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TECHNICAL NOTE

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The Determination of Male Adult Age at Death by Central and Posterior Coxal Analysis—A Preliminary Study*

ABSTRACT: In forensic anthropological analysis, the pelvis is of particular interest as it is often a comparatively well-preserved part of the skeleton. This study in age determination uses the acetabulum, the central element of the pelvis, as a complement to the examination of the auricular surface. The test sample consisted of 30 individuals. First, the authors studied the auricular surface using the Lovejoy criteria. Second, they isolated four criteria based on chronological changes in the acetabulum. Third, they conducted an evaluation of each of these variables. The study examines the correlation between these criteria and the age of the individuals. A significant correlation was found between the acetabular criteria and age, and between the acetabular criteria and the Lovejoy criteria of the auricular surface. For forensic purposes, the acetabulum is an effective predictor in the determination of age. This newly proposed method explores the same criteria of ageing as the Lovejoy method. The combination of the two methods produces relatively consistent results in the estimation of age.

KEYWORDS: forensic science, forensic anthropology, age estimation, human identification, pelvis

The pelvis is anthropologically useful because it is one of the best surviving elements of the skeleton (1). In 1985, Lovejoy developed an anthropological technique for estimating age based on the morphological changes in the auricular surface of the pelvis (2). The general nature of the surface changes with age. He noted changes in grain, density, macroporosity appearance, billowing and striations, arthritic changes of the apex, retroauricular activity and the disappearance of transverse organization. He defined five basic phases ranging from 20 to 60+ years of age. The Lovejoy method is useful for two reasons: the good state of preservation of the posterior portion of the pelvis and its potential application to individuals over 50 years of age (3). However, this technique has not been validated and is subject to observational error and interpretation (4,5). The acetabulum, the central element of the pelvis, is routinely studied in techniques for the determination of sex (6). The acetabulum, like the auricular surface, is fairly resistant to degradation forces. The acetabulum is a joint which, like the pubic symphysis or the sacro-iliac articulation, is subject to degeneration with increasing age. The primary objective of this study is to develop ageing indicators based on morphological changes observed on the acetabulum, using criteria similar to Lovejoy's.

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Materials and Method

The study sample consisted of 30 male coxal bones. Twenty-one were from Spanish subjects buried in Granolers cemetery in the last half of the 20th century. Nine were from Caucasian individuals who had been the subject of forensic autopsies carried out in Toulouse. The age of all the subjects was known, ranging from 24 to 81 years.

Examination of the study sample was conducted by a single examiner. This examiner was not aware of the age of the bodies when he made the assessment (he didn't know the sample). In the first part of the study, the auricular surface was examined using the Lovejoy criteria. In the second part of our study, we examined the acetabulum. Based upon Lovejoy's work, we examined the sample several times and isolated four sets of observable criteria:

A. Appearance of the rim of the acetabulum: The rim of the acetabulum varies between individuals. It is a diagnostic feature. It can appear blunt-edged, or rather sharp (as a consequence of arthritic lipping). Sometimes it is the site of osteophytes that can become substantial. In some cases, the osteoarthritis degeneration is very important and the rim of the acetabulum is destroyed. The appearance of the rim of the acetabulum was classified in five stages: Stage 1: blunt-edged (Fig. 1), Stage 2: blunt-edged with some localized osteophytes (Fig. 1), Stage 3: rather sharp appearance with extensive osteophytes (Fig. 1), Stage 4: localized destruction (Fig. 2), and Stage 5: generalized destruction around the entire rim, or substantial osteophytes (i.e., bone loss) (Fig. 2).
B. Appearance of the acetabular fossa: The back of the acetabular cavity sometimes appears to be very dense. We observed perforations of the subchondral bone of the auricular

