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Commentary

Comment to “A.J. Collins, K. Brown, Reconstruction and physical fit analysis of fragmented skeletal remains using 3D imaging and printing” [Forensic Sci. Int.: Rep. 2 (2020) 100114].

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ABSTRACT

The creation of virtual 3D-models of objects of forensic interest and the use of 3D printing gained more and more importance in the forensic field during the last years. Comparing radiological imaging techniques, such as CT technology, with surface scan technology for anthropological studies is a field of research in which we are also actively working. This is the reason why we were particularly interested in this paper. As researchers working in a center in which the application of 3D technology including Computed Tomography (CT), 3D Surface-Scanning (3DSS) and 3D printing is integrated in daily casework, we feel committed to answer to this study, because we are surprised by the chosen study design and we cannot agree with the obtained conclusion.

Dear editor.

We read with interest the article by Amber J. Collings and Katherine Brown titled “Reconstruction and physical fit analysis of fragmented skeletal remains using 3D imaging and printing”.

We applaud the authors for the idea to apply new 3D technologies for physical fit analysis (PFA) in forensic anthropology. Indeed, the creation of virtual 3D-models of objects of forensic interest and the use of 3D printing gained more and more importance in the forensic field during the last years [1,2].

Comparing radiological imaging techniques, such as CT technology, with surface scan technology for anthropological studies is a field of research in which we are also actively working. This is the reason why we were particularly interested in this paper.

Nevertheless, as researchers working in a center in which the application of 3D technology including Computed Tomography (CT), 3D Surface-Scanning (3DSS) and 3D printing is integrated in daily casework, we feel committed to answer to this study, because we are surprised by the chosen study design and we cannot agree with the obtained conclusion.

We think that the readership should be made very aware that all structured light scanning (SLS) technologies are not equivalent. There are many types of SLS and a huge number of technical devices, which vary significantly in many aspects, such as the resolution of the 3D-model obtained, the rapidity of data acquisition, the sensitivity to artefacts, the integration of color information, costs etc. [3]. Their variety can be compared to those of photo cameras, where one can choose an expensive professional equipment or the simplest single-use camera. Evidently, the photos obtained are not the same.

In their study, Amber J. Collings and Katherine Brown compared a high-resolution micro computed tomography (μCT) with a low cost handheld 3D surface scanner. The results of such a comparison are obvious and do not require analyses. Computed Tomography (CT) and surface scanning are two different imaging techniques and each one has its advantages and limitations. μCT is a high resolution CT that is only applicable for small objects (the size as well as the obtained resolution depends on the model of μCT scanner). Therefore, if they would really like to compare the limits for surface-visualization of bone fragments using these two imaging techniques, and if they use an expensive high-resolution μCT, they should have compared it to a high-resolution 3D surface scanner in order to compare devices of the same category.

If this study was trying to find out which of the different technologies are better fitted for digitizing the surface of bone fragments, the authors should have chosen adequate devices to represent the two techniques.

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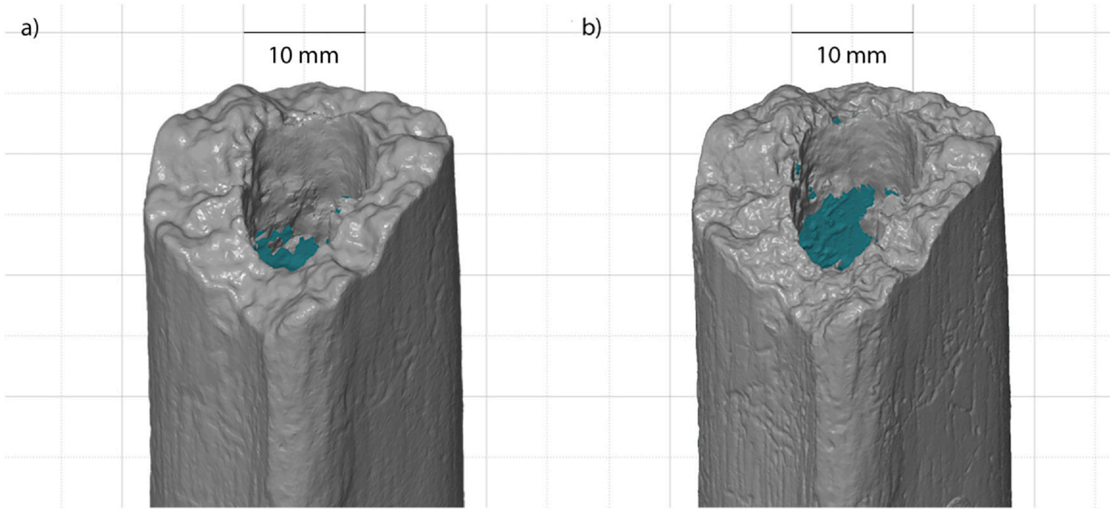

Fig. 1. a) 3D mesh of the femur fragment scanned with EinScan Pro 2X Plus. b) 3D mesh of the femur fragment scanned with GOM ATOS Compact Scan 5 M.

