The changes to the appearance of bone due to the effects of fire or intense heat, both on the surface layer and microscopic

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Abstract

The identification of burned remains is one of the most difficult aspects of forensic investigations. The basis of this investigation is to understand how fire affects bone composition and its appearance, i.e., colour change, the appearance of splinter/fractures and more microscopic aspects such as collagen, porosity or crystallinity levels. Understanding fire and bone separately are critical points of focus for a further understanding of how one may affect the other. With factors such as raging temperatures, heat fluxes and dependency on ventilation conditions, the burning path of a fire can be easily influenced and altered, labelling fire an unpredictable and dangerous occurrence (Dehaan, 2008).

Similarly, understanding bone and its composition such as the type, compact or spongey, long, short, or cranial (White, T.D, 2011), can provide a preface of what reactions may occur post-burning/heating. This study not only provides insight towards forensic investigations but also aspects of forensic anthropology, as a strong focus on bones and post-mortem identification is a key factor within anthropological studies (Ciaffie, 2018).

Aims & Objectives

- Look at multiple types of bones in depth and understand the biology and composition of each.
- Understand how fire effectively works and the physics behind it.
- Analyse surface level changes of each bone post-burning/heating.
- Analyse microscopic level changes of each bone post-burning/heating.
- Analyse how various contributing factors may have affected the changes in appearance .i.e. remaining tissue.
- Use multiple techniques, such as SEM, XRF and FT-IR to compare and contrast the changes.

Why study this?

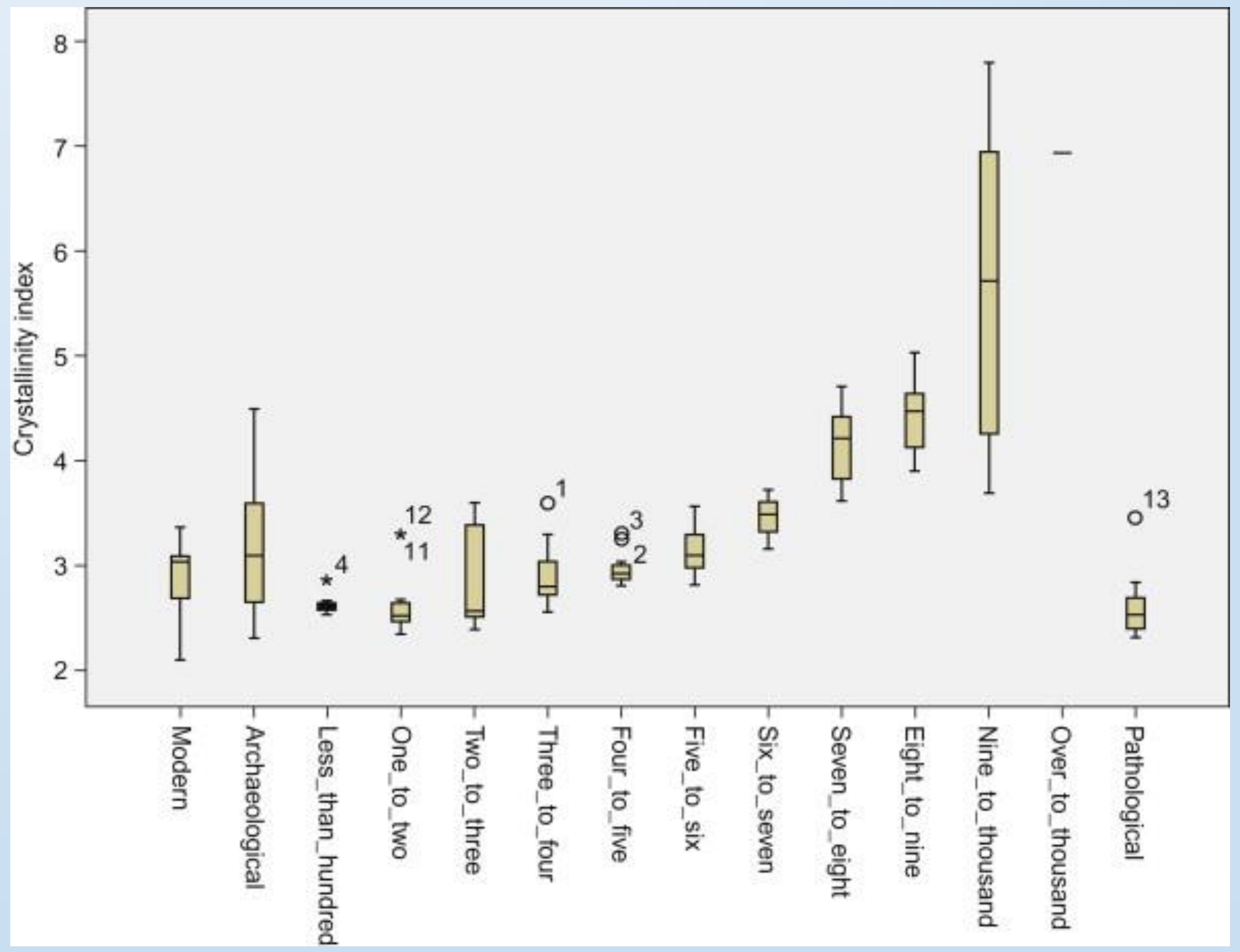
- Adding to the literature on the subject for further studies resources.
- Gaining data that can be applied to real-world scenarios.
- Transferable knowledge that can be applied to other studies in similar fields.

