



Forensic Anthropology Population Data

Determining sex with the clavicle in a contemporary Spanish reference collection: A study on 3D images



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ABSTRACT

Sexual dimorphism of the clavicle based on metric studies has been determined among different populations from different eras. Due to the need to know about sexual dimorphism in the Spanish population in order to apply the results to the field of Forensic Anthropology, a study has been carried out on a sample in the contemporary Spanish population, made up of the right and left clavicles of 50 males and 50 females. A metric, volumetric and curvature study was performed. To do so, 3D scanning was completed on the entire sample using the Picza 3D Laser Scanner, and the study was performed using reproductions. There were taken 6 metric measurements and 4 volumetric measurements using the Geomagic software, and for the study of curves, an index was calculated which related the direct length of the clavicle and its length as cast onto a surface. The data are presented for all of the variables, distinguishing between the right and left side, and there were processed using the statistical program PASW Statistics 18. The results show that the classification functions which best categorize the sample with a unique variable are volumetric, which classify the sample correctly in 94% of cases based on diaphysis volume, followed by total volume, which provides an accurate classification in 92% of all cases. The sagittal diameter at midshaft provides an accurate classification in 90% of cases and the maximum length in 88% of cases. The curvature index shows that there are no statistically significant differences by side and the only curvature index that shows significant differences by sex is the total anterior curve of the left clavicle being the males curve more pronounced. The validation study performed on a sample of 20 individuals confirms the high discriminatory power of the volume obtaining an accurate classification rate of 85–100% depending on the variable studied.

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1. Introduction

Studying the clavicle is of particular interest, it is the only bone in the shoulder girdle which forms a synovial joint with the torso, also being the only bone which connects the upper limb to the axial skeleton [1]. Moreover, the clavicle is the last bone to complete ossification, and therefore it is of interest in terms of verifying whether this bone displays greater sexual dimorphism or asymmetry than others as a result of its late maturation.

Sexual dimorphism in the clavicle has been studied among different populations from different eras [2–12]. Most notable are the studies by Parsons, in which interest is shown not only in the metrics of the clavicle, but also in the differences in angle

depending upon laterality and sex [13]. The volume of the clavicle has also been studied, though on few occasions. Most notable is the work by Singh and Jit [14] to study the volume of the clavicle, based on Archimedes' principle, calculating volume by the displacement of fluid. The study of the clavicle's asymmetry has aroused great interest in the field of Anthropology [15–21] also the study of clavicle's biomechanics in the field of Medicine [22–28], in the latter case with the objective of performing broader studies on variability in the clavicle to provide better treatment of fractures. The clavicle's curvature has also been studied by several authors [26,29–33]. New lines of research aimed at the field of geometric morphometrics began to form in order to ascertain new information about sexual dimorphism of the clavicle and to discover whether results can be improved when determining sex by combining morphology and size [19,33].

The objective of this study is to contribute classification functions which help to determine sex on the basis of the clavicle

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in the Spanish population and to indicate what percentage of accurate classification is achieved when determining sex in this manner. In a forensic environment, it is not always possible to recover the full sample, and therefore there are cases in which very few skeletal remains are available. In these cases it is necessary to obtain the greatest possible information so it is essential to create specific classification functions for a population in order to determine sex in a reliable manner, or at least with awareness of the margins of error. Because of this, it is also important to carry out new studies to attempt to find variables on the basis of which better results may be obtained, so in this study the discriminatory power of the volume variable was studied, as well. Besides not always is it possible to recover the bone on a good state of preservation and some parts could be missed or damaged so having classification functions based on certain regions could be useful to determine sex in such cases. Also it is interesting to study the extent of their sexual dimorphism to know if there is some region with a higher sexual dimorphism. It has been subject to very little study, though it improves upon the results achieved using metric variables. Another hotly debated topic has been study of the clavicle's curvature [29,30,34], and therefore in this study has been attempted to verify whether the right clavicle truly does display greater curvature than the left clavicle, establishing a relationship between the length of the clavicle and the length on the surface of the curve.

2. Material

The study sample was obtained from two contemporary Spanish reference collections of the School of Legal Medicine of Madrid (Complutense University). The first is made up of 132 individuals born between the years 1881 and 1973 in different Spanish regions and died between the years 1975 and 1985, while the second collection is made up of 88 individuals born between the years 1941 and 1976 and died in 1996. In all, it was possible to recover the right and left clavicles of 100 individuals (50 males and 50 females) in a good state of preservation, for the study. For the validation study were taken into account those clavicles which were in good condition, but of which there was an odd number; in all, 20 clavicles (from 10 males and 10 females).

