Title page

The comparison and application of silicone casting material for trauma analysis on well preserved archaeological skeletal remains

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*Highlights (for review)

The comparison and application of silicone casting material for trauma analysis on well preserved archaeological skeletal remains

Highlights

- Three silicone-based casting products were compared to identify which was the least destructive and the most effective in recovering tool marks
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- A comparison of the application and the effect of the products on bone revealed that not all casting products are safe to use on skeletal remains

- The microscopic analysis of silicone casts allow for the identification of tool marks previously undetected macroscopically

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ABSTRACT

The analysis of tool marks in bone is important in both archaeological and forensic examination to enhance our knowledge of the funerary context. Some tool mark characteristics are difficult to identify macroscopically and often additional imaging equipment is needed. Microscopic analysis of trauma has proven to be beneficial in determining individual characteristics of tool marks. However, due to the sample size restrictions or pre-analysis treatment of the sample, microscopy is not commonly used to analyse trauma on archaeological skeletal remains. The creation of casts of the tool marks is an obvious solution, but often the perceived risk of damaging the skeletal remains deters its use. Casting materials are used by many forensic scientists but there is little mention within the literature on the effectiveness of using these products to record tool marks on archaeological skeletal remains. This research used three commonly used silicone-based casting products, Xantopren L blue, Mikrosil, and Alec Tiranti RTV putty silicone, to record tool marks in modern and archaeological bone. Forty-five casts were analysed to identify which product is the least destructive and most effective in recovering tool characteristics from the skeletal remains. The results show that all of the products tested were able to replicate blade trauma and allowed the affected area to be analysed in greater detail. A comparison of the application and the effect of the products on bone revealed that Alec Tiranit putty was the best product to use on well preserved archaeological remains. Although the creation of casts using Alec Tiranti putty took longer in comparison to the other products, it did not damage the cortex of archaeological bone whereas this was not the case with Xantopren and Mikrosil. To demonstrate these results on human skeletal remains, Alec Tiranti putty was used to cast peri-mortem modification on an Iron Age cranium from Peterborough, Cambridgeshire. These casts were non-destructive and allowed for previously unidentified tool marks to be discovered.

Keywords: Tool marks; SEM; knife marks; sharp-force trauma; peri-mortem trauma; Iron Age

1. INTRODUCTION

The analysis of sharp-force trauma, specifically, tool marks on human skeletal remains is important in both archaeological and forensic contexts (Andahl, 1978; Bonte, 1975; Fiorato, 2000; Mitchell et al., 2011; Thompson and Inglis, 2009; Symes and Berryman, 1989; Schultz, 2003; Symes et al., 2010; Shipman and Rose, 1983). The analysis of tool marks from archaeological sites has allowed for great advancements in our knowledge of funerary practices (White, 1986), type and effectiveness of stone tools (Domínguez-Rodrigo et al., 2009), butchery practices (Perez et al., 2005; Johnson and Bement, 2009; Garvey et al., 2011; Thompson and Henshilwood, 2014), and post-mortem medical intervention (Dittmar and Mitchell, 2015; Witkin, 2011).

Drawings, exact measurements, and photographic imaging are primarily used to record these features (Errickson et al., 2014). In recent decades scanning electron microscopes (SEM) have been utilised to enhance the detail of traumatic lesions (Rose, 1983; Tucker et al., 2000; Domínguez-Rodrigo, 2009; Sansoni et al., 2009; Symes et al., 2010; Reichs, 1998; Bromage 1984). However, there are a number of limitations to using this type of equipment. For example, the equipment's standoff height (the distance between the stage and lens or beam), can often be a limiting factor, as intact human remains cannot be placed into the average sized SEM chamber. Secondly, some SEMs require the sample to be coated prior to the analysis (Alunni-Perret et al., 2005). This is especially problematic if the remains are human or are from a forensic context. As an alternative, casts have been used to record the traumatic lesions in its three dimensions. The casting material retains the characteristics of the tool mark when removed from the bone in the form of a direct negative.

First outlined by Rose (1983), casting archaeological bone has several advantages, including the portability of casts, and the ability to fit them inside the restrictive chambers of certain microscopes. This in turn, allows for the samples to be analysed under increased magnification (Rose 1983). Prieto (2007) noted that some individual elements become visible even if they have previously gone unnoticed during macroscopic examination. Even though the advantages of analysing tool marks on human skeletal remains microscopically are well established casting is still not utilised to its full extent due to the perceived limitations and conservation concerns.

The most pressing concern of casting archaeological bone is that the casting material may remove the cortex when the cast is removed. The inverse situation, the inability to remove all of the casting material or the staining of the bone by colored materials, is just as undesirable. The literature discussing these issues on archaeological material is rare and often conflicting. Shipman (1981) recommended the use of Xantopren for museum objects but Cook (1986) warned that casting materials such as Xantopren blue may stain archaeological artifacts. There is no mention if these risks are likely to increase if the bone is unfossilised or not perfectly well preserved. The reported limitations of casting within the forensic literature, such as the possibility that casting materials may not recover all of the morphology of a wound (Thali et al., 2003), raise further questions about the suitability of this technique for archaeological remains.

Although various casting products have been utilized by archaeologists since the 1970s, a comparative study has never been undertaken to test the suitability of various casting products for archaeological skeletal remains. This research utilised three silicone-based products as recommended by Du Pasquier et al. (1996) for tool marks. Specifically, Xantopren L blue, Mikrosil, and Alec Tiranti RTV putty silicone were used for recording tool marks on modern and moderately well preserved archaeological bone. The aim of this research is to determine whether casting techniques are useful in providing additional information in comparison to macroscopic analysis, and to assess the destruction and conservation implications when using this material on archaeological skeletal remains.

2. MATERIALS AND METHODS

2.1 Materials

Three sheep femora were macerated and divided into four sections using a hacksaw. The epiphyses were discarded and a series of three incisions, approximately 2cm apart were made on each shaft using an alternate-set hacksaw. A total of nine saw incisions were created. Each of the incisions was made by a single pass of the saw so that an individual saw stria was produced. In addition, six animal bones that displayed evidence of butchery from the Victorian excavation at Preston Kitchen Garden, Middlesbrough (Daniels, 2011) were selected for analysis. The state of preservation of these bones was visually assessed to be in moderate condition with some post-mortem erosion and flaking of the cortex on long bone shafts. The margins of articular surfaces and some prominences are also eroded. The state of weathering according to Behrensmeyer (1987) was designated as phase 2.