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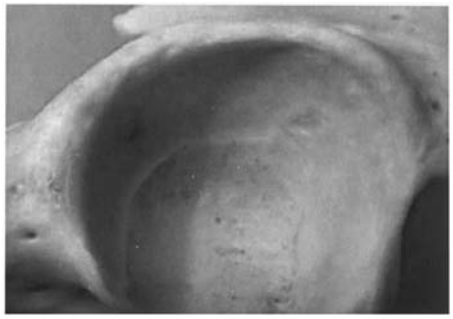
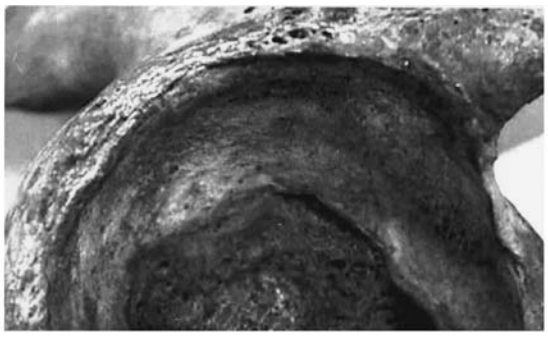


Rim acetabulum - stage 1

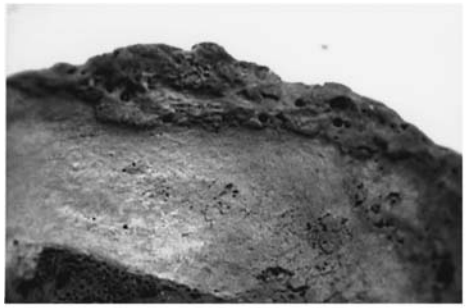
Rim acetabulum - stage 2

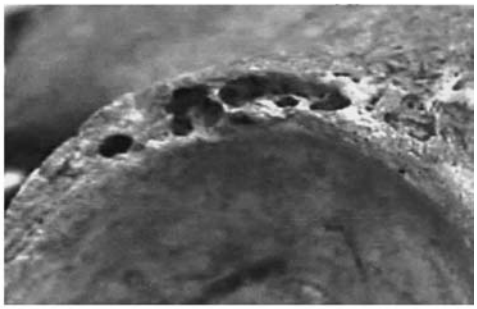
Rim acetabulum - stage 3

FIGURE 1



Rim acetabulum - stage 4





Rim acetabulum - stage 5

FIGURE 2

surface. This is not to be confused with those that arise as a consequence of hyperostosis or osteopenia. In some subjects, we noted the presence of small pores (microporosity). Other pelvises displayed bone loss with large pores (macroporosity). We defined four stages: Stage 1: dense with potential peripheral macroporosity (Fig. 3), Stage 2: microporosity (Fig. 3), Stage 3: appearance of trabecular bone (Fig. 4), and Stage 4: bone destruction with extensive macroporosity (Fig. 4).

C. Porosity of the lunate surface: The peripheral part of the acetabulum is articular and is known as the articular crescent; its extremities are called cornus. The appearance of the articular crescent differs from individual to individual. Most surfaces retain a granular appearance until it is lost to other surface

