

# SEXUAL DIMORPHISM OF THE LATERAL ANGLE OF THE INTERNAL AUDITORY CANAL AND ITS POTENTIAL FOR SEX ESTIMATION OF BURNED HUMAN SKELETAL REMAINS

## Abstract

The potential of the petrous bone for sex estimation has been recurrently investigated in the past because it is very resilient and therefore tends to preserve rather well. The sexual dimorphism of the lateral angle of the internal auditory canal was investigated in two samples of cremated Portuguese individuals in order to assess its usefulness for sex estimation in burned remains. These comprised the cremated petrous bones from fleshed cadavers (N = 54) and from dry and disarticulated bones (N = 36). Although differences between males and females were more patent in the sample of skeletons, none presented a very significant sexual dimorphism thus precluding any attempt of sex estimation. This may have been the result of difficult application of the method and of differential impact of heat-induced warping which is known to be less frequent in cremains from dry skeletons. Results suggest that the lateral angle method cannot be applied to burned human skeletal remains.

Keywords: forensic anthropology; biological anthropology; burned bones; internal auditory canal; heat-induced changes; biological profile

## Introduction

Similar to what happens with the estimation of other parameters of the biological profile, sex estimation of burned human skeletal remains is often complicated by the effect of heat-induced changes[1]. Several authors have proposed the petrous pyramid of the temporal bone for the development of sexing methods since it tends to preserve well in contexts involving burned remains [2-6]. Evidence of that is the fact that 82% of 320 calcined temporal bones from individuals cremated in Italy and examined by Masotti et al.[6] were sufficiently preserved to allow for the estimation of sex. However, all efforts regarding sex estimation based on burned petrous bones have been relatively fruitless until now. Schutkowski [2] obtained an accuracy rate of 77% resorting to discriminant function analysis based on several measurements of the petrous bone but this result cannot be considered to be completely satisfactory, especially if the analysis has forensic implications. Using the lateral angle of the internal auditory canal, Masotti et al. [6], obtained even more disappointing results. Sexual dimorphism was significant enough only to correctly assess the sex of 58% of their sample. The present paper gives the results of a similar endeavour which aim was to evaluate the potential of the lateral angle method for sex estimation of unknown burned skeletal remains.

## Material and Methods

The research focused on two different samples composed of individuals of Portuguese ancestry cremated at a civil cemetery. The cremations were therefore carried out at a

commercial crematorium and were not done under controlled and standardized conditions. One of the samples was composed of petrous bones from individuals cremated soon after death which were therefore still fleshed – henceforth designated as cadavers. The second sample was composed of cremated petrous bones from completely skeletonized individuals – henceforth designated as skeletons. These skeletons were from individuals previously inhumed at the cemetery. According to the Portuguese law, three years after the inhumation and as long as the remains are completely skeletonized, they must be exhumed to free the burial ground for other inhumations. They may be transported to permanent graves owned by the family of the deceased or, in some cases, such as the ones focused in this investigation, skeletons may be cremated. Sometimes, remains present in permanent graves vaults are also subject to cremation, for example to free some space.

The cemetery has records of every individual comprising our samples. The cadavers were identified in terms of age and sex and were from individuals who died between 2008 and 2011. The skeletons were from adult individuals who died between 1936 – at least, since the date of death was unknown in some older cases – and 2003 and were identified in terms of sex while age was only known for some of them. The cause of death and the clinical history of the individuals were not known. Two samples were used in order to check if any difference could be found between them, since bone warping is a much more frequent occurrence in fleshed remains [7]. The sample of cadavers comprised 26 females (mean age = 68.4; sd = 15.5; max.: 93; min.: 35) and 28 males (mean age = 74.9; sd = 16.2; max.: 97; min.: 41). The sample of skeletons comprised 21 males and 15 females. In this case, only 12 males (mean age = 66.3; sd = 17.7; max.: 92; min.: 23) and 9 females (mean age = 75.7; sd = 19.4; max.: 99; min.: 30) were of known age. Skeletons of unknown age were included in the sample nonetheless, since age has not been identified as a significant factor for the variability of the lateral angle in previous studies [6, 8]. Cadavers and skeletons were subject to a mean temperature of combustion of 948.6° C and 764.7° C, respectively. The duration of the cremation was very variable but was never lower than 60 minutes in the case of cadavers and 15 minutes in the case of skeletons. In both samples, some of the remains were left overnight in the cremator and only recollected in the following morning. This is a common procedure at the crematorium that aims to save energy and take advantage of the heat accumulated in the cremator to do the last cremation of the day. This procedure was much more frequent in the case of cadavers – 21 cases against 3 in the sample of skeletons. Excluding these cases, the mean duration of cremation was 103.5 minutes (n = 33) and 30.9 minutes (n = 33) for cadavers and skeletons, respectively.

Because it cannot be measured directly on the bone, the lateral angle was measured on casts of the internal auditory canal (IAC). For that purpose, the procedure of Norén et al.<sup>5</sup> was followed, by using Coltène President© - a silicone light bodied dental casting material – which was applied to the IAC after the surface was cleaned and coated with vaseline. This was done in order to facilitate the removal of the cast after drying. The cast was bisected longitudinally with a cutter knife (Figure 1) and the lateral angle was then measured on photos of one of the halves, resorting to the measuring tools of Adobe Photoshop CS2©. The shots were taken on an orthogonal plane. The lateral angle is formed by the intersection of the posterior external surface of the petrous bone and the adjacent surface of the IAC [5, 8-10]. The median value of three attempts of measurement was used for the analysis.

