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TECHNICAL NOTE

ANTHROPOLOGY

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A Simple Technique for Imaging the Human Skeleton Using a Flatbed Scanner*

ABSTRACT: A simple technique for imaging the human skeleton with a flatbed scanner is presented using the auricular surface of the ilium as an example. A flatbed scanner with resolution capabilities of 600 dpi or greater allows for images of human bones. The auricular surface of the ilium was selected to demonstrate this technique as it is a fairly three-dimensional area that can be difficult to record photographically. Fifty left ilia of various ages at death from the Athens Collection were selected from which three observers (SCF, CE, and IM) scored the morphology of the auricular surface using a well-established aging method. Observations were taken of the dry bone, of digital photographs of the bone, and of scanned images of the bone, and in that sequence. Results indicate that scores of scanned images are equivalent or better than digital images of the same ilia. This technique allows for sharing data electronically with ease.

KEYWORDS: forensic science, forensic anthropology, digital image, scanner, photographic documentation, Lovejoy aging method

Photographic images of the human skeleton are routinely used by anthropologists to document, share, compare, and exchange ideas about findings. Photography is often critical in forensic science, with applications from the crime scene to the morgue, to the laboratory, and finally to the courtroom. Additionally, photographs serve as a necessary part of various methodologies. For example, they are used to demonstrate the different morphological phases of the auricular surface of the ilium for aging the human skeleton, such as in the method developed by Lovejoy et al. (1,2). However, the limitations of photography are well known. These include image distortion, lighting difficulties, shadows, and problems with both the exposure and depth of field, affecting the sharpness of images. These difficulties can be exacerbated with automatic settings on cameras as well as the variable of the photographer's skill and experience. As a result, discrepancies do often occur between observations made on dry bone versus photographic images.

This issue has been addressed by Hutchinson and Russell (3) who recommended caution when estimating age from either photographs or digital images. This paper proposes an alternative method of capturing a digital image of skeletal structures. This new technique, borrowed from geoarcheology (4), uses a flatbed scanner to digitally record skeletal elements. To test the suitability of this technique when applied to studies of human skeletal remains, the auricular surface was selected as the area under examination. The Lovejoy et al. (1) aging method was employed to score the ilia. This bony region was selected because it is relatively flat, yet it has some three-dimensional features and very subtle changes from one phase to the next that renders it difficult to record photographically.

The auricular aging method is well established and frequently used by anthropologists in both archeological and forensic contexts, having the advantage that this portion of the ilium is dense and has a relatively high survival rate.

The purpose of this study, however, is not to test the accuracy of the auricular aging method itself, but to use it as a tool to test the potential of scanned images as an accurate representation of the actual bone, especially in comparison with photographs.

Materials and Methods

Our goal was to test whether a scanner could replace a camera in the documentation of human skeletal elements. The sample used for this study consists of 50 innominates (*os coxae*) from the Athens Collection. This is a modern, documented collection housed at the Department of Animal and Human Physiology at the University of Athens, Greece. It consists of 225 skeletons of known sex, age, occupation, place of birth, and cause of death (5).

The subsample of 50 specimens was selected by stratified random sampling by one of the authors (SKM), thus ensuring that innominates from both sexes (31 men, 19 women) and all adult age categories were represented. The samples were photographed with a high-resolution digital camera (Nikon Coolpix 5700; Nikon Corporation, Tokyo, Japan) and were then positioned with the auricular surface in contact with the glass on a simple flatbed scanner (Epson 1640XL; Seiko Epson Corporation, Nagano, Japan) and saved with a resolution of minimally 600 dpi (Fig. 1).

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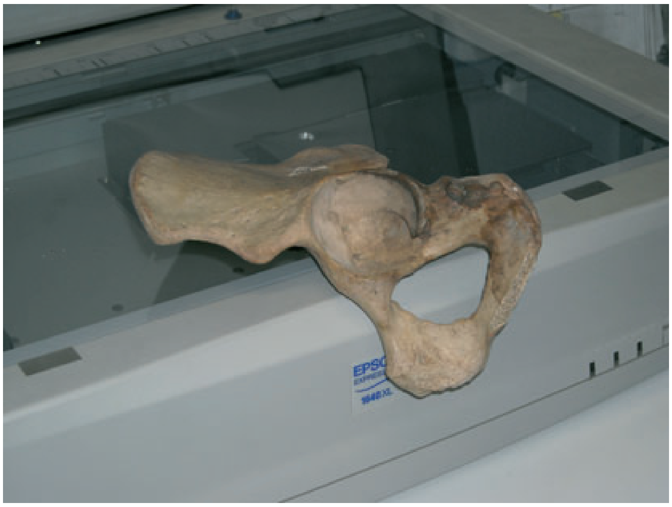