To show the differences between various types of SLS to the readers of this journal, we performed 3D acquisitions of femur bone fragments with two different types of SLS:

- EinScan Pro 2X Plus (low cost handheld scanner, comparable to the one Amber J. Collings and Katherine Brown used in their paper) (Fig. 1a)
- GOM ATOS Compact Scan (high resolution SLS fixed on a stand) (Fig. 1b)

In Fig. 1b it is evident that the result of the GOM ATOS Compact Scan is largely superior in terms of resolution when compared to the EinScan Pro 2X Plus. It should even be considered that this resolution can compete with the result of the μCT scans that the authors performed. It is worth noting that the GOM device used with a Measuring Volume of 150 mm is not even the maximum that can be acquired using a SLS Device.

Therefore, we do not agree with the conclusion that the SLS technique in general is outperformed by μCT. Only the device chosen by the authors was outperformed. All other devices for SLS were not tested in this study. The authors could have made the aim of the study clearer.

Beside this major issue, there are several other points that led us to question the study. Here are some examples:

We do not understand the chronological decision of 3D acquisition. Why did the authors perform first the SLS where the fragments needed to be sprayed with an antireflex-spray, then clean them before putting them with powder residues in the μCT? Would not it make more sense to perform first the μCT scan without powder residues and then spraying the fragments before performing the SLS? From our understanding, burnt remains were used in order to reflect the real case scenario of burnt human remains after a specific event, such as a fire. It is a legitimate reason to use burnt remains for the study, even though the remains needed to be sprayed. Nevertheless, in order to see the real effect of the antireflex-spray, the fragments should have been scanned once before and once after spraying. The comparisons should have been the basis of the argument as to why the SLS device used could still have been chosen for a comparison with the μCT even when a spray was included only for one device. It is evident that comparing imaging techniques should involve a comparison with elements that underwent the same procedure and treatment prior to the scan. Therefore, the grade of the influence of the spray should have been tested in advance.

Furthermore, as a detail, we noticed a small but important mistake in the figures of this article. In Fig. 1, the authors define the black line as a scale bar of 0.8 mm. This seems incorrect, particularly looking at the picture with the finger present. When exposed to fire and high temperatures the various properties of bone tissues are altered and undergoes different chemical and mechanical changes. These changes include discoloration, warping, and as said by the authors, breakage and fragmentation [4]. However, another important aspect of the heat-induced change is the shrinkage of the bone [4]. But even if there has been a shrinking process because of the burning, the value of 0.8 mm for the scale bar seems too small still. Maybe the authors meant 0.8 cm.

In Figs. 2 and 3, the opposite is the case. The white line was defined as 170 mm. Considering this scalebar (170 mm = 17 cm), by measuring in the image the fragments would have a size of about 34 × 34 × 34 cm. The whole femur would be too big to be of human origin. Maybe the authors meant 17 mm as the scale bar.

Furthermore, it should have been clarified if the measurements mentioned in the material part were taken before the heating process, and if so, the dimensions of the burned fragments should have been added in this chapter.

Additionally, we saw that there is no precise information about methods and materials. Did the authors really study only some fragments of one single bone? If so, how did they come to the general conclusion that PFA is possible by using the two tested methods if they only put together the pieces that they know originate from the same bone and therefore know that those fit together? Was there really a scientific approach to analyze if a PFA is possible or not? In our opinion, this would require multiple bone fragments and several blind-tests with various observers. Therefore, we think that the conclusion "*We therefore recommend μCT imaging paired with FFD 3D printing as an excellent option*

Fig. 2. 3D-Print of the fractured part of the human femur.

Fig. 3. Original fractured femur and 3D print of the fractured part.

for non-destructive physical fit confirmation when working with small fragments and burned bone." is not supported by the presented study. It should remain a hypothesis until it has been tested in a scientific manner. The specific recommendation of a "*CT imaging paired with FFD 3D printing as an excellent option*" makes the whole study somehow obsolete. For this recommendation a comparison with the SLS was not really necessary. They could have tested the µCT, prove it works (which was actually expected when choosing these samples) and then recommend it. Furthermore, the authors do not discuss the real case scenario in the conclusion. There are other limiting factors when using a µCT in the field during a mission, which might make it almost impossible to use µCT for Disaster Victim Identification (DVI) missions, for example. One of the main aim was "to determine if structured light scanning is sufficient to offer a cheaper, less labor intensive option than µCT for the 3D reconstruction of bone fragments". But this initial aim was not followed, as they used only the one low cost SLS and concluded "While SLS certainly demonstrated potential, it was outperformed by µCT…" This is not supported by the study as they generalize all SLS, which is an incorrect representation and might have led to a misguided study design in the first place. Perhaps, the sentence could be corrected to say: "While the SLS scanner used in this study certainly demonstrated potential for FPA, it was outperformed by µCT which provided a better physical fit for the small bone fragments tested in this scenario".

Finally, in our opinion, it does not make much sense to conduct scans with a very high resolution if the fragments are printed with a low cost and low resolution 3D printer for the PFA, since the high resolution of the scans gets lost in the process. In Figs. 2 and 3, you can see the 3D print of high resolution SLS (GOM ATOS Compact Scan 5 M), printed with 3D Projet 3510 SD from 3D Systems, as an example. Almost no details of the SLS scan is lost in the 3D print. A lot of details are still visible on the surface of the 3D print and the printing layers are not visible comparing to a fused filament deposition 3D printer the authors used.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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