3. Methodology

The methodology apply to this study has been very similar to the one applied on the previous published work about sex determination by talus and radii volumes [35]. The study sample underwent three-dimensional scanning to work with the resulting 3D reproductions. To do this, a PICZA 3D laser scanner was used, the mechanism of which consists of a rotating platform in the middle of which the clavicle is placed. A laser is projected from the right side, which gradually moves from its base to a set maximum height, while the surface of the bone is scanned. In order to scan the entire clavicle, it was necessary to perform 6 surface scans (corresponding to each of the 6 perspectives or views), changing the orientation of the clavicle each time. A rotating scan, which would have made it possible to scan almost the entire clavicle, could not be performed due to its morphology, which does not allow for proper scanning of the bone's contour. A distance between points of 0.4 mm was selected because this was considered to be the optimal option in terms of quality/time. The time needed to scan a clavicle ranges from 40 to 50 min. In order to join the 6 orientations together (Fig. 1), the software Pixform was used. To join 2 shells, it is necessary to manually mark 3 points in common between both orientations and then join the different meshes successively (Fig. 2). Each time 2 orientations are joined, the two shells are merged automatically to remove the

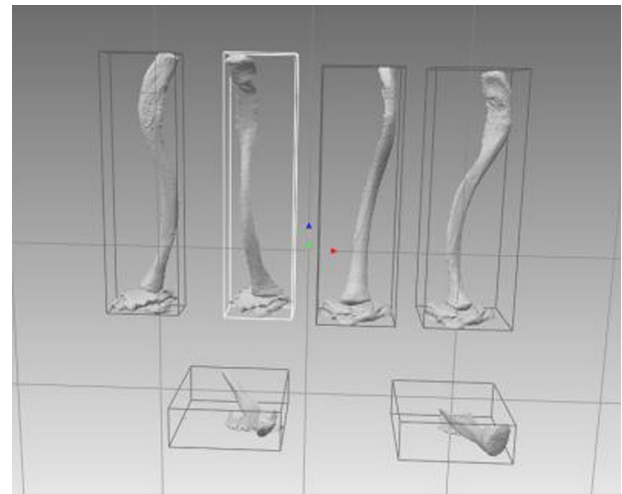


Fig. 1. Orientations of rotating and slice scans of the clavicle.

overlapped regions between shells and to stitch the neighboring boundaries together with newly added faces. The time needed to obtain the whole image depends on the expertise of the professional varying from 15 to 30 minutes. The result and accuracy of shells are still maintained after merging. Once the final 3D model is obtained it is necessary to remove spikes in order to straighten the surface by detecting and flattening single-point spikes. A low level smoothness has been chosen to not alter in excess the surface. The average of triangles for the 3D models has been 60.603 for female clavicles and 83.948 for male clavicles.

For the metric study, a total of 6 linear measurements were taken in the 3D reproductions of the bone. These were: maximum length, sagittal diameter at the midpoint of the diaphysis, vertical diameter at the midpoint of the diaphysis, sagittal diameter at the distal end, vertical diameter at the distal end and vertical diameter at the height of the conoid tubercle (Fig. 3 and Fig. 4). The description of the measurements is shown in Table 1. In order to take the measurements, the software Geomagic was used, which makes it possible to measure distances by positioning the two points which limit the measurement on the image.

The measurements were taken twice with a time interval of 2 months in between. A paired t-test was carried out to verify that

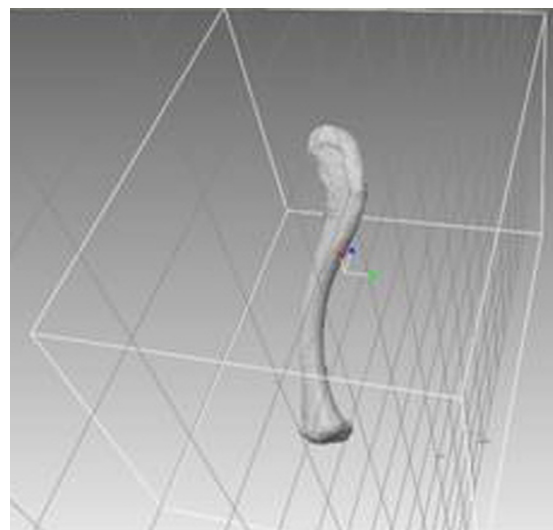


Fig. 2. Assembled orientations of the clavicle.

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