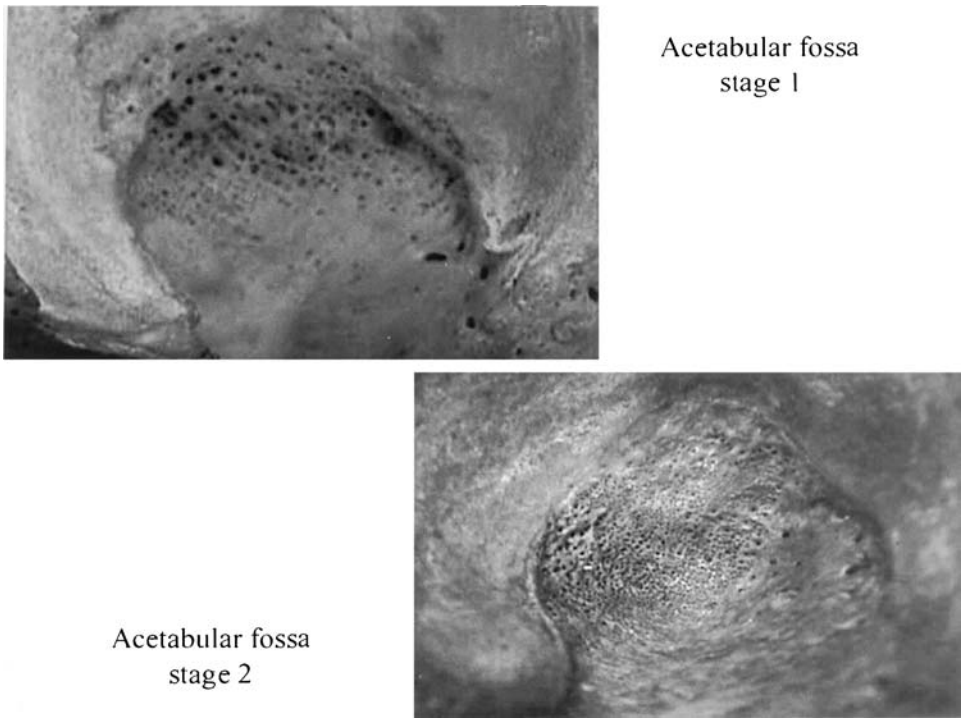


FIGURE 3

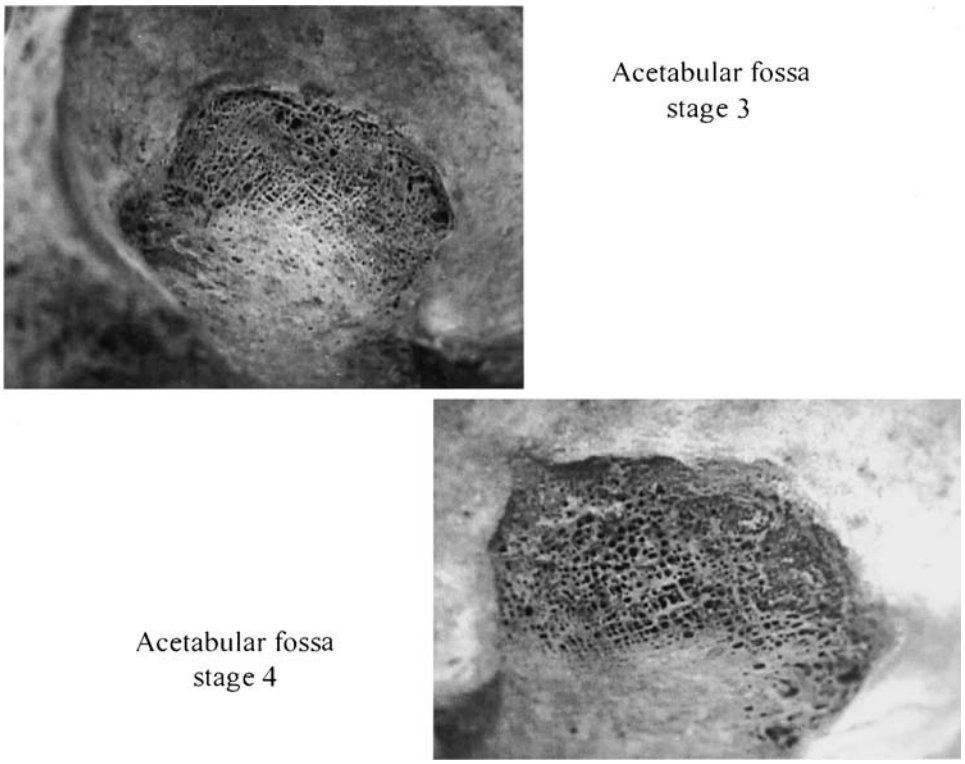
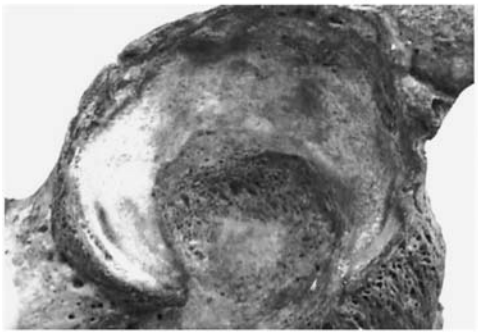