The silicone-based casting products used were Xantopren L blue, Mikrosil, and Alec Tiranti RTV silicone putty. Mikrosil is a two-part casting putty that hardens when mixed together which is marketed as being ideal for 'shallow marks with small details, requiring large magnification' (product description). Xantopren L blue is a double mix polysiloxane precision casting material that sets when mixed with a hardener. The silicone putty made by Alex Tiranti Ltd is a two-part compound that also requires the putty and a catalyst to be mixed by hand.

The silicone products were used in rotation to cast the tool marks present on all nine of the incisions located on the sheep bone and all 6 of the archaeological bones. Each casting material was applied in a rotating order on each incision so that any negative effects (either removal or staining of the cortex) could be identified for each substance without risk of any contamination from a previous application (Table 1). A total of 27 casts were made from the trauma on the modern bone and 18 were created of the trauma from the archaeological bone.

Table 1: Showing the rotation order of the casting material, (Xantopren L blue (X), Mikrosil (M), Alec Tiranti RTV silicone putty (AT), on the modern samples (MOD) and the archaeological samples (PKG).

Sample	Casting Order			Sample	Casting Order		
MOD1_1	AT	X	M	PKG1a	AT	X	M
MOD1_2	AT	X	M	PKG2a	AT	M	X
MOD1_3	AT	X	M	PKG3a	X	M	AT
MOD2_4	X	M	AT	PKG4a	X	AT	M
MOD2_5	X	M	AT	PKG5a	M	AT	X
MOD2_6	X	M	AT	PKG6a	M	X	AT
MOD3_7	M	AT	X				
MOD3_8	M	AT	X				
MOD3_9	M	AT	X				

2.2 Methods

2.2.1 Preparation procedures

The Mikrosil paste was mixed with the catalyst in a ratio of 3:2 on a plastic tray using a plastic spoon. The putty was mixed until the mixture began to thicken slightly (approximately 20 seconds) and then immediately applied on the affected area of the bone. The casts were allowed to set for 30 minutes (but were hardened within 3 minutes) and then carefully removed. Xantopren L blue paste was mixed with a hardener at a ratio of 3:2 using the same methods described for the Mikrosil. These casts had set within 5 minutes and were then removed. The putty silicone by Alec Tiranti was mixed in a 1:10 ratio of catalyst to putty, as per instructions. The 2 substances were kneaded together with gloved hands until thoroughly mixed and the color became a uniform yellow. The putty was then placed onto the affected area and pressed down lightly to ensure the putty filled the kerf. The casts were left to cure for 60 minutes before removal.

2.2.2 Removal and Analysis

All modern and archaeological bones and 45 casts were macroscopically assessed and then microscopically analysed using a Hitachi TM3000 Tabletop SEM. The surface of the bone was visually assessed after the removal of each cast so that any damage to the bone could be identified. Each cast was also examined immediately following removal for structural integrity (i.e. any gaps in the casting material due to air bubbles or tearing due to improper mixing) and for the presence of cortical bone and other casting material. Any defects in the casting material or adherent cortex were recorded. Following SEM analysis, all images were examined for evidence of damage to the bone's cortex and to observe whether the casting material could accurately capture the exact characteristics of the tool mark.

The overall suitability of each casting material was assessed by averaging the scores of both the technical application of the material, and the effect each product had on the osteological remains when the casting material was removed. The time required for each material to set was also recorded. Each category was judged on a 1-3 scale (see Table 1).

3. RESULTS

3.1 Technical Application of Materials

When mixing Xantopren it was difficult to approximate the amount of catalyst required to achieve the desired texture, which influenced the application. When the amount of catalyst was underestimated the mixture did not set making it difficult to apply to target area. Similar difficulties were found when estimating the catalyst to paste ratio with Mikrosil, however the opposite effect occurred and the mixture rapidly set before it could be applied to the bone. No problems were encountered when mixing the putty by Alec Tiranti or applying the material. Mikrosil had the shortest time required to set (2-4 minutes), followed by Xantopren (4-8 minutes) followed distantly by Alec Tiranti putty which required 45-60 minutes. All of the completely set casts from all three materials were easily removed from the bone surface.

3.2 Assessment of Damage to Bone Surface

The 27 casts made from the modern bone samples did not show any evidence of removing the cortex during removal. More surprisingly, of the 18 archaeological casts examined, none of them appeared to remove bone cortex. These results were confirmed by the SEM analysis of the bones' surface following casting. 66.6% (4/6) of the Alec Tiranti casts did pick up a large amount of soil that was adhered to the bone, especially from within the medullary cavity. In two cases the adhered soil obscured the tool marks and required a further two casts to be repeated.

3.3 Staining and Visible Residues

After the removal of Mikrosil casts, a brown residue was present on 40% (6/15) of the casts made on the modern and archaeological bone. Staining appeared on 22% (2/9) of the casted areas on modern bone and on 66% (4/6) of the casted areas on the archaeological bone. This residue was not always apparent to the naked eye as an additional case where a residue was left on an archaeological bone was detected by brown residue on an Alec Tiranti cast, which stained the cast brown. Similarly, Xantopren L blue also left behind a residue on the cortex of both the archaeological and modern bone. Blue residue was also picked up by the Alec Tiranti putty on 33% (3/9) of casting sites on modern bone and on 50% (3/6) of the areas casted on the archaeological bone. No evidence of permanent staining was caused by Alec Tiranti putty (see discussion).

Figure 1: Alec Tiranti putty cast of trauma showing adhering Xantopren L blue removed from the surface of an archaeological bone

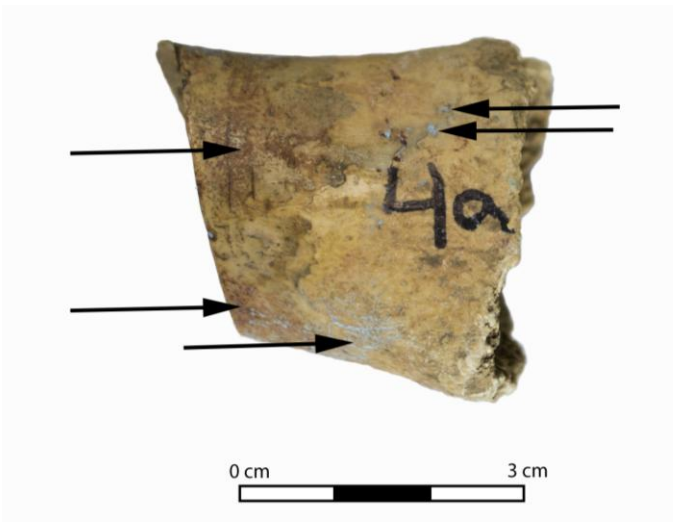

Figure 2: Archaeological bone showing staining from Xantopren L blue and Mikrosil

3.4 Analysis of the Cut Marks and Visibility of Features

All of the 45 casts created on both modern and archaeological bone replicated the tool mark on each sample. The characteristics of the tool marks were easily identifiable across all three types of silicone material. In addition, SEM analysis identified additional tool marks on two archaeological samples that were not seen macroscopically.

