewart et al., 2017).

### 2.2.3 Age determination

Archaeology investigates different ages. The significant one in forensic is the estimation of the individual's age at death, not the chronology that has passed since death. Estimating the age at death is one of the most crucial aspects of bio-archaeological and forensic investigations; it contributes to understanding the demographic composition and structure of the sample (Luna, 2006).

The process can be destructive, with sections of half-tooth, it can also be non-destructive, keeping the tooth intact. Methods with minimal damaging interference are preferred for protection, care of the archaeological vestige as well as for ethical purposes. Dental age can be estimated using numerous methods such as using development traits or degenerative changes of the tooth (Meinl, 2007).

**Related to Development traits**, incremental structures in the crown:

- **Related to the pulp-dentine complex**; These methods rely on the growth of secondary dentine with the crown and the root completed. Secondary dentine is continuously created by the odontoblasts in concentric layers around the pulp chamber and is not remodelled throughout life. There is a significant correlation between the surface area of the pulp chambers and a reduction in size with age in adults. A tooth and pulp ratio is estimated by dividing the pulp area by the tooth area. It is performed on tooth sections, but a preservative way exists using a digital X-ray image of the tooth. The Canine Radiological Age

estimation (CRA), requires the use of a linear regression equation, linking the age and the pulp/tooth area ratio (RA<sub>upper</sub>/ lower).

The following formula is used for upper canines:  $\text{Age} = 101,3 - 556,68 \times \text{RAu}$  (Cameriere et al., 2009). Other similar equations exist for lower canines and premolars tooth. When estimating the age of Neolithic adult individuals from canine samples unearthed in Apulia, Italy; the CRA proved to be a precise and accurate way to estimate age at death. (Fabbri et al., 2015). Using these methods on tooth sections, age was determined with 92,8% accuracy ( $\pm 4$  to 5 years) on archaeological tooth samples from Belleville, Canada. This method is easily replicable (D'Ortenzio et al., 2017). Comparisons with skeletal determined age and modern samples with known age were done for both studies.

- **Related to changes in cementum:** As the acellular cementum can't repair or regenerate, it is considered stable and has a periodical growth. This growth pattern displays in the microstructure as annual layers, the cementum annulation. A dark layer implies a slowing down of growth in winter or autumn; a light-colored layer represents a period of growth in summer or spring. This pattern is usually identifiable via destructive cross-sections or longitudinal sections of the tooth with microscopic analysis, where counting the number of layers provides the age at death. For archaeological purposes, non-destructive imaging methods (virtual histology) are studied. Using a synchrotron X-ray tomography to visualize the interior structure in three dimensions, it is possible to scroll through the depth at different sections thickness and optimize the visibility of annulation for counting. With a sample of 20 adult archaeological canines from the 18<sup>th</sup> to 19<sup>th</sup> century with known age, a strong relationship was found between real and estimated age at death, making it a promising technique (Le Cabec et al., 2019).

**Related to degenerative changes:**

- **related to occlusal tooth wear:** Dental wear represents the cumulative loss of enamel and dentine occurring by frictions processes of the tooth surface. Friction happens by proximal, occlusal, and inter-dental attrition; abrasion, for rubbing with particles; and by erosion, the chemical dissolution. All are simultaneous and natural throughout life, increasing the rate of tooth wear with age. Wear can be seen directly on the occlusal surface, so, it is an easy pattern to observe and score.

The easier method to register tooth wear consists of four states: no wear; wear pattern only in the enamel; dentine exposed, and exposure of the pulp cavity. More detailed grading is necessary for age determination. Brothwell's Tooth Chart (Brothwell, 1981), estimates wear stages and age groups by tooth type. The main chart covers the first to the third molar (M1, M2, M3) in four age groups: 17-25 years, 25-35; 35-45 and over 45 years old. The first molar suffers the most wear, the third the least, and the second molar between them. Tooth wear can be studied the same way in Neanderthal tooth and 16th centuries tooth, so, it is a suitable tool for archaeological work (Brothwell, 1981).

Age is assessed within a range of upper and lower limits in a statistical confidence interval.