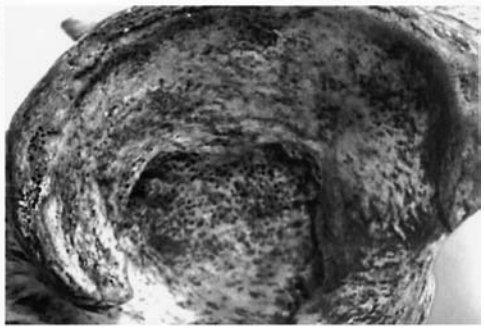
FIGURE 4

features. It is smooth in some instances and may present pores to varying degrees in other cases. With respect to the articular surface, there frequently occur small to large perforations that are to some extent associated with age changes. We observed these variations in porosity in three different places: the anterior cornu, the posterior cornu, and the superior part of the crescent. At each point, the porosity was classified as follows (Fig. 5): Stage 0: absence of porosity, Stage 1: localized microporosity, and Stage 2: extensive microporosity or macroporosity. We defined a measure called the "total porosity." This measure corresponds to the sum of the stages identified at the three different points.

Porosity lunate surface - stage 0



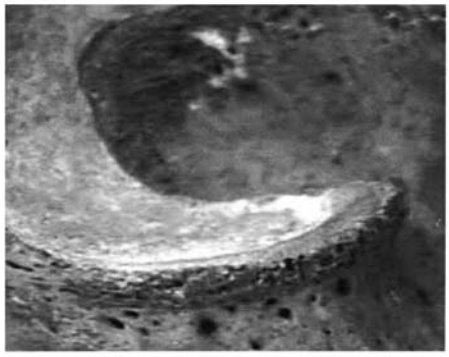
Porosity lunate surface - stage 1



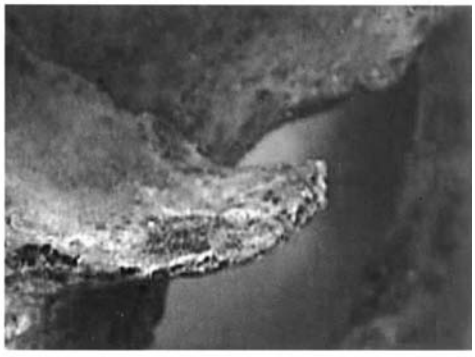
Porosity lunate surface - stage 2

FIGURE 5

Apical activity - stage 0



Apical activity - stage 1



Apical activity - stage 2

FIGURE 6

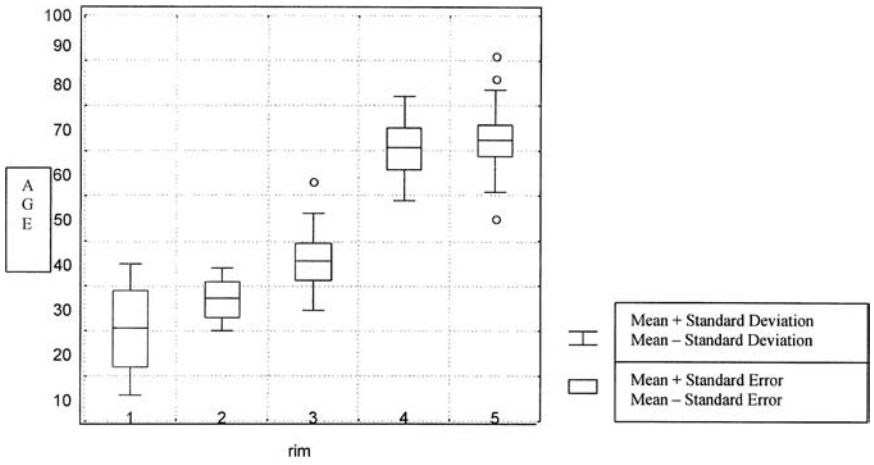


FIG. 7—*Correlation between criteria "rim of the acetabulum" and age ($p = 5 \times 10^{-4}$).*