FIG. 1—*Position of the* os coxae *on the flatbed scanner.*

Design of the Statistical Tests

The samples were scored using the Lovejoy method (1) during three separate sessions by three observers (CE, IM, and SCF). In the first session, observations were made on dry bone, in the second the rating was based on photographs (Fig. 2*a*), and the third made use of the scanned images (Fig. 2*b*). The age estimates obtained from visual observations of the actual bones were used as a baseline.

The focus of this study is on the differences between the three methods, not on the differences between the observers. Thus, comparisons were made between the observations for photographs and scanned images for the three observers, using the eight aging phases of the Lovejoy (1) method.

Statistics

The data for the auricular surface is ordinal, and this indicates that a nonparametric test provides the most robust results. For this analysis, a nonparametric method is used to test the hypothesis that there is no statistical difference in scoring mainly between photographs and scanned images. The best method chosen for this is the comparison of the two samples. STATGRAPHICS Plus v 2.1 was the statistical software used for this analysis (StatPoint Technologies, Inc., Warrenton, VA). This procedure is designed to compare two data sets. One option runs a Mann–Whitney *U*-test to compare the medians of the two samples. Another option runs a Kolmogorov–Smirnov test to compare the distributions of the two samples.

Results and Discussion

The results of scoring photographic and scanned images were compared against the observed age estimates from the actual bones (Table 1). Table 2 presents the age categories according to the Lovejoy method (1). The mean percentages of the age estimates that fall within one standard deviation are as follows: 73% for the photographs and 74% for the scanned images.

The nonparametric analyses for the comparison between photographs and scans are presented in Table 3. The results of the nonparametric analyses indicate that there is no statistically significant difference between the medians of the two samples compared (photographs and scans). But in the instance of the comparisons

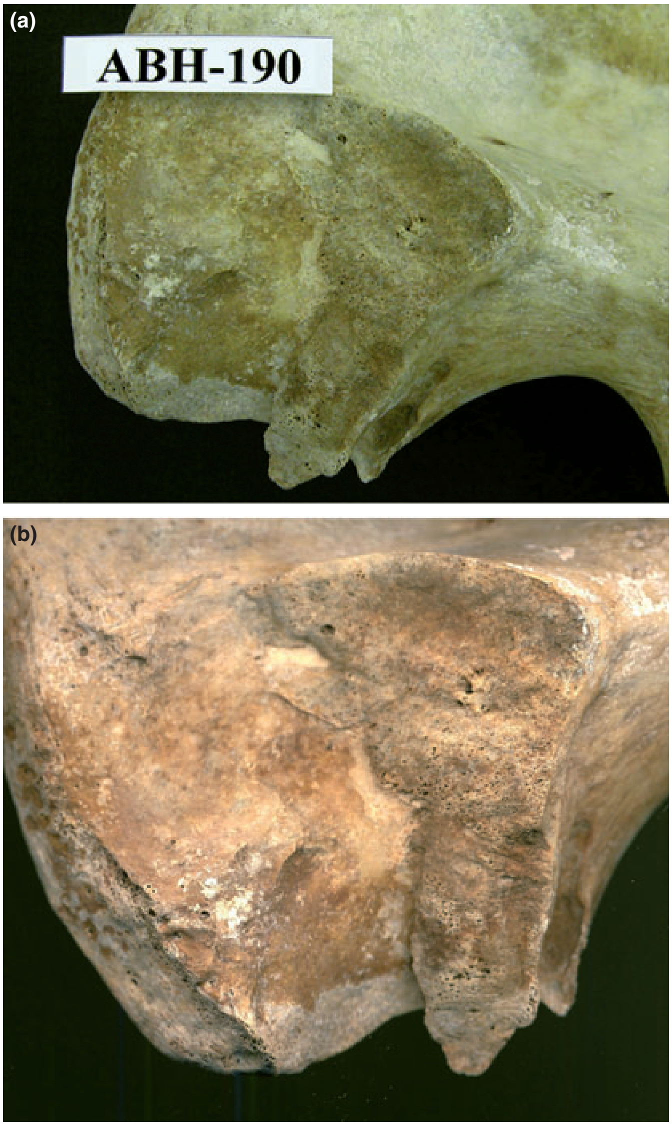

FIG. 2—*(a) Example of a photographic image of an auricular surface: ABH-190. (b) Example of a scanned image of the same auricular surface: ABH-190.*