A study involving 298 teeth from a Brazilian prehistoric archaeological series, showed results of less than 8,22 years of age difference using the wear chart when compared to skeletal age estimations. It is a consistent tool with satisfactory results for reproducibility, but it implies some subjectivity. Moreover, it is not time-consuming like other methods using the tooth (Oliveira et al., 2006). The study of tooth wear also tells us about the lifestyle, the diet, dental and general health of population groups (Richter and Eliasson, 2017).

- **Related to tooth colour:** Histological change of the tooth's structure occurs in the form of dentine translucency. With age, the primary dentine tubules in the root are gradually occluded by hydroxyapatite crystals, allowing light to pass through the dentine. Non-occluded tubules render the dentine opaque. This translucency is seen macroscopically on the external root surface, backlit against a light source. This three-dimensional pattern grows with age from the root apex toward the crown and from the periphery to the pulp. The 1970 Bang & Ramm method uses root translucency length correlated with age on a regression equation for uniradicular teeth. On archaeological tooth samples from the 18<sup>th</sup> century in a crypt and a cemetery in London, the Bang & Ramm method has an accuracy comparable to result obtained from modern samples and other tooth age estimation methods, but only for tooth least affected by diagenesis (Tang et al., 2014). With computerized densitometric (optical density) analysis of 100 years, old tooth samples; root dentine translucency proved to be an age-dependent variable with reasonable accuracy for age estimation (> 45% for errors of  $\pm 5$  ears) (Drusini et al., 1991). Other methods such as colour gradient and chart according to the

age exist but are not relevant for archaeological work due to the environment of conservation (Luna, 2006).

### **Combined methods**

Combined methods estimate age at death by regrouping and linking multiple tooth patterns, providing more accurate results.

The common method is the Gustafson technique of 1950, which includes 6 dental features: secondary dentine apposition around the pulp chamber, apical cementum apposition, occlusal attrition, the extent of root translucency and two more patterns; the apical resorption and periodontosis, the position of the epithelial attachment. Each of these factors assigns points, and then a regression line linking these characteristics to age is created. This method can be applied well for the forensic purpose and archaeological studies; however, it must allow the destruction of the tooth material by vertical or longitudinal sections of the sample. Moreover, it is complex to realize, and the formula was conceived using a reference sample, limiting the accuracy of other studies (Whittaker, 1992; Baccino and Schmidt, 2006).

The Lamendin method developed in the 1980s is today used more efficiently for age at death assessment. It uses only two criteria: root translucency, the most important factor in Gustafson's technique, and periodontosis, the only independent criterion of root translucency. It also includes the root length to minimize the influence of tooth size on age estimation (Baccino and Schmidt, 2006).

Lamendin proposed the following formula for intact mono-radicular tooth without any preparation or destruction of the tooth:  $\text{Age} = (0,18 \times \text{Periodontosis} \times 100/\text{root length}) + (0,42 \times \text{Translucency} \times 100/\text{root length}) + 25,53$  (Lamendin et al., 1992).

A test study using the Lamendin method was carried out on samples of historical teeth from the 18th and 19th centuries buried in Great Britain. The age of the individuals was already known. Root length, root translucency and periodontal regression were measured directly on the teeth using a dental caliper and a light source. Periodontosis is a yellowish area which represents the degeneration of the soft tissues around the tooth, beginning with a darker line on the tooth surface below the crown. The technique proved to be precise for individuals of 25 to 49 years old with a lowest mean error of 7,7 years but with a higher mean error for individuals over 49 years old, affected mainly by the antiquity of the samples and the postmortem environment (Megyesi et al., 2006). The possibility to apply the Lamendin

method without any preparation, directly on the tooth sample, makes it suitable for anthropological studies.

### **III. DISCUSSION**

Through all the articles and books reviewed, the good durability of the tooth even better than the bones in the context of archaeological studies is an acknowledged fact. Their potential use in forensic investigations, the multiple information they contain, and the methods used to be able to retrieve that information are also well documented and described. New investigations methods are being developed on the tooth for forensic purpose.

The main disadvantage of the study of archaeological teeth is the possible impact of the diagenesis process with taphonomical changes on the tooth which can lead to misinterpretation and confusion. Everything is limited by what is conserved and the techniques used (Le Cabec et al., 2019).