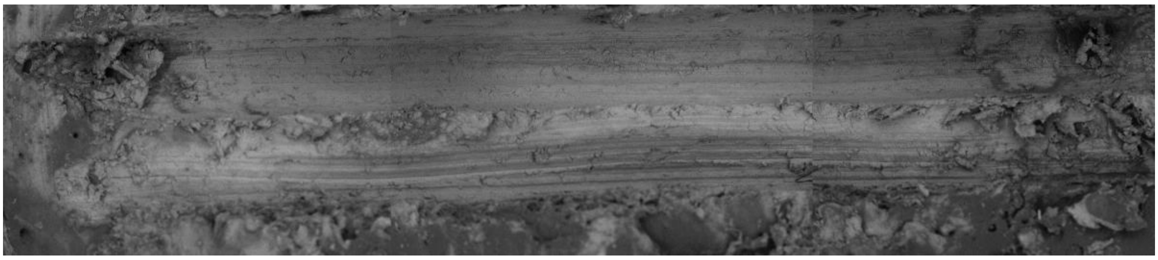

Figure 3: SEM composite micrograph (x30) of kerf number 7 in modern bone

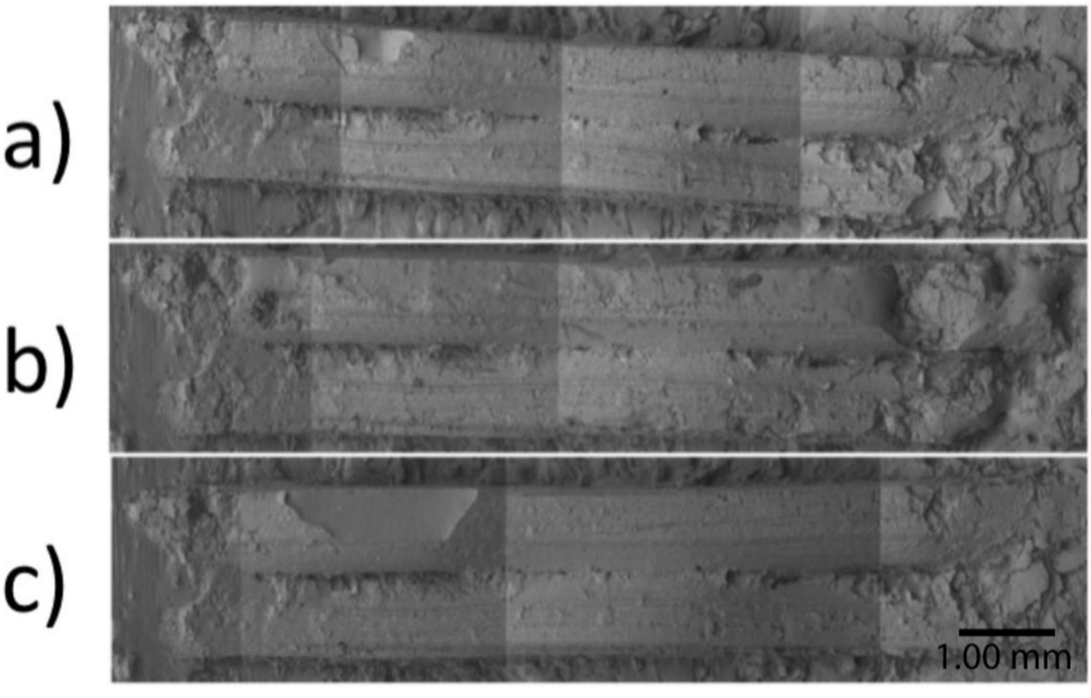

Figure 4: SEM composite micrographs (x30) of casts made of kerf 7 with a) Alec Tiranti putty silicone b) Mikrosil and c) Xantopren L blue

Table 2: Comparison of Xantopren L blue, Mikrosil and Alec Tiranti casting material on modern and archaeological bone assessing the technical application of material and the effect of the product on osteological material

		Xantopren	Microsil	Alec Tiranti	Key
Technical application of material	Mixing	3	2	1	1: Easy to execute actions, requires minimal effort to achieve desired result. 2: Moderate effor required to achive desired results, re-reading or additional attempts may be undertaken. 3: Very difficult to execture action, or high failure rate of procedure resulting in multiple attempts before achieving desired result, or results not achieved.
	Application	2	2	1	
	Set Time	2	1	3	
	Removal	1	1	1	
Effects on osteological material	Damage to cortex	1	1	1	1: None 2: Moderate 3: Significant
	Staining	3	3	1	
	Air gaps	2*	2*	2*	
Suitability for use on bone		2	1.71	1.43	

*Dependant on application and corrext mixing

4. DISCUSSION

4.1 Technical Application of Materials

Several problems were encountered when mixing and applying Mikrosil and Xantopren, but not when mixing the Alec Tiranti putty. The mixing process of Alec Tiranti is guided by visual cues in the form of a change in colour. This visual change in color ensures the appropriate mixing duration. The golden yellow catalyst material is mixed with the white putty until the mixture is a uniform pale yellow colour. The colour change also can be used as a guide to ensure the appropriate ratio of catalyst to putty. The lack of visual cues when mixing the catalyst and the paste in Mikrosil and Xantopren likely contribute to the improper mixing and thus, the problems encountered during application.

An effect of improper mixing was encountered through the creation of air pockets within the casting material. The air pockets created ‘gaps’ within the cast of the kerf resulting in the loss of some information (Figure 3). These air pockets are a result of the casting material not completely filling the tool mark or the incomplete mixing of the casting material and catalyst. These results echo Thali et al. (2003) who stated ‘some fine details of the wound morphology often cannot be recorded.’ This is a concern because important information may remain unrecorded. However further impressions of the same area can be made to ensure this is not an issue. All of the products had at least one cast that had to be redone because the cast did not reach the bottom of the kerf floor. These ‘air gaps’ seem to be more dependent on the way the putty is applied by the user, rather than the product itself. Practice with the material is recommended before replicating the methods used in this study on archaeological material.

