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

Jenna M.Dittmar<sup>1\*</sup>, David Errickson<sup>2</sup>, Anwen Caffell<sup>3,4</sup>

\*Correspondence author

<sup>1</sup>Department of Archaeology and Anthropology, University of Cambridge, The Henry Wellcome Building, Fitzwilliam Street, Cambridge CB2 1QH

<sup>2</sup> School of Science and Engineering Teesside university, Borough Road, Middlesbrough TS1 3BA

<sup>3</sup> Department of Archaeology, Durham University, Dawson Building, Department of Archaeology, South Road, Durham DH1 3LE

<sup>4</sup> York Osteoarchaeology, Ivy Cottage, 75 Main Street, Bishop Wilton, York YO42 1SR

Corresponding author: Jenna M. Dittmar  
Correspondence email: [jjdd2@cam.ac.uk](mailto:jjdd2@cam.ac.uk)  
Phone: +44 (0)7415 183226

## **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
- 
- 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

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

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4 **\*Corresponding author email [jjdd2@cam.ac.uk](mailto:jjdd2@cam.ac.uk)**

5  
6 **ABSTRACT**

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

32  
33 **Keywords:** Tool marks; SEM; knife marks; sharp-force trauma; peri-mortem trauma;  
34 Iron Age

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37 **1. INTRODUCTION**

38 The analysis of sharp-force trauma, specifically, tool marks on human skeletal  
39 remains is important in both archaeological and forensic contexts (Andahl, 1978;  
40 Bonte, 1975; Fiorato, 2000; Mitchell et al., 2011; Thompson and Inglis, 2009; Symes  
41 and Berryman, 1989; Schultz, 2003; Symes et al., 2010; Shipman and Rose, 1983).  
42 The analysis of tool marks from archaeological sites has allowed for great  
43 advancements in our knowledge of funerary practices (White, 1986), type and  
44 effectiveness of stone tools (Domínguez-Rodrigo et al., 2009), butchery practices  
45 (Perez et al., 2005; Johnson and Bement, 2009; Garvey et al., 2011; Thompson and  
46 Henshilwood, 2014), and post-mortem medical intervention (Dittmar and Mitchell,  
47 2015; Witkin, 2011).

48  
49 Drawings, exact measurements, and photographic imaging are primarily used to  
50 record these features (Errickson et al., 2014). In recent decades scanning electron

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

63

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

72

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

84

85 Although various casting products have been utilized by archaeologists since the  
86 1970s, a comparative study has never been undertaken to test the suitability of various  
87 casting products for archaeological skeletal remains. This research utilised three  
88 silicone-based products as recommended by Du Pasquier et al. (1996) for tool marks.  
89 Specifically, Xantopren L blue, Mikrosil, and Alec Tiranti RTV putty silicone were  
90 used for recording tool marks on modern and moderately well preserved  
91 archaeological bone. The aim of this research is to determine whether casting  
92 techniques are useful in providing additional information in comparison to  
93 macroscopic analysis, and to assess the destruction and conservation implications  
94 when using this material on archaeological skeletal remains.

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96

## 97 **2. MATERIALS AND METHODS**

### 98 **2.1 Materials**

99 Three sheep femora were macerated and divided into four sections using a hacksaw.  
100 The epiphyses were discarded and a series of three incisions, approximately 2cm apart

101 were made on each shaft using an alternate-set hacksaw. A total of nine saw incisions  
 102 were created. Each of the incisions was made by a single pass of the saw so that an  
 103 individual saw stria was produced. In addition, six animal bones that displayed  
 104 evidence of butchery from the Victorian excavation at Preston Kitchen Garden,  
 105 Middlesbrough (Daniels, 2011) were selected for analysis. The state of preservation  
 106 of these bones was visually assessed to be in moderate condition with some post-  
 107 mortem erosion and flaking of the cortex on long bone shafts. The margins of  
 108 articular surfaces and some prominences are also eroded. The state of weathering  
 109 according to Behrensmeyer (1987) was designated as phase 2.