The inter- and intra-observer error was assessed on a sample of 17 individuals by calculating both the absolute and relative technical error of measurement [11] which give the accuracy indices of a measurement. Bilateral asymmetry was investigated to see if the results of either antimeres could be extrapolated to the other. This was carried out by using a Wilcoxon signed ranks test. Mean differences between the lateral angle of males and females were evaluated on the sample of cadavers by using a t-test for unpaired samples and a Mann-Whitney test on the sample of skeletons. All statistics were calculated using the Statistical Package for the Social Sciences (SPSS), version 14.0.

## Results

The intra-observer absolute and relative technical errors of measurement were 3.47° and 2.3%, respectively, while the coefficient of reliability was 0.9. On the other hand, the inter-observer absolute and relative technical error of measurement was 12.7° and 3.9%, respectively, while the coefficient of reliability was 0.5. Although the results attested for good repeatability of the method, its replicability was not as good.

No significant difference ( $U = -0.722$ ;  $p = 0.470$ ) was found between the left and right internal auditory canals so the latter were used for this investigation because the right sample was larger. Left bones were used when right bones were not available due to poor preservation or to incomplete retrieval from the cremator. In the sample of cadavers, no significant difference ( $t = -0.176$ ;  $df = 52$ ;  $p = 0.860$ ) was found between the female mean lateral angle ( $n = 26$ ; mean = 49.6;  $sd = 13.1$ ) and the male mean lateral angle ( $n = 28$ ; mean = 50.3;  $sd = 17.0$ ). In the skeletons sample, an almost significant difference ( $U = 97.0$ ;  $p = .052$ ) at the 0.05 level was found between the female mean score ( $n = 15$ ; median = 56.5; range = 44.4) and the male mean score ( $n = 21$ ; median = 48.6; range = 44.9). Although both results were somewhat different, the sex-pooled lateral angle means of the cadavers (50.0°) and the skeletons (49.8°) were quite similar.

## Discussion

Regrettably, this research did not find any sexual dimorphism in the IAC. Although similar outcome has been attained previously in unburned bones [12], this comes in contrast with the results from other investigations [5, 8, 10, 13], especially with the one from Masotti et al. [6] which also focused on burned remains. This may have been because of our difficulty in applying the method – evidenced by a large inter-observer error – and to the possible impact of heat-induced shrinkage and warping on the natural sexual dimorphism of the internal auditory canal, as suggested by Masotti et al. [6].

The fact that, when compared to skeletons, cadavers presented less sexual differences may be indicative of the dramatic effect of heat-induced changes, since the former do not seem to be as affected by warping [7]. Nonetheless, if heat-induced changes are indeed responsible for this, they did not differentially affect antimeres, at least significantly, in our study. Of course, this occurred only at the sample level and not at the individual level. In some cases, differences

between antimeres were larger than 25°. This demonstrates that in burned remains, even if sex estimation based on the lateral angle is possible, it may sometimes depend on the side chosen for measurement possibly due to the differential effect of heat-induced changes, at least at the individual level. The use of the mean of the two IAC – as carried out by Masotti et al. [6] may eventually solve part of this problem, but this approach was not followed in this research because only a fraction of the samples presented good preservation of both petrous bones. Similar limitation may often impair the use of that approach in forensic burned skeletal remains.

One striking difference found between these and the results obtained by Masotti et al. [6] refers to the sex-pooled mean lateral angle. While the latter reported 37°, the one from the present investigation was closer to 50.0°. Most probably, this difference can also be the result of problems related with the inter-observer application of the method and with the effect of heat-induced changes. Inter-population differences can hardly explain such contrasting results. In addition, although Masotti et al. [6] found significant sexual dimorphism in their sample, it was not sufficient to allow for reliable sex estimation of unknown burned remains. This apparently confirms that the internal auditory canal is of little use for the sex estimation of calcined remains, although other methods must yet be tested on this kind of remains [14, 15]. This is disappointing because great expectations have been laid on the petrous bone for sex estimation of burned skeletal remains.

## Conclusion

Regrettably, no easily replicable and reliable sex estimation method based on the petrous bone has been developed until now, regardless of whether the remains are burned or not. One exception may be the one based on the osteometry of the bony labyrinth which allowed for correct classifications up to 84% [15]. However, similar to what has been seen for other features, the sexual dimorphism of this structure may be affected by heat-induced changes as well. This question remains unanswered for now. More research is needed prior to completely discard the lateral angle method for sex estimation in burned remains though. In particular, a more comprehensive understanding of heat-induced warping must be attained. The only way of investigating its true impact on the lateral angle seems to be the comparison between pre- and post-burning human petrous bones. Then, a clearer view of its potential for sex estimation will be obtained.

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Figure caption

**Figure 1 Lateral angle measurement recorded on a silicone cast of the internal auditory canal**