Few articles and scientific work focus on the diagenesis of the teeth and the reasons of this preservation; the scientists behind those researches have the same opinion that greater efforts are needed to understand diagenesis in dental tissues, little reliable information is available on the decomposition process of these mineralized tissues (Higgins, 2013; Hollund, 2013). The relationship between microbial destruction of mineralized tissues and survival of bio-molecular evidence is unresolved.

About the DNA, its preservation process in hard tissues is not clear, and the location of preserved DNA in bones and teeth relative to the decontamination and extraction process must also be looked at (Turner-Walker, 2008; Hollund, 2013). There are currently no standardized forensic protocols regarding the handling, sampling and DNA extraction of teeth recognizing the unique features of teeth (Higgins, 2013).

Although the possibility to search the tooth proteome is promising, lots of procedures are necessary to prepare and control the samples to impede contamination from the environment; also, ancient peptides can suffer from cleavages due to the protein degradation by diagenesis and of damaging modifications. These modifications can be hard to detect, but new strategies are currently being implemented like iterative (repetitious) search methods (Froment et al., 2020).

The number and letter labelling system is used widely in all the osteological publications. It cannot be used for databases as it is not suitable for computers. To alleviate this problem, the use of the common World Dental Federation (FDI) system is preferred, as it allows each tooth to be represented with a unique number to then proceed to prevalence analysis (Antoine, 2017).

Before making the determination of sex, age, ancestry; it is primordial to be able to compare unknown variables with standard ones obtained from known series which shares the same biological attributes. Researchers should also be aware of the limitation of these series such as different lifestyles or physical conditions that can affect the rate of tooth wear (White, 2011b).

When estimating age at death, measurements taken directly on the tooth in sections or half teeth are simpler to perform and provide more accurate data. Radiographic images provide less accurate results, the image sharpness and resolution cause errors even when using computerize help; incorrect positioning when taking the radiography cause rendering errors. There is a tendency to underestimate the age of people over 50, while younger individuals are over-estimated. Underestimation is to be noted when using root dentine translucency and cementum annulation as individual criteria; however, the relationship between decreases in pulp chamber size and increase in age is accurate for older individuals (D'Ortenzio et al., 2017). This frequent situation leads to the underestimation of the elderly for demographic studies. (Tang et al., 2014).

The method chosen depends on multiple criteria such as the overall tooth preservation condition, the uniqueness of the sample and mainly of what is available to the researchers.

Sex estimation from dental measurements is quick and easy to use in the fields of archaeology and forensic medicine. The most used dimensions are from the crown. The teeth presenting the most divergence between male and female are the mandibular and maxilla canine. However, the analysis is population-specific. If the methods are applied to a population other than that for which they were designed, the result can be low or biased. The solution is to develop a methodology for sex determination, then to apply a population-specific equation to the unknown sample. Dental data from individuals with sex already established by pelvic or skull features must be used (Viciano et al., 2015).

Also, attention should be given to existing limiting factors that complicate the measures. They can be physiological factors: tooth wear, caries, calculus deposit, hypo-plastic defects; individual factors: dental anomalies, shape of volume, position of teeth; external factors: taphonomic and diagenetic effects as well as sample handling and storage. The most common limiting factor is tooth wear. These factors may slightly increase or decrease the values (Viciano et al., 2011). The values should be taken with caution. For accuracy, a digital dental caliper is required (0,01mm).

In the American Journal of Physical Anthropology, from only two articles published on dental anthropology in the 1920s only about living human, this number has risen to 200 in the 2010's about living human, living primates, hominids/fossils, but also on forensic and methodology. It was not until the late 1980s that this theme acquired a significant presence in publications. Dental anthropology has developed and evolved in the last decade; The next 100 years of research should teach us more about the metrics, morphology and variability of primate tooth development (Guatelli-Steinberg, 2018).

#### **IV. CONCLUSION**

Teeth are immutable, durable, and quite imperishable; they constitute an incredible forensic tool. With the many existing methods and those to come, teeth are practically an inexhaustible source of information not only on sex, age, taxonomy but also on geographical origin, migration, dental health, diet, profession. The development of the practice of forensic dentistry for archaeology brings new possibilities to today's forensic sciences, especially when dealing with cases of mass disasters or war graves.

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