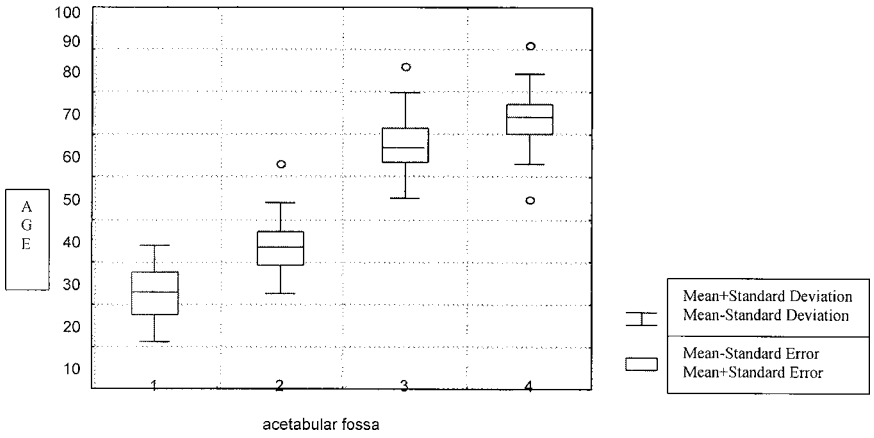


FIG. 8—*Correlation between criteria "acetabular fossa" and age ($p = 2 \times 10^{-4}$).*

D. Apical activity: The appearance of the extremity of the posterior cornu varies from individual to individual, with structural phenomena sometimes present in the form of osteophytes. It can be sharp and distinct; it may also be broader (as a consequence of arthritic lipping) and vaguely triangular in form, or become blunted by the formation of a rim. We described this activity in three stages (Fig. 6): Stage 0: absence of activity, Stage 1: moderate activity, and Stage 2: pronounced activity.

Statistical Method

The descriptive and comparative statistics were produced using the "Statistica 5.1" software. For the graphic presentation of the distribution of the quantitative variables, we resorted to the "box whisker" system with the following indicators: the central line indicates the mean, the box represents the standard error, and the whiskers correspond to the standard deviation (11).

We used non-parametric methods because of small sample sizes. The Kruskall-Wallis test was performed to assess the relation between age and acetabular criteria. In view of many ties, we used the small sample size GAMMA statistic method (Kendall test) to compare the correlation between the various acetabular criteria. The correlation between acetabular and the Lovejoy criteria was estimated by the Kendall test. A 5% threshold has been adopted as significant.

Results

Correlation Between the Criteria Classified by Stage and Age

For the "acetabular rim" and the "acetabular fossa" criteria, there was a significant link between the various stages and age (Figs. 7 and 8). We also observed a trend for the significance to increase with greater age.

The result for the "apical activity" criterion was also noteworthy. The link between the criteria stages and age is significant. The progression trend is notable (Fig. 9). For the "porosity of the lunate surface" criterion, the results were not satisfactory. The link between the criteria stages and age is notable and there is a progression trend. However, there is substantial overlapping between the age group, and rather large variations within each group. The results for the "total porosity" criterion are significant (Fig. 10).

Correlation Between the Various Criteria

We studied the correlation between the criteria in pairs (with GAMMA statistic). There was a notable correlation between several of the criteria (Table 1). A correlation between the criteria of the

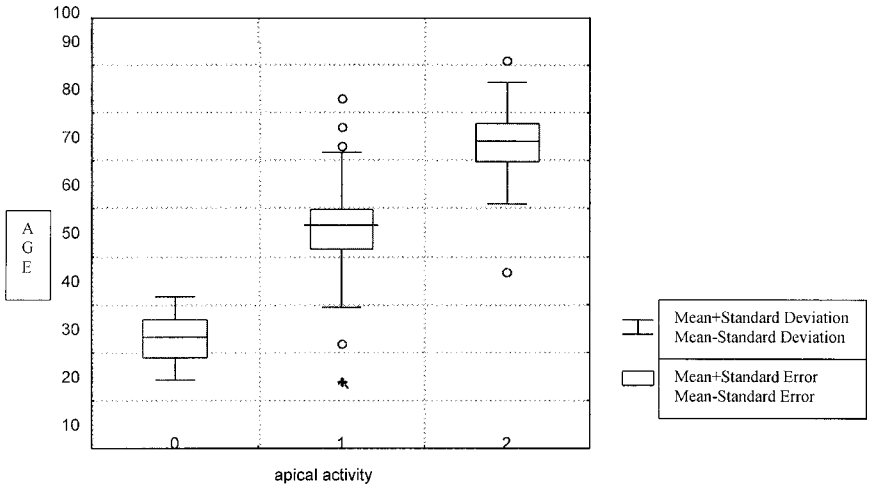


FIG. 9—*Correlation between criteria "apical activity" and age ($p = 7 \times 10^{-3}$).*