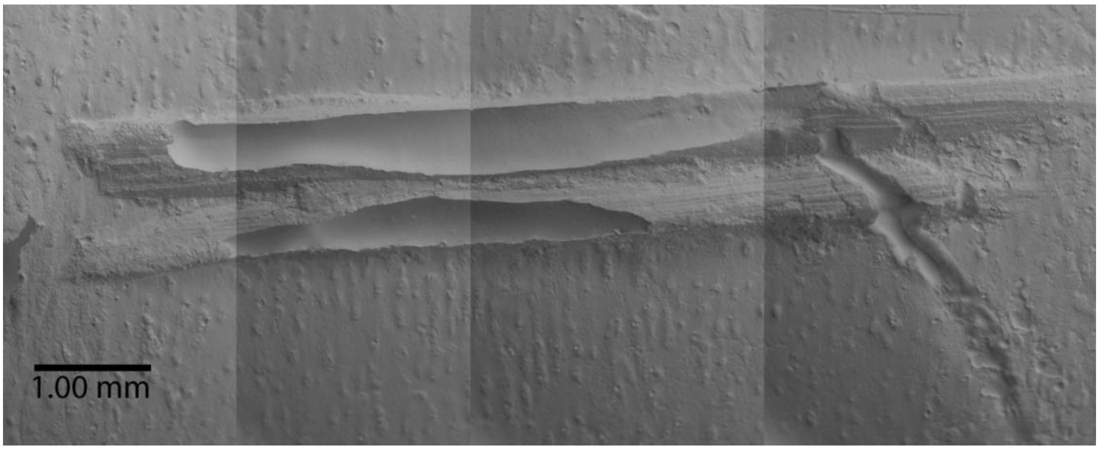

Figure 5: Composite SEM micrograph (x30) showing 'gaps' created by air pockets in a Mikrosil cast

The clean removal of the casts shows that the possibility of well-preserved bone being destroyed or the removal of the bone's cortex is not an issue. Although this method is a contact technique, the results show none of the bone's morphological appearance was altered with any of the casts. This is important because this technique has largely been unused due to these concerns, but these results show that these concerns can now be dismissed. Although all of the products tested had limitations, none of them caused physical damage to the cortex of moderately-robust archaeological bones during the removal process.

An additional consideration of these materials is cost. Alec Tiranti (which is demonstrated to be the most appropriate) costs approximately £27.00 where Xantopren L blue costs significantly more at around £74.00. The least expensive product to purchase is Mikrosil which costs around £23.00. Therefore, on top of Alec Tiranti's applicable advantages, the material is also affordable.

4.2 Effect of the Products on Osteological Material

Staining and residues left on the cortex proved to be the greatest conservational concern. Cook (1986) stated that material like Xantopren L blue might stain an object, which was supported in our research. These results also show that staining was a problem when using Mikrosil on both archaeological and modern bones. Therefore, the authors caution against Xantopren L blue and Mikrosil for use on archaeological skeletal material. No staining was recorded on the bones when using the Alec Tiranti putty. However, it should be noted that the presence of a clear residue or 'wet' spot was temporarily present at the location of the cast on the cortex of some of the archaeological bones. These stains were greasy to touch and were the result of using too much of the catalyst in the mixture. Although additional experiments can be undertaken to analyse whether there was any chemical composition change to the bone as a result of this, visually the bone remained unaltered and the stain disappeared almost immediately. Therefore the research demonstrates that Alec Tiranti can be safely used to cast tool marks on robust skeletal remains.

4.3 Replication and Analysis of Cut Marks

All of the correctly casted tool marks replicated the intended trauma. In addition to the tool marks recorded, the casts also recovered characteristics that were previously unnoticed macroscopically. Likewise, as the casts are replicating the lesion, measurements can be taken allowing the collection of depth, shape, and topography data for further quantitative evaluation. Measurements taken, e.g. on the kerf width, may give additional information on the type of blade used (Symes et al., 2010). Substantially, the cut mark can be documented indefinitely allowing analysis even long after the skeletal remains have degraded or been reburied. This can have a large impact on the analysis of skeletal trauma as additional unrecorded tool marks may be present that in turn provide further contextual information.

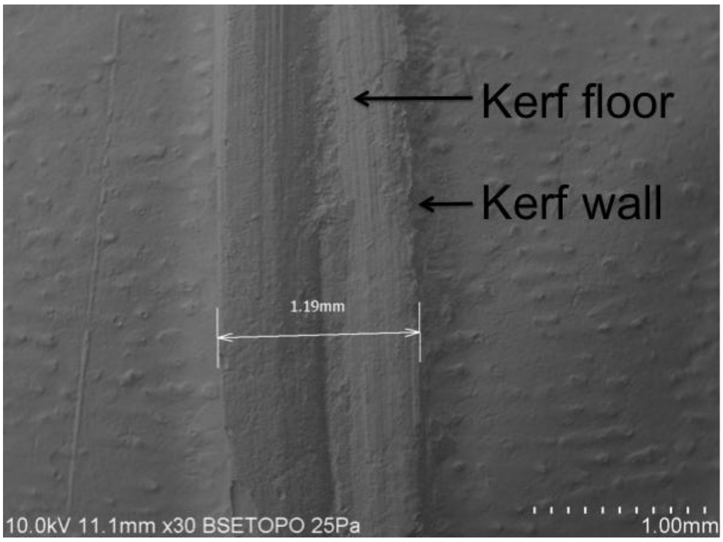

Figure 6: SEM micrograph (x30) showing the saw mark characteristics and the kerf width measurement

4.3 Case Study

Image 7: Reconstructed cranium of burial 90 from Stanground South, Peterborough, Cambridgeshire

To demonstrate the results of this research an Iron Age cranium excavated at Stanground South, Peterborough, Cambridgeshire [burial 90] that exhibited several peri-mortem modifications was selected for analysis (Taylor, Unpublished). The cranium, although initially fragmented, had been reconstructed prior to analysis. Therefore, any analysis using instruments with a low standoff height (such as an SEM) could not be accomplished. Consequently, the authors took casts using Alex Tiranti putty on several significant locations across the cranium using the method discussed in this paper.