between the distributions, there is a statistically significant difference among two of the three observers. This can be interpreted that there is no significant difference between these two procedures. In other words, the scanned images have the same value as the photographic images, but the trend is that the scanned images are a little better than photographic images.

Based upon these results, scanned images provide the necessary information to the observer to age the auricular surface of the ilium with at least as much accuracy as digital photographs of the same bone. To further test this result, a comparison was then made between all three estimates against the known age category to which each specimen belonged (actual age).

The combined average number (between all three observers) for accurately classifying the age estimates into the appropriate categories indicates perfect classification (zero values) among 24% (n = 12.0) of the actual bone observations and identical averages of 23% (n = 11.3) for both the photographic and scanned images. This is an additional indication that scanned images work just as well as photographs to obtain an accurate age estimate.

TABLE 1—*Experimental data by visually observed ilium bone, photograph, scan, and actual age category.*

Skeleton WLH/ABH	Observer 1			Observer 2			Observer 3			Age Category	Actual Age
	Real Bone	Photograph	Scan	Real Bone	Photograph	Scan	Real Bone	Photograph	Scan		
2	6	7	6	5	7	5	5	6	6	8	64
16	4	5	4	2	3	3	2	5	5	4	36
26	6	6	6	6	8	8	4	6	6	6	46
34	5	5	5	5	5	5	5	5	5	8	81
38	6	6	6	6	7	7	5	5	6	5	43
41	4	5	4	3	2	2	2	2	3	2	27
49	7	7	7	4	4	4	5	5	6	7	56
64	6	5	5	4	3	3	4	5	6	8	65
67	6	7	7	5	5	6	5	5	6	7	56
72	3	2	2	2	1	1	1	1	1	2	27
73	7	6	4	4	3	3	5	5	5	8	62
74	3	5	5	4	4	4	3	2	3	2	26
79	5	7	4	4	4	4	4	5	5	7	51
82	6	5	6	7	7	8	6	6	6	6	48
92	7	7	6	4	4	4	4	7	5	7	54
95	5	5	5	7	3	3	3	5	3	4	37
100	7	7	6	7	7	7	5	8	6	8	64
103	4	4	5	4	2	3	2	2	2	1	24
104	6	7	7	7	7	8	5	8	7	7	57
108	6	5	5	3	2	2	1	3	2	2	28
110	7	6	6	4	3	4	3	6	6	7	58
111	7	6	5	6	6	6	4	5	5	5	44
112	8	8	8	8	8	8	8	8	8	7	56
113	7	5	5	7	4	4	6	7	6	8	67
118	5	6	7	8	6	6	4	6	6	6	45
126	8	6	7	7	6	6	6	7	7	8	74
127	3	4	5	3	3	3	2	3	3	2	29
129	7	6	7	5	7	7	6	6	7	8	65
130	8	7	8	7	8	8	7	7	8	8	69
132	6	6	7	8	7	7	4	7	8	8	74
133	6	8	8	5	7	6	5	6	7	7	58
135	2	5	4	6	5	5	3	4	5	3	34
137	5	5	5	5	6	6	4	5	6	5	41
139	5	4	4	4	6	6	4	5	5	5	44
146	7	4	5	4	4	4	5	6	6	7	58
154	7	7	7	7	8	7	7	7	7	7	54
188	4	6	3	7	3	7	6	6	6	4	38
190	2	5	5	3	4	6	3	3	5	1	20
191	5	5	4	4	2	2	6	3	6	3	32
194	6	7	6	3	3	3	4	5	5	4	35
197	5	4	4	4	2	2	3	1	3	4	36
200	5	5	5	2	6	6	2	3	4	5	43
203	3	4	5	4	4	4	3	2	5	1	24
207	4	6	7	7	7	6	5	3	5	4	37
208	7	8	8	8	8	8	7	7	7	6	47
210	5	6	6	6	7	6	3	5	5	5	43
211	2	5	5	4	2	2	1	1	2	2	28
213	3	4	3	3	2	2	2	3	3	3	32
217	3	3	4	2	2	2	1	2	2	1	22
223	5	6	5	4	5	5	4	5	5	4	38

Finally, when the mean percentages of the age estimates from the photographs and scanned images falling within one standard deviation of the actual age categories are compared, once again identical results are obtained, each with 63% accuracy.