110

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

118

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

126

127

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

131

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				

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## 2.2 Methods

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### 2.2.1 Preparation procedures

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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

141 hardener at a ratio of 3:2 using the same methods described for the Mikrosil. These  
142 casts had set within 5 minutes and were then removed. The putty silicone by Alec  
143 Tiranti was mixed in a 1:10 ratio of catalyst to putty, as per instructions. The 2  
144 substances were kneaded together with gloved hands until thoroughly mixed and the  
145 color became a uniform yellow. The putty was then placed onto the affected area and  
146 pressed down lightly to ensure the putty filled the kerf. The casts were left to cure for  
147 60 minutes before removal.

148

### 149 **2.2.2 Removal and Analysis**

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

160

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

166

167

## 168 **3. RESULTS**

### 169 **3.1 Technical Application of Materials**

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

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### 182 **3.2 Assessment of Damage to Bone Surface**

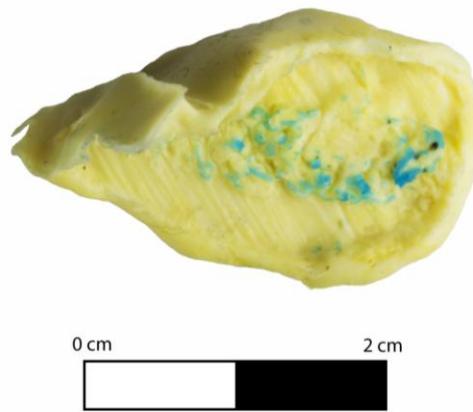
183 The 27 casts made from the modern bone samples did not show any evidence of  
184 removing the cortex during removal. More surprisingly, of the 18 archaeological casts  
185 examined, none of them appeared to remove bone cortex. These results were  
186 confirmed by the SEM analysis of the bones'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

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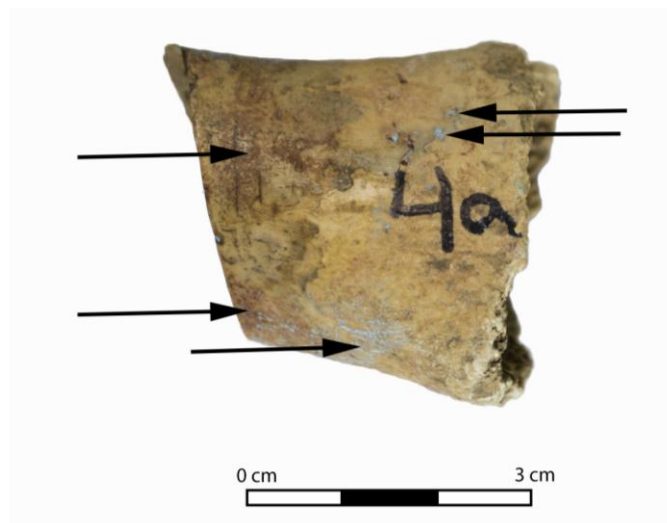
191 **3.3 Staining and Visible Residues**

192 After the removal of Mikrosil casts, a brown residue was present on 40% (6/15) of the  
193 casts made on the modern and archaeological bone. Staining appeared on 22% (2/9)  
194 of the casted areas on modern bone and on 66% (4/6) of the casted areas on the  
195 archaeological bone. This residue was not always apparent to the naked eye as an  
196 additional case where a residue was left on an archaeological bone was detected by  
197 brown residue on an Alec Tiranti cast, which stained the cast brown. Similarly,  
198 Xantopren L blue also left behind a residue on the cortex of both the archaeological  
199 and modern bone. Blue residue was also picked up by the Alec Tiranti putty on 33%  
200 (3/9) of casting sites on modern bone and on 50% (3/6) of the areas casted on the  
201 archaeological bone. No evidence of permanent staining was caused by Alec Tiranti  
202 putty (see discussion).