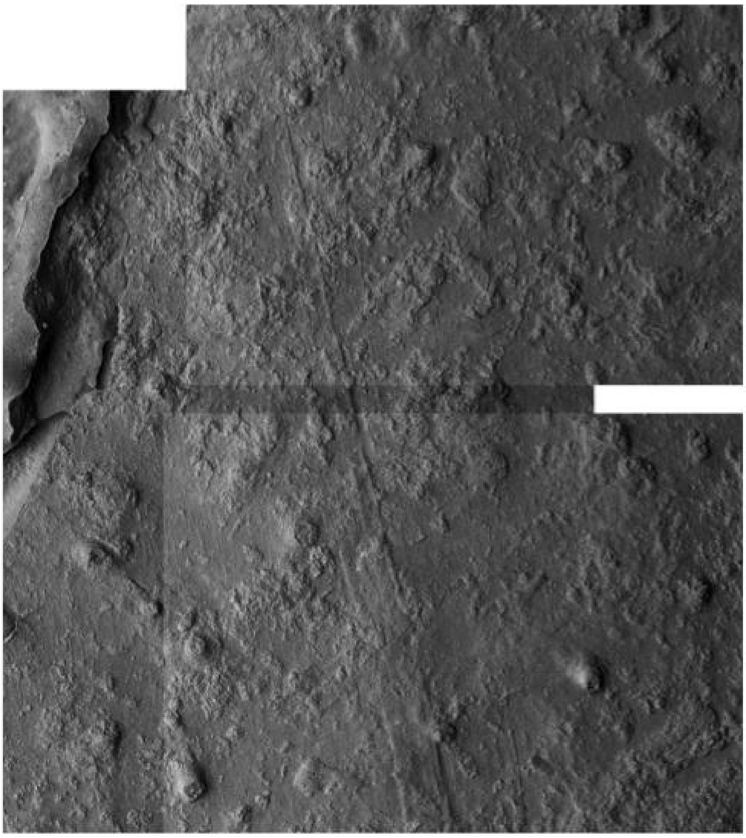

Figure 8: SEM micrograph showing extensive tool mark trauma on a cranium from burial 90 from Stanground South, Peterborough, Cambridgeshire

Upon removal of the casting material the cranium was neither modified nor damaged. The casts were then observed under a SEM at 40x-100x magnification. These micrographs clearly showed the intended tool marks on the cranium. Interestingly several additional tool marks that had been previously unnoticed were also observed (Figure 6). Furthermore, the results showed the use of more than one tool. These findings are similar to those by Prieto (2003) who discussed the visualisation of previously unseen marks. This is important because aspects of the purposeful alteration of the Stanground cranium may have never been visualised without this casting method. This case study demonstrates the value of casting for revealing additional unseen information without damaging the cortex.

5. CONCLUSION

Silicone casting material has been sporadically used for casting a range of objects. With regards to archaeological human remains, a comparison of the different silicone casting materials has never been previously undertaken. In this study it is demonstrated that although the Alec Tiranti putty took longer to apply and set in comparison to the other techniques used, it did not damage the cortex or the bone when lifted from the surface unlike the Xantopren and Mikrosil methods which stained the cortex blue and brown respectively. This additional time constraint is meaningless if the necessity to conserve bone is taken into consideration. Therefore, although practice with the material is recommended before replicating cut marks in bone, Alec Tiranti can be safely used based on the results of this research.

The results of this research may have a great impact on how blade trauma on archaeological material is analysed. Blade trauma is primarily analysed visually while microscopic analysis is often rejected due to the sample size limitations. Most commonly, in archaeological assemblages blade trauma is identified on the skull, but large items such as crania cannot be placed within most SEM chambers due to the machine's standoff height. The creation of impressions is an obvious solution, but often the perceived risk of damaging the element deters its use. However, the results of this research show that silicone casts allow for sharp force trauma to be recorded and analysed in greater detail while not damaging modern or archaeological samples. Further research is required to assess the chemical integrity of the bone and how contact with the casting materials may affect other analyses.

The authors agree casting would be ideal to document the morphology of sharp-force trauma especially if the remains are rapidly deteriorating or to be reburied. This allows additional analysis that otherwise may not be possible.

5.1 Considerations

The authors advise caution when using these methods on fragile objects and recommend further experiments are undertaken before casts on fragile objects become commonplace.

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7. REFERENCES

Alunni-Perret, V., Muller-Bolla, M., Laugier, JP., Lupi-Pegurier, L., Bertrand, MF., Staccini, P., Bolla, M., Quatrehomme, G., 2005. Scanning electron microscopy analysis of experimental bone hacking trauma. Journal of Forensic Science. 50 (4), pp. 796-801.

Andahl, R. O., 1978. The examination of saw marks. Journal of the Forensic Science Society. 18, pp. 31-46.

Behrensmeyer, A. K. 1978. Taphonomic and ecologic information from bone weathering. Paleobilogy 4 (2): 150-162.

Bonte, W., 1975. Tool marks in bones and cartilage. Journal of Forensic Sciences. 20, pp. 315-325.

Bromage, Timothy G., and Alan Boyde, 1984. Microscopic Criteria for the Determination of Directionality of Cutmarks on Bone. American Journal of Physical Anthropology 65:359-366.

Cook, J. 1986. The application of Scanning Electron Microscopy to Taphonomic and Archaeological Problems. In: Studies in the Upper Palelthic of Britain and Northwest Europe, edited by D. A. Roe pp143-163. BAR International Series 296. British Archaeological Reports, Oxford.

Daniels, R., 2011. Archaeological investigations at the Kitchen Garden, Preston Park. Unpublished Report, 11/11.

Dittmar-Blado, J. and Wilson, A.S., 2012. Microscopic examination of the tool marks. In: Powers, N. and Fowler, L. (Eds.) Doctors, dissection and resurrection men: excavations in the 19th-century burial ground of the London Hospital, 2006. MOLA Monograph Series 62. Laverham Press, London, pp. 180-184.

Dittmar, J.M. and Mitchell, P.M. 2015. New criteria for identifying and differentiating human dissection and autopsy in archaeological assemblages. *Journal of Archaeological Science: Reports*, Volume 3. doi:10.1016/j.jasrep.2015.05.019

Domínguez-Rodrigo, M., De Juana, S., Galán, A. B., & Rodríguez, M. (2009). A new protocol to differentiate trampling marks from butchery cut marks. *Journal of Archaeological Science*, *36*(12), 2643-2654.

Errickson, D., Thompson, T.J.U., Rankin, B.W.J., 2014. The application of 3D visualization of osteological trauma for the courtroom: A critical review. Journal of Forensic Radiology and Imaging. 2 (3), pp. 132-137.

Fiorato, V., Boylston, A., & Knüsel, C., 2000. Blood red roses: The archaeology of a mass grave from the Battle of Towton AD 1461. Oxbow, Oxford [England].

Garvey, J., Cochrane, B., Field, J., Boney, C. 2011. Modern emu (*Dromainus novehollandiae*) butchery economic utility and analysis for the Australian archaeological record. Environmental Archaeology 16 (2): 97-112.

Johnson, E., & Bement, L. C. 2009. Bison butchery at Cooper, a Folsom site on the Southern Plains. Journal of Archaeological Science. 36: 1430-1446.

Mitchell, P. D., Boston, C., Chamberlain, A. T., Chaplin, S., Chauhan, V., Evans, J., Fowler, L., Powers, N., Walker, D., Webb, H., Witkin, A., 2011. The study of anatomy in England from 1700 to the early 20th century. Journal of Anatomy, 219(2), pp. 91–99. doi:10.1111/j.1469-7580.2011.01381.x

Pasquier, E.D., Hebrard, J., Margot, P., Ineichen, M., 1996. Evaluation and comparison of casting materials in forensic sciences: Applications to tool marks and foot/shoe impressions. Forensic Science International. 82, pp. 33-43.

Perez, V. R., Godfrey, L. R., Nowak-Kemp, M., Burney, D. A., Ratsimbazafy, J., Vasey, N. 2005. Evidence of early butchery of giant lemurs in Madagascar. Journal of Human Evolution. 49: 722-742.

Prieto, J. L., 2007. Stab wounds: the contribution of forensic anthropology: A Case Study. In: Brickley, M. B., Ferllini, R. (Eds.) Forensic Anthropology: Case Studies from Europe. Charles C Thomas, Springfield, IL, pp. 19-37.

Reichs, K. J., 1998. Forensic osteology. Advances in the identification of human remains, 2nd edition. Charles C. Thomas, Springfield, IL.

Rose,J.J., 1983. A Replication Technique for Scanning Electron Microscopy: Applications for Anthro-pologists. American Journal of Physical Anthropology 62:255-263.

Sansoni, G., Cattaneo, C., Trebeschi, M., Gibelli, D., Porta, D., Picozzi, M., 2009. Feasibility of contactless 3D optical measurement for the analysis of bone and tissue lesions: new technologies and perspectives in forensic sciences. J. Forensic Sci. 54 (3), pp. 540-545.

Schultz, M. 2003. Light microscopic analysis in skeletal paleopathology. In: Ortner, D. J. 2003. Identification of pathological conditions in human skeletal remains. 73-107.

Shipman, P., 1981. Applications of Scanning Electron Microscopy to Taphonomic Problems. Annals of the New York Academy of Sciences. 376, pp. 357-386.

Shipman, P., and J.J. Rose, 1983. Evidence of Butchery and Hominid Activity at Torralba and Ambrona: An Evaluation Using Microscopic Techniques. Journal of Archaeological Science 10(3):465-474.

Symes, S. A., Chapman, E. N., Rainwater, C. W., Cabo, L.L., Myster, S. M. T., 2010. Knife and saw toolmark analysis in bone: A manual designed for the examination of criminal mutilation and dismemberment. National Institute of Justice: Report number: NCJ 232227.

Symes, S. A., Berryman, H. E., 1989. Dismemberment and mutilation: General saw type determination from cut surfaces of bone. 41st Annual Meeting of the American Academy of Forensic Sciences, Las Vegas, NV. February 13-18.

Taylor, E., Wolframm-Murray, Y., Yates, A., 2011. Archaeological Excavation at Stanground South Peterborough: Assessment Report and Updated Project Design, Northamptonshire Archaeology, Unpublished Report 11/01

Thali, M.J, Braun, M., Brueschweiler, W., Dirnhofer, R., 2003a. ‘Morphological imprint’ determination of the injury-causing weapon from the wound morphology using forensic 3D/CAD supported photogrammetry. Forensic Science International. 132 (3), pp. 177-181.

Thali, MJ., Braun, M., Dirnhofer., 2003b. Optical 3D surface digitizing in forensic medicine: 3D documentation of skin and bone injuries. Forensic Science International. 137, pp. 203-208.

Thompson, J. C., Henshilwood, C. S. 2014. Tortoise taphonomy and tortoise butchery patterns at Blomboc Cave, South Africa. Journal of Archaeological Science. 41: 214-229.

Thompson, T. J. U. and Inglis, J. 2009. 'Differentiation of serrated and non-serrated blades from stab marks in bone', International Journal of Legal Medicine, 123 (2), pp.129-135. 10.1007/s00414-008-0275-x

Tucker, B. K., Hutchinson, D. L., Gilliland, M. F., Charles, T. M., Daniel, H. J., & Wolfe, L. D. 2001. Microscopic characteristics of hacking trauma. *Journal of forensic sciences*, *46*(2), 234-240.

Witkin, A. V., 2011. The Health of the Laboring Poor, Surgical and Post-mortem Procedures, 2 at the Bristol Royal Infirmary, 1757-1854: A Biohstorical Approach. PhD Thesis, University of Bristol.

White, T. D., 1986. Cut Marks on the Bodo Cranium: A Case of Prehistoric Defleshing. American Journal of Physical Anthropology 69:503-509.

Table 2

		Xantopren	Microsil	Alec Tiranti	
Technical application of material	Mixing	3	2	1	1: Easy to exec minimal effort 2: Moderate ef desired results, attempts may b difficult to exe failure rate of p multiple attemp desired result,
	Application	2	2	1	
	Set Time	2	1	3	
	Removal	1	1	1	
Effects on osteological material	Damage to cortex	1	1	1	1: None 2:
	Staining	3	3	1	
	Air gaps	2*	2*	2*	
Suitability for use on bone		2	1.71	1.43	

*Dependant on application and corrext mixing

Alec Tiranti putty cast of trauma showing adhering Xantopren

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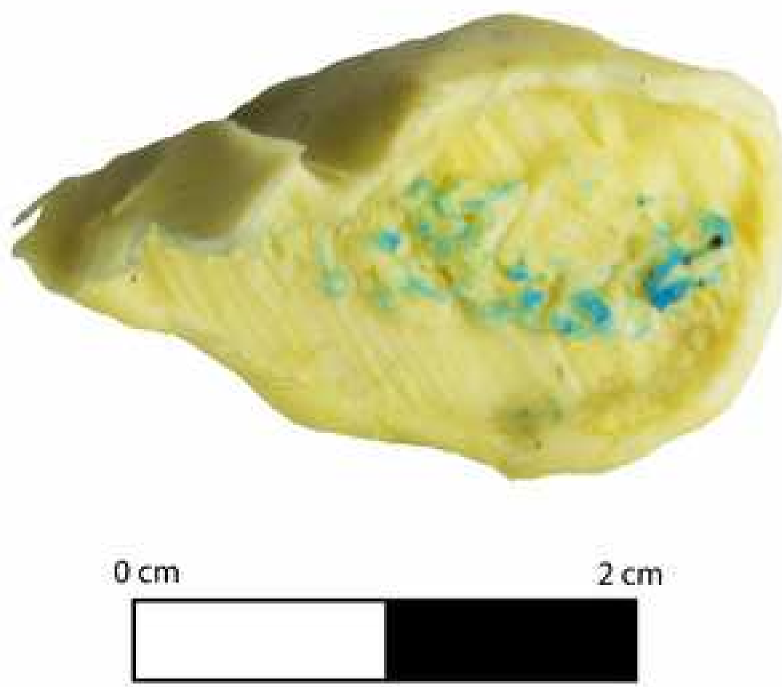

Archaeological bone showing adhering Xantopren and Mikrosil

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SEM composite micrograph (x30) of kerf number 7 in modern bone

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SEM composite micrographs of casts made of kerf 7 with a) Alec T
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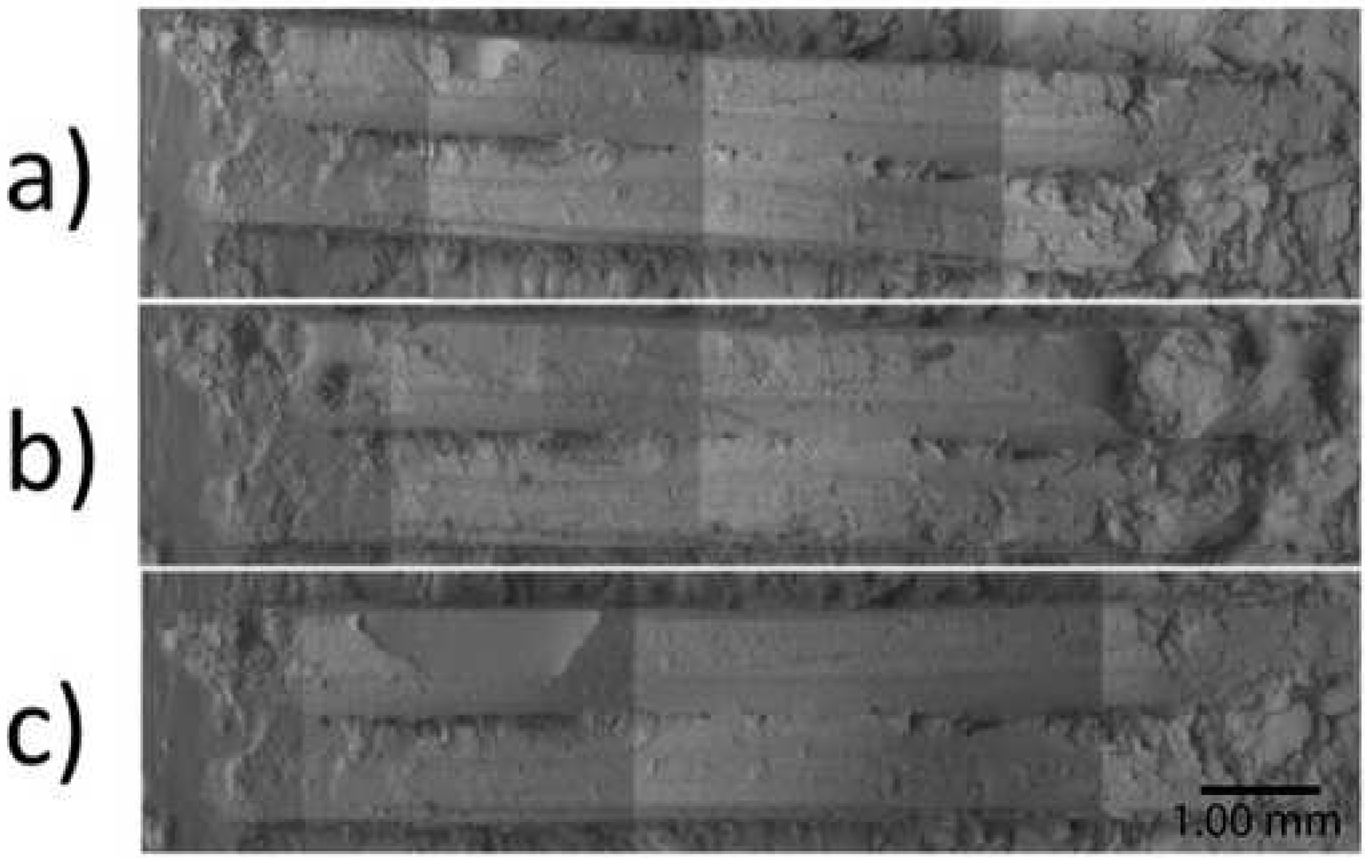

Composite SEM micrograph showing 'gaps' created by air pockets i
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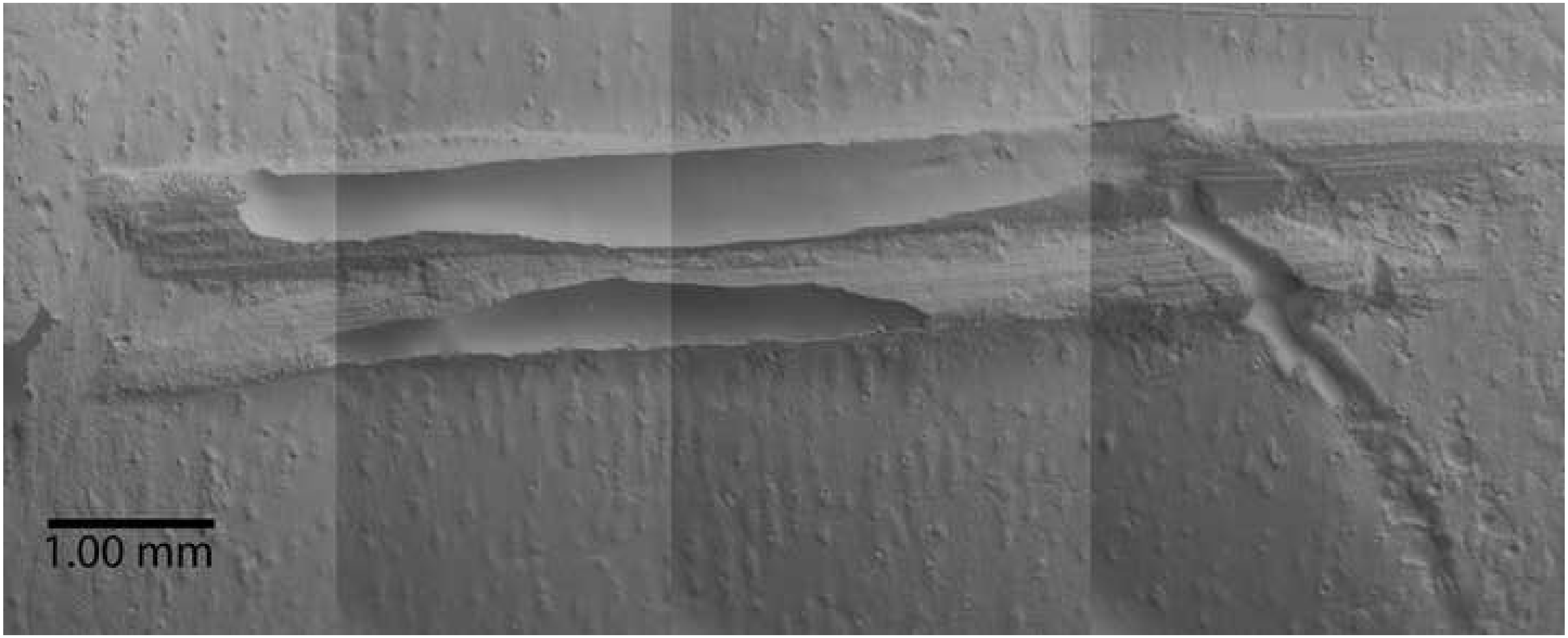

SEM micrograph showing the saw mark characteristics and the kerf

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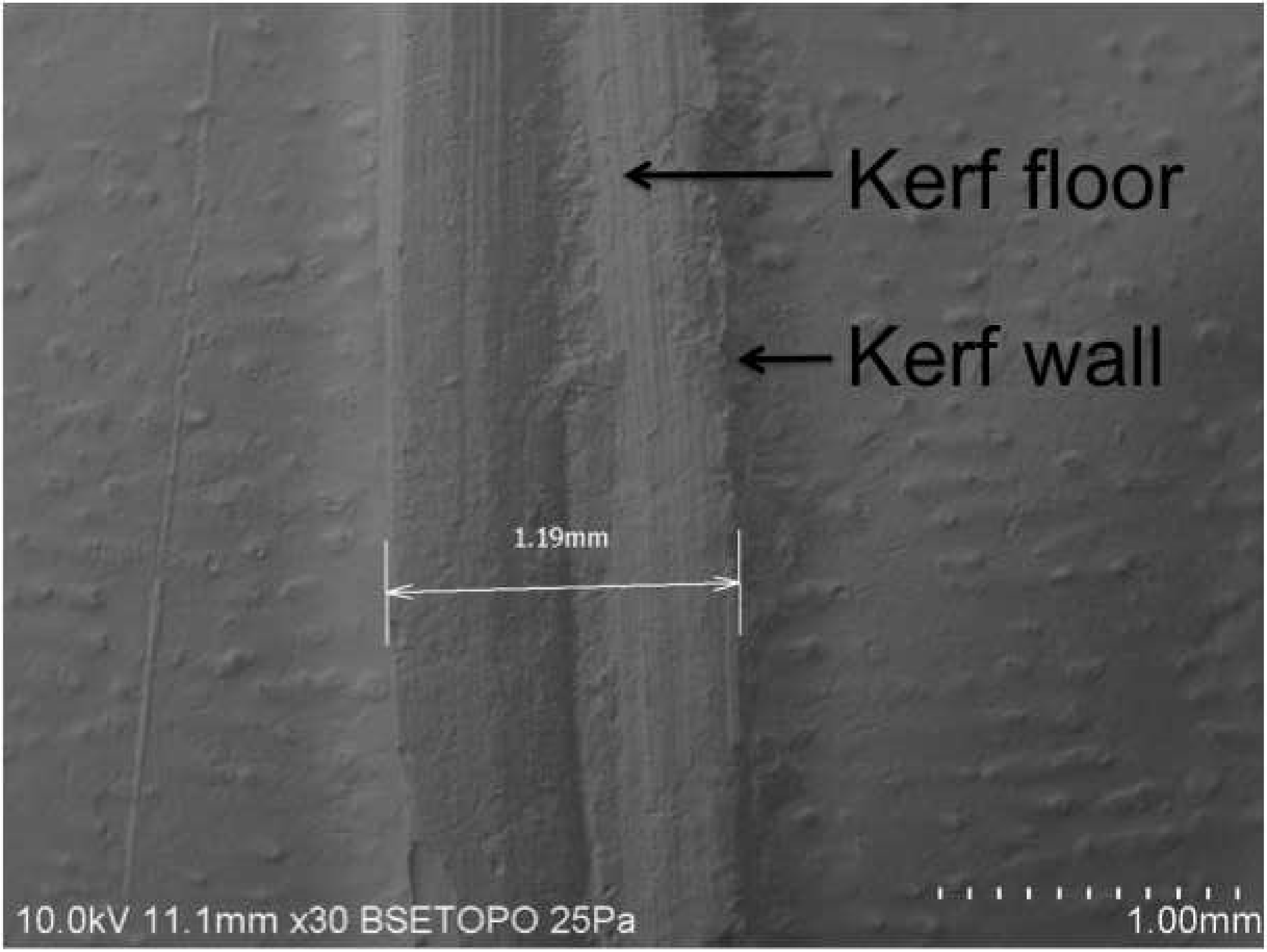

Reconstructed cranium of burial 90 from Stanground South, Peterb

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SEM micrograph showing extensive tool mark trauma on a cranium f

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