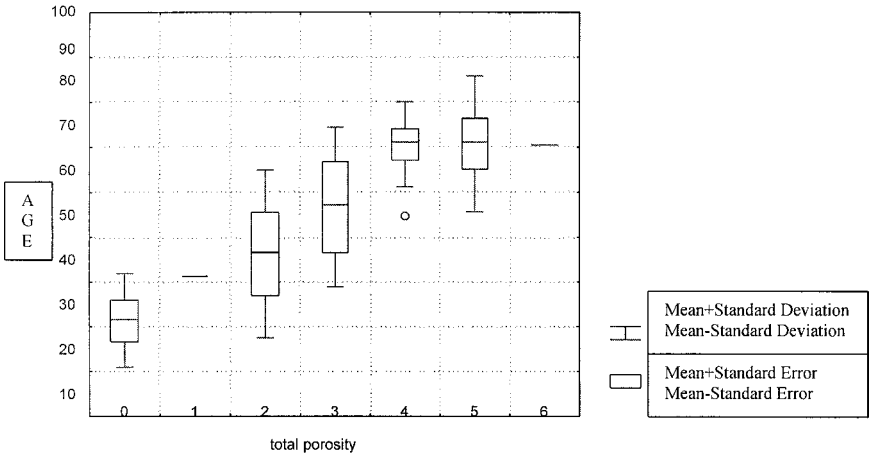


FIG. 10—*Correlation between criteria "total porosity of lunate surface" and age ($p = 10^{-3}$).*

acetabulum and the Lovejoy criteria of the auricular surface was found (Table 2).

Discussion

Use of the acetabulum can be criticized. Hip dysplasia being common, one might anticipate a bias in age estimation. However, a review of biomechanical studies leads us to conclude that dysplasia results, primarily, in localized overloading (7). This phenomenon manifests itself in localized hyperpressure resulting in localized cartilage attrition. The study of the acetabulum as a whole is therefore possible (8). We have studied only male bones, given the different ageing criteria between the sexes and the fact that ageing criteria in women are often less accurate. The series was homogeneous, formed of individuals ranging from 30 to 81 years of age. The limited size of the series makes statistical analysis problematic. We have attempted to overcome this by using appropriate statistical methods, and by only defining a few stages for each criterion (9, 10). We have not studied inter-observer variability. Having studied this small sample several times, it has not been possible to carry out objectively an inter-observer study. However, the "acetabular rim" and "acetabular fossa" appear to be useful criteria. The tests are significant. The grouping of individuals in four or five stages permitted a good definition of the age class. These criteria show a notable correlation. "Apical activity" is a useful criterion but the distribution of individuals is only possible in three age groups. This type of distribution can contribute little to the estimation of age.

The "porosity of the lunate surface" criteria also appears to be useful. The tests are significant. However, the distribution of individuals is again limited to three age groups. Furthermore, the variations are substantial and the definition of the age bracket contributes little. The "total porosity" criterion enables a subdivision of the age groups. However, given the small size of our sample, this method also reduces the number of individuals per stage. We found a significant correlation between the acetabular criteria studied and Lovejoy's criteria. This observation is not surprising because all of these criteria are based on a description of ageing signs. This result is useful because an examination of the acetabulum may allow to refine Lovejoy's technique.

The present study demonstrates the usefulness of using the acetabulum. Based on Lovejoy's work, we have identified easily observable criteria in the acetabulum which correlate with age. These criteria also correlate with the Lovejoy criteria. This is particularly interesting because the posterior part of the pelvis is often present. Simultaneous study of the acetabulum and the auricular surface may enable an improvement in the estimation of age.

This is a preliminary study, but we believe the results are sufficiently encouraging to pursue it on a larger scale sampling,

following a descriptive and exploratory approach. Of course, it would be highly desirable for a second observer to perform the assessments so that some measure of inter-observer variation could be provided. It would also be desirable for the original observer to reassess his observations, which would provide a measure of intra-observer variation.

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