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205 *Figure 1: Alec Tiranti putty cast of trauma showing adhering Xantopren L blue*  
206 *removed from the surface of an archaeological bone*  
207  
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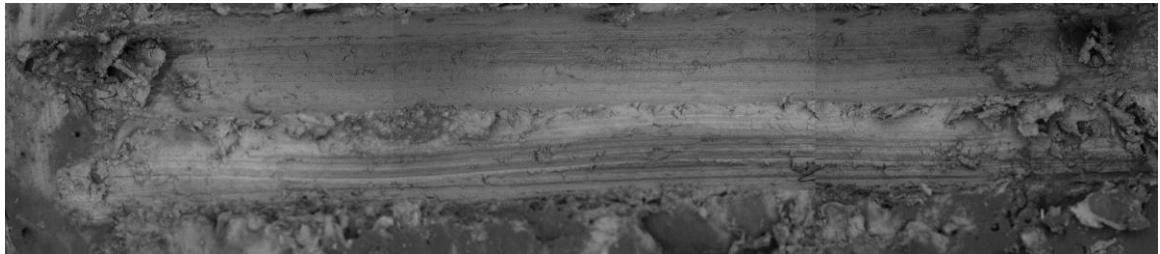
209 *Figure 2: Archaeological bone showing staining from Xantopren L blue and Mikrosil*  
210  
211 **3.4 Analysis of the Cut Marks and Visibility of Features**  
212



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

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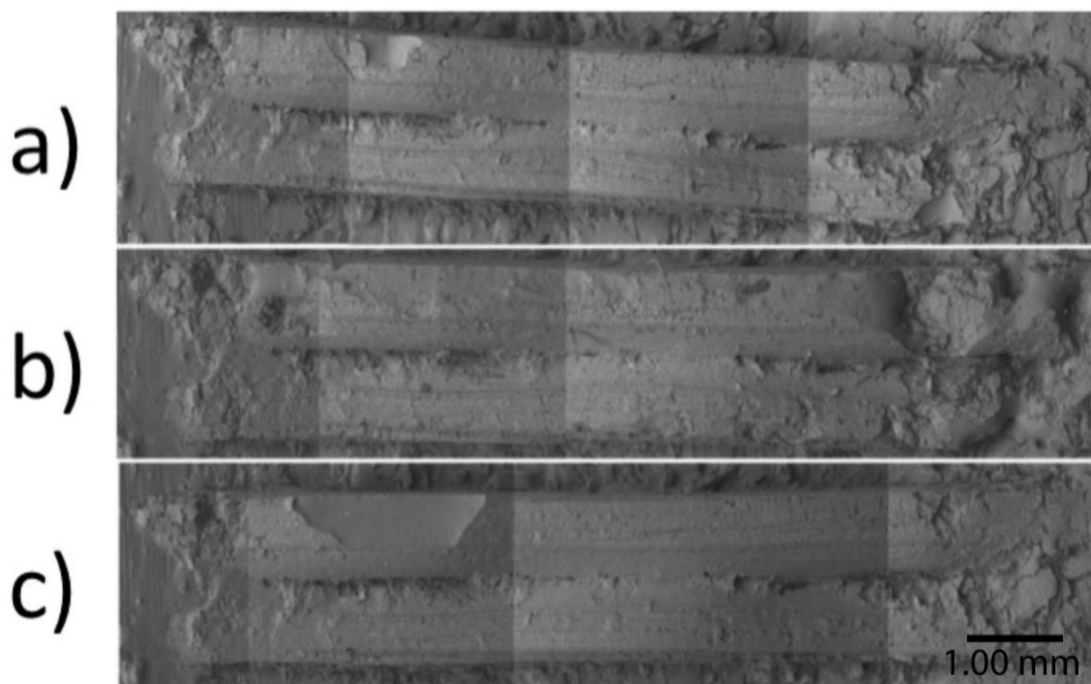
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*Figure 3: SEM composite micrograph (x30) of kerf number 7 in modern bone*

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

227

228 *Table 2: Comparison of Xantopren L blue, Mikrosil and Alec Tiranti casting material*  
229 *on modern and archaeological bone assessing the technical application of material*  
230 *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 effort required to achieve desired results, re-reading or additional attempts may be undertaken. 3: Very difficult to execute 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 correct mixing

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## 4. DISCUSSION

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### 4.1 Technical Application of Materials

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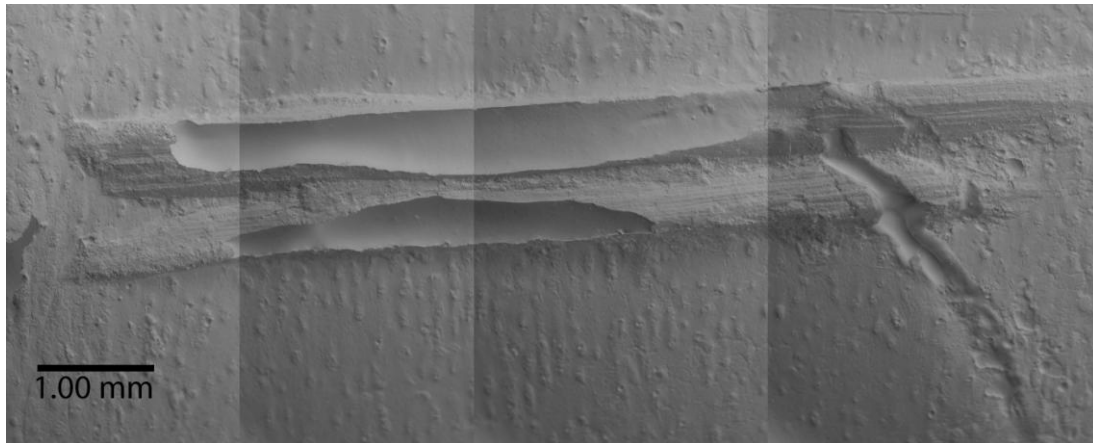
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An effect of improper mixing was encountered through the creation of air pockets within the casting material. The air pockets created 'gaps' within the cast of the kerf resulting in the loss of some information (Figure 3). These air pockets are a result 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.



260  
261  
262 *Figure 5: Composite SEM micrograph (x30) showing 'gaps' created by air pockets in*  
263 *a Mikrosil cast*

264  
265  
266 The clean removal of the casts shows that the possibility of well-preserved bone being  
267 destroyed or the removal of the bone's cortex is not an issue. Although this method is  
268 a contact technique, the results show none of the bone's morphological appearance  
269 was altered with any of the casts. This is important because this technique has largely  
270 been unused due to these concerns, but these results show that these concerns can now  
271 be dismissed. Although all of the products tested had limitations, none of them caused  
272 physical damage to the cortex of moderately-robust archaeological bones during the  
273 removal process.

274  
275 An additional consideration of these materials is cost. Alec Tiranti (which is  
276 demonstrated to be the most appropriate) costs approximately £27.00 where  
277 Xantopren L blue costs significantly more at around £74.00. The least expensive  
278 product to purchase is Mikrosil which costs around £23.00. Therefore, on top of Alec  
279 Tiranti's applicable advantages, the material is also affordable.

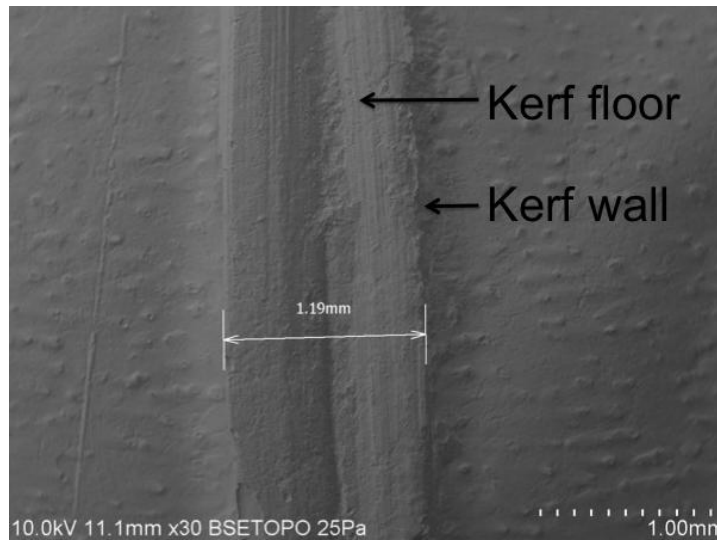
#### 280 281 **4.2 Effect of the Products on Osteological Material**

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

299 **4.3 Replication and Analysis of Cut Marks**

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

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

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318 **4.3 Case Study**

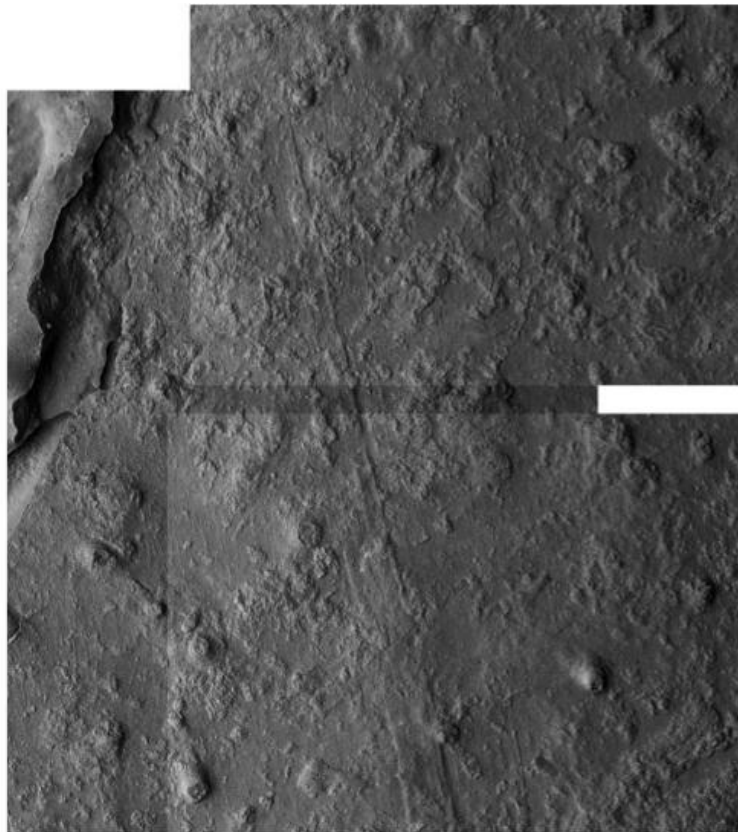
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320 *Image 7: Reconstructed cranium of burial 90 from Stanground South, Peterborough,*  
321 *Cambridgeshire*

324 To demonstrate the results of this research an Iron Age cranium excavated at  
325 Stanground South, Peterborough, Cambridgeshire [burial 90] that exhibited several  
326 peri-mortem modifications was selected for analysis (Taylor, Unpublished). The  
327 cranium, although initially fragmented, had been reconstructed prior to analysis.  
328 Therefore, any analysis using instruments with a low standoff height (such as an  
329 SEM) could not be accomplished. Consequently, the authors took casts using Alex  
330 Tiranti putty on several significant locations across the cranium using the method  
331 discussed in this paper.  
332



333  
334 *Figure 8: SEM micrograph showing extensive tool mark trauma on a cranium from*  
335 *burial 90 from Stanground South, Peterborough, Cambridgeshire*  
336

337  
338 Upon removal of the casting material the cranium was neither modified nor damaged.  
339 The casts were then observed under a SEM at 40x-100x magnification. These  
340 micrographs clearly showed the intended tool marks on the cranium. Interestingly  
341 several additional tool marks that had been previously unnoticed were also observed  
342 (Figure 6). Furthermore, the results showed the use of more than one tool. These  
343 findings are similar to those by Prieto (2003) who discussed the visualisation of  
344 previously unseen marks. This is important because aspects of the purposeful  
345 alteration of the Stanground cranium may have never been visualised without this  
346 casting method. This case study demonstrates the value of casting for revealing  
347 additional unseen information without damaging the cortex.  
348

## 349 **5. CONCLUSION**

350 Silicone casting material has been sporadically used for casting a range of objects.  
351 With regards to archaeological human remains, a comparison of the different silicone

352 casting materials has never been previously undertaken. In this study it is  
353 demonstrated that although the Alec Tiranti putty took longer to apply and set in  
354 comparison to the other techniques used, it did not damage the cortex or the bone  
355 when lifted from the surface unlike the Xantopren and Mikrosil methods which  
356 stained the cortex blue and brown respectively. This additional time constraint is  
357 meaningless if the necessity to conserve bone is taken into consideration. Therefore,  
358 although practice with the material is recommended before replicating cut marks in  
359 bone, Alec Tiranti can be safely used based on the results of this research.

360

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

372

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

376

### 377 **5.1 Considerations**

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

381

382

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390

391

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Table 2

		Xantopren	Microsil	Alec	Tiranti	
Technical application of material	Mixing	3	2	1		1: Easy to execute with minimal effort
	Application	2	2	1		2: Moderate effort required to achieve desired results, multiple attempts may be necessary
	Set Time	2	1	3		difficult to execute, high failure rate of procedure
	Removal	1	1	1		multiple attempts may be required to achieve desired result, (1)
Effects on osteological material	Damage to cortex	1	1	1		
	Staining	3	3	1		1: None 2: 1
	Air gaps	2*	2*	2*		
Suitability for use on bone		2	1.71	1.43		

\*Dependant on application and correct mixing

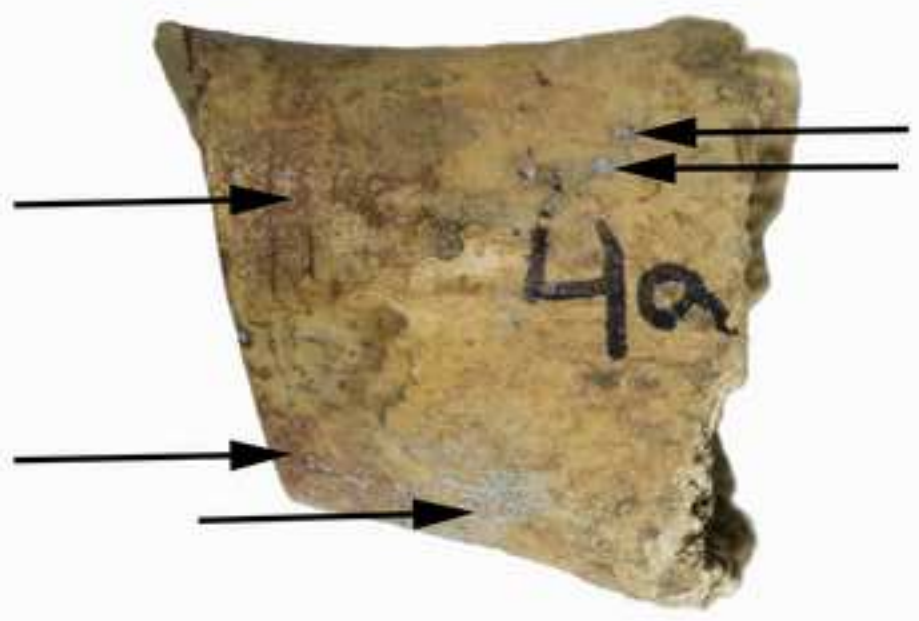
Alec Tiranti putty cast of trauma showing adhering Xantopren  
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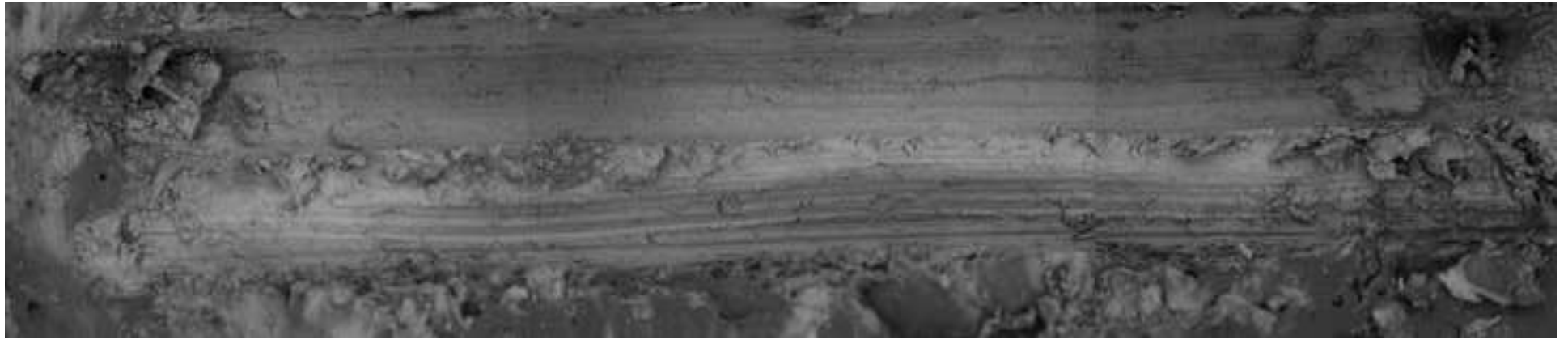
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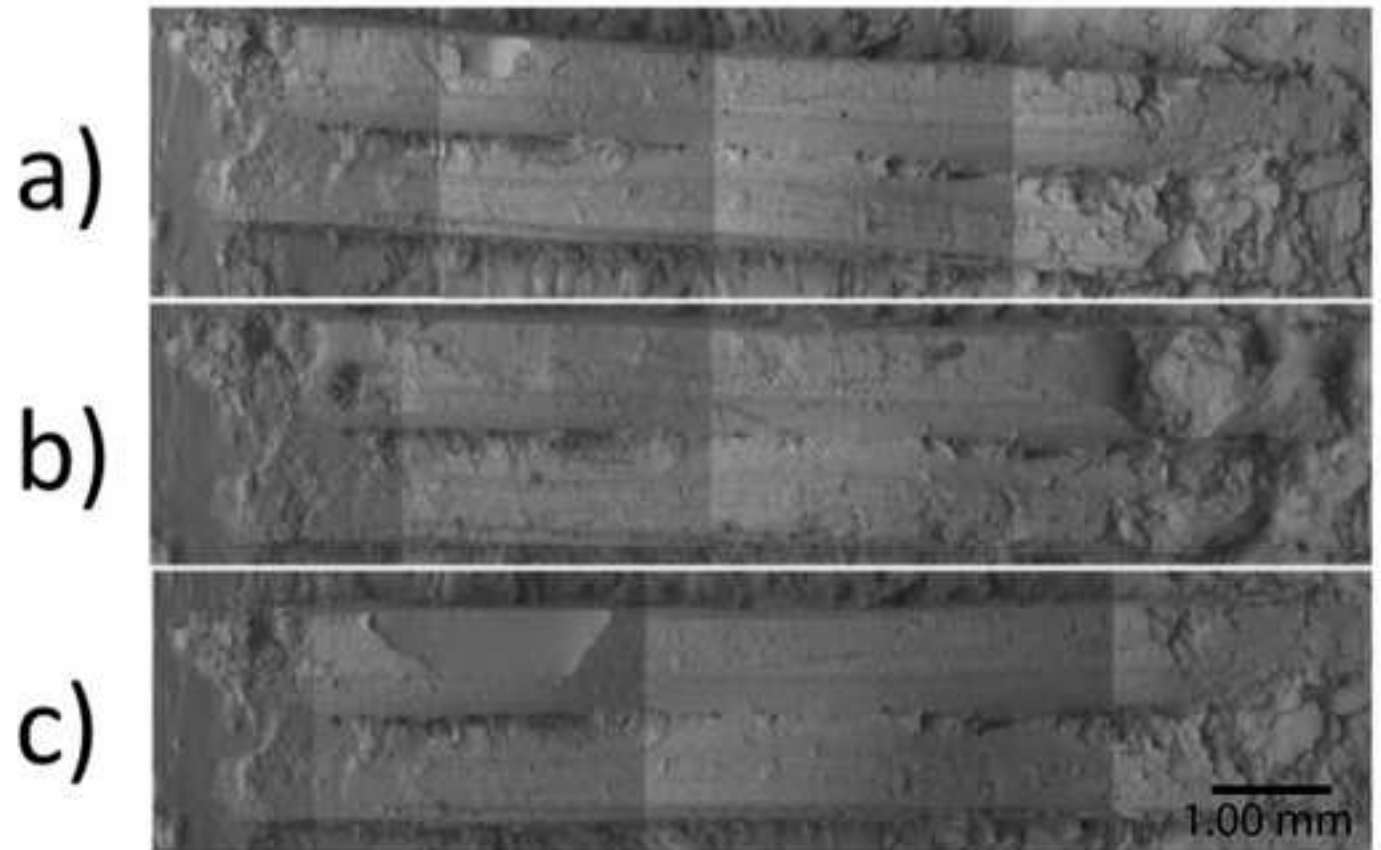
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