Methodology

This research will focus mainly on the changes in appearance bones will experience after the effects of burning or intense heating. The changes are split into surface level or microscopic changes, with surface level changes including alterations in colour, and the presence of fragmentation or splintering, along with the appearance of burn/heat lines. The microscopic aspects will look into various changes such as changes in hydration levels, the appearance of burn lines, fragmentation/splintering and finally the levels of crystallinity and porosity (Imaizumi, 2015).

As porcine bone samples are quite similar to human (Cone, et al. 2017), the results obtained will provide an understanding of how the levels of fire or intense heat would affect humans, such as in a house fire or industrial accident, which would therefore require forensic investigations. It should be taken into account the differences between porcine and human bone and how this will affect the result is being applied to a realistic scenario. For example, one difference may become clear if using porcine shoulder joints, due to pig being quadrupedal, there is a variation in the shielding pattern different to that of humans (Keough, 2015).

This research will be composed of a primary study into the literature of the topic of forensic investigation in fire and touching on forensic anthropology. This study will include the heating/burning of the bone samples, this will also include varying ignition sources as the types of burning will require a range of accelerants to mimic real life scenarios. The study will include the use of multiple analysis techniques such as Colourimetry for changes in colour, FTIR for collagen levels, XRF to determine the structural materials such as silicone, potassium, and calcium, and finally SEM for other compositional changes.

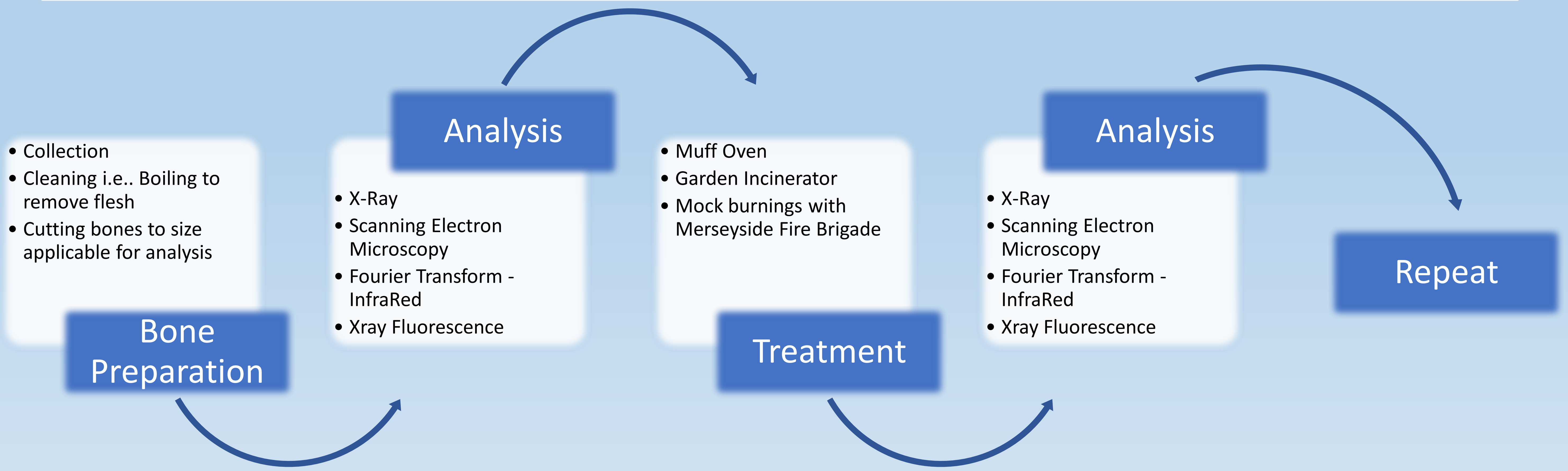


Expected results

There will be expected but similar results for each type of bone, such as an expected change in colour and significant decreases in various minerals, however the specific levels may vary. An expected decrease in collagen levels is expected due to the intense temperatures similarly with a decrease in density and crystallinity. The appearance of fracturing or splintering will able be expected in the bone samples. Contrary to this, an increase in the aspect of porosity is highly anticipated as the intense heat is applied to the bone. Other aspect changes such as minerals and crystallinity will also be observed.

For each of the expected results there is also an expected difference between the alternative bone samples. The varying results will depend on the different composition such as long bone, a cranial bone or possible another bone such as scapula or neck. As each bone is composed of similar, but not exactly alike qualities, the reactions to fire/heating will assumingly provide varying results.

The results will aim to show various changes that can then be compared between the different types of bones and also between the different temperatures used in each burning type. A set parameter of 300 - 900 degrees, in increments of 150 degrees, will be applied and used to obtain vastly different readings throughout each of the potential changes. This parameter will allow to understand the differences in bone composition by how low a temperature may be needed before a change occurs and also how high a temperature the bone may withstand before it may become completely destroyed.



Discussion

Although there is a reduced amount of literature on this particular subject, previous have found results that are similar to what is expected of this study. A key study composed by Thompson in 2015, focused on the analysis of the changes in heat altered crystallinity. The study focused on bones due to their structure as a complex heterogeneous material containing a crystal structure. This particular structure is represented as $Ca_{10}(PO_4)_6(OH)_2$. The understanding of the changes in crystallinity levels allows for a better understanding of the contexts in which a bones or a skeleton has been deposited.

As seen in the image to the left, the study found significant but non-linear changes in the levels of crystallinity post heating. The figure shows a slow change throughout the heating treatment until around 500 degrees Celsius, where there is a clear acceleration in Crystallinity index data was collected with the use of an FTIR (Thompson, 2015). The crystallinity index measures the degree of crystals within a bone sample and is portrayed through a mathematical calculation:

$$\mathrm{CI} = \{A_{565} + A_{605}\} / A_{595}$$

This calculation explores crystallinity through the process of absorbance. A baseline is applied and as the crystal sizes increase, there is a correspondence with the vibrating bands of phosphate thus resulting in an overall increase of the CI (Thompson, 2015). The study concluded that although there have been considerable advances in the deciphering of change in crystallinity within burned bone, the current techniques may require further study for improvements on various aspects such as accuracy, precision and reliability. However, the results of the study are still credible and widely accepted, particularly in understanding the context of burnings rather than heat-induced changes (Thompson, 2015).

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This research project also aims to look at the effects of fire on bones (porcine) alongside various contributing factors, such as remaining soft tissue. A study composed by Keough in 2015, found the remaining tissue to effectively protect the bones and reduce the effects of what may have occurred from burning. The study also found the assessment of the bones after burning also gave an insight into the levels of decomposition the bones were currently at. One indicator found was the appearance of ‘burn lines’ (Keough, 2015). Burn lines are indicators of where soft tissue has remained and thus has left a mark on the bone as it has burned, however the less dense and more decomposed the tissue, the lighter and less dense the burn line.

The study found the results to provide reliable traits that can be applied to scenarios fitting the parameters applied, i.e., 30 minutes burn time with ranging levels of decomposition. The results found a significant differences in the levels of calcification post-burning, with increases in charring as the level of decomposition increased (Keough, 2015).

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