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ABSTRACT

Tattoos can be used in forensic human identification as a secondary means of identification (other means being, but not limited to, personal descriptions and artefacts) allowing the identification procedure to be strengthened in this way. Despite this, the decomposition of tattoos is a topic not extensively studied in taphonomic research (study of how organisms decay). In this communication, we assess optical coherence tomography (OCT) as a method to reliably identify tattoos before and after decomposition, by imaging tattooed porcine samples. OCT was able to penetrate up to 3 mm below the surface and visualize parts of tattoos after 16 days of decomposition, which were no longer visible and recognizable using conventional photography-based methods. We believe this imaging modality has the potential to increase the reliability of tattoos in forensic human identification.

Keywords: forensic identification, optical coherence tomography, tissue imaging

1. INTRODUCTION

Forensic identification of human individuals in a number of scenarios is important to link criminals and victims to a location/scene and to identify unknown individuals.[1] Physical features such as tattoos and scars can be used to strengthen usual forensic methods such as DNA identification in the process of supporting or establishing an identity.

A big issue to overcome when employing these physical features (namely, tattoos) as identifiers is whether we are able to still perform a meaningful recognition after tissue decomposition.[2] While conventional, visible-light photography may fail to identify these, infrared and UV photography have proven to reliably work on both *in-vivo* and *ex-vivo* human tissue.[2] However, by being photography-based methods, these techniques merely provide a representation of the most superficial layers of the tissue.

Optical coherence tomography (OCT), on the other hand, provides three-dimensional representations of translucent media using near-infrared light, with micron-level resolutions over a range of a few millimeters.[3] It is also a contactless and non-destructive technique, which is important in forensic studies - leaving samples intact leaves room for further evidence collection and tests.Furthermore, OCT imaging can be repeated at different viewing angles on the same sample, allowing a more detailed representation.

OCT imaging has been previously used[4,5] for tattoo identification in *ex-vivo* porcine tissue, however without the effects of decomposition being investigated. Furthermore, the environment of decomposition plays a role in the type and rate of decomposition,[6] which could be studied further with OCT imaging. In this communication, we aim to determine whether OCT is a feasible technique of tattoo visualization, post-decomposition within a soil environment.

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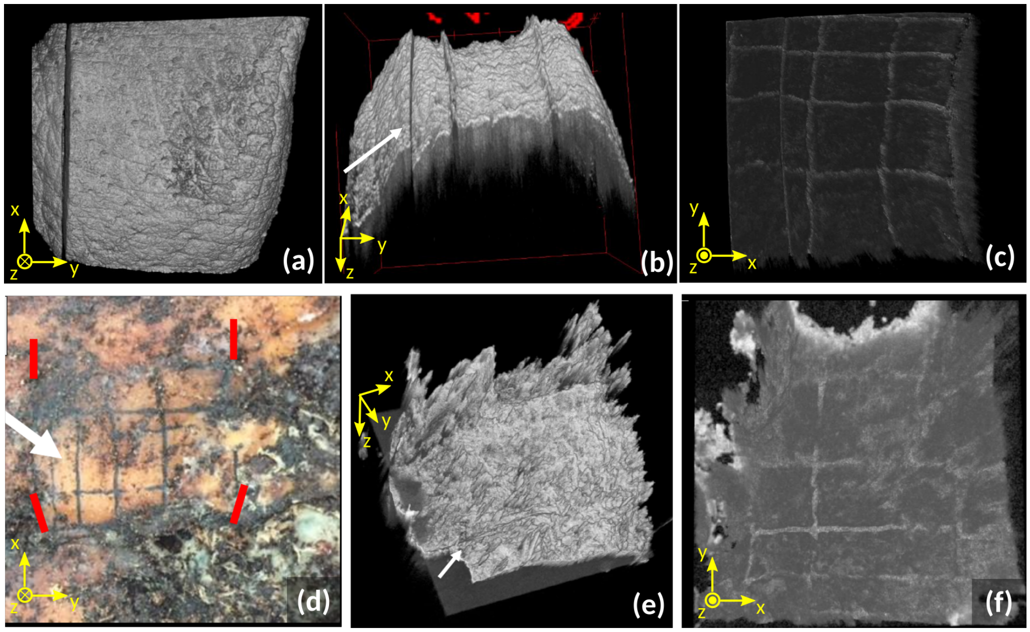

Figure 1. OCT imaging of tattooed porcine tissue at different stages. (a) 3-D OCT volume render of the freshly excised tissue pre-tattooing, visualized from above; (b) 3-D OCT volume render of the same section of tissue, post-tattooing (red arrows depict the surface marks left by the tattooing process, whereas the white arrow represents a cut in the skin tissue used for imaging orientation); (c) 3-D OCT volume render of the same section as (b), as seen from below, highlighting the tattooed pattern; (d) color photograph of the same section of tissue, post-decomposition (the red markings depict the pins embedded into the sample to aid volume registration); (e) 3-D OCT volume render post-decomposition, evidencing the dramatic change in the surface topography; (f) 3-D OCT volume render post-decomposition, shown in the same viewing angle as (c), highlighting the tattooed pattern.

2. METHODS AND RESULTS

The OCT system used employs a swept-source operating at a central wavelength of 1050 nm with a tuning range of roughly 100 nm, and has been described elsewhere.[7] The axial/lateral resolutions of this system during imaging were roughly 10 μm and 15 μm, respectively, with a lateral field of view of $25 \times 25\,\text{mm}^2$. OCT data was processed using the Complex Master/Slave (CMS) method,[8] which allowed for direct visualization of the tissue being imaged.

As an example of one of the studies, freshly excised porcine dermal tissue was obtained and imaged (Fig. 1 (a)). This section of tissue was then tattooed with a grid pattern and re-imaged (Fig. 1 (b) and (c)), after which the tissue was deposited in a soil container and left undisturbed for 16 days.

The tissue section was then exhumed and slightly cleaned with a scraping tool, small brush and water to remove the bulk of the soil around it. On direct observation, the tattoo is only partly visible (Fig. 1 (d)). This tissue section was then re-imaged by the OCT system, yielding 3-D representations as presented in Fig. 1 (e) and (f).

3. DISCUSSION AND CONCLUSIONS

In conclusion, we have successfully demonstrated the usefulness of OCT imaging to identify tattoos in tissue, even post-decomposition. The decomposition process has dried out the outermost layers, changing the

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topography of the surface and preventing a reliable representation of the tattooed pattern to occur.

The three-dimensional volume reconstructions yielded by OCT imaging are not only useful for the forensic investigators but can also be helpful to assist lay people in court visualizing evidence.[2] Moreover, the underlying layers of the tissue can be imaged even through thin layers of certain kinds of soil (predominantly non-metallic ones), which might mean OCT could be employed as an on-field imaging modality, virtually sectioning the sample without compromising its physical integrity - this being particularly useful when the outermost layers are damaged and the only form to reliably visualize the tattoo design is to access the deeper layers.

There are some limitations in the scope of this study, however: using animal surrogates (namely swine), while validated by previous studies and necessary due to ethical concerns, still introduces some concerns in terms of variability in the decay process.[2] More pressing than this is the fact that *ex-vivo* porcine tissue was used for tattooing the patterns, which meant that the tissue was unable to heal (as shown in Fig. 1 (b)), and the tattoo pattern was also not able to age naturally (the pigments would normally migrate to deeper layers of the skin[9]). The sections of tissue used are also of small size, which influences the rate and type of decomposition observed.[2] Larger sections of tissue can be imaged by the OCT system, however this might require changes in the interface optics to occur and will necessarily increase the acquisition time.

Future work in this might extend beyond forensic identification and more into the realms of taphonomic research, namely on studying the decomposition behavior of the different layers of the tissue, using functional extensions of OCT imaging such as polarization-sensitive OCT.

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