This simple technique using a flatbed scanner to record, in this example, part of the human pelvis, can be used successfully in place of a digital camera. Advantages of employing this technique include excellent images that can be obtained without a camera, special lighting conditions, or advanced photographic skills. Neither ambient light nor a photographic flash are necessary. In fact, good quality depictions of somewhat three-dimensional bony structures, such as auricular striae and billows, can be easily obtained, thus proving that even three-dimensional objects can produce usable images with a flatbed scanner. The scanned images can be readily shared electronically without the additional step of either downloading or printing the images. Image quality is superior in digital format, and as such, it is recommended by the authors to share digital images electronically rather than in printed format. Limitations were encountered using this technique when the auricular surface could not be positioned flat against the glass of the scanner. The actual bone morphology affects results and can compromise the quality of the final image. In this test, it was observed that the scanned images of male ilia of small size were usually of a poorer quality and resolution. These results are attributed to the difficulties in positioning the bone in close proximity to the scanner glass, because of the narrow morphology of the greater sciatic notches. Greater image distortion is created with increasing distance from the glass surface of the scanner.

Although testing the aging method itself was not the principal aim of this study, it is worth noting that each of the three observers

TABLE 2—*Age categories of the Lovejoy et al. (1985) auricular surface aging method.*

Phase	Age Range (Years)
1	20–24
2	25–29
3	30–34
4	35–39
5	40–44
6	45–49
7	50–59
8	60+

TABLE 3—*Statistical results of the nonparametric comparison of the two samples (photograph and scan) of the three observers (using Mann–Whitney U- [Wilcoxon] and Kolmogorov–Smirnov [K-S] tests).*

Statistic Comparison	Observer 1	Observer 2	Observer 3
Median of photographic images	6.0	4.5	5.0
Median of scanned images	5.0	5.0	5.0
Average rank of photographic images	52.23	49.91	47.98
Average rank of scanned images	48.77	51.09	53.02
Median 1 versus median 2 (Wilcoxon) *U*	1163.5	1279.5	1376.0
p-value*	0.542649	0.839821	0.376348
Estimated overall statistic	0.38	0.20	0.38
Two-sided large sample K–S statistic	1.90	1.00	1.90
Approximate *p*-value	0.0014636**	0.271006	0.0014636**

*There is no statistically significant difference between the median values at the 95.0% confidence level.

**Statistically significant difference between the two distributions at the 95.0% confidence level.

found that the Lovejoy method (1) tended to underestimate the age of older individuals and overestimate the age of younger individuals. Similar results have been obtained by others (3). Although some improvement with each subsequent repetition of the Lovejoy method (1) may have been achieved by the observers, it is not believed to have skewed the results.

The authors selected the auricular surface of the ilium in this test because of its somewhat three-dimensional morphology and the special difficulties of recording this bony region photographically. Other skeletal elements, especially the postcranial skeleton, could be similarly recorded by using a flatbed scanner. The authors of the present study have used this method to record structures such as sterna, clavicles, metacarpals, metatarsals, and phalanges. A recent study also includes the use of a scanner to capture the shape of metacarpals (6).

Furthermore, other types of evidence could also be recorded in this manner. It should be noted, however, that this technique is only suitable for relatively flat structures. Although three-dimensional scanners are increasingly being used (7), a simple flatbed scanner (with 600 dpi resolution or greater) is capable of producing images that are of similar quality to those from a digital camera. This technique is offered as an alternative to photography for special situations that may include the lack of a camera, photographic inexperience on the part of the researcher, or inadequate lighting conditions. A flatbed scanner will never be a substitute for either the naked eye or a digital camera at the hands of an experienced photographer, but scanned images of the human skeleton can offer solid documentation that can be readily shared electronically by anthropologists in both forensic and archeological contexts.

Conflict of interest: The authors have no relevant conflicts of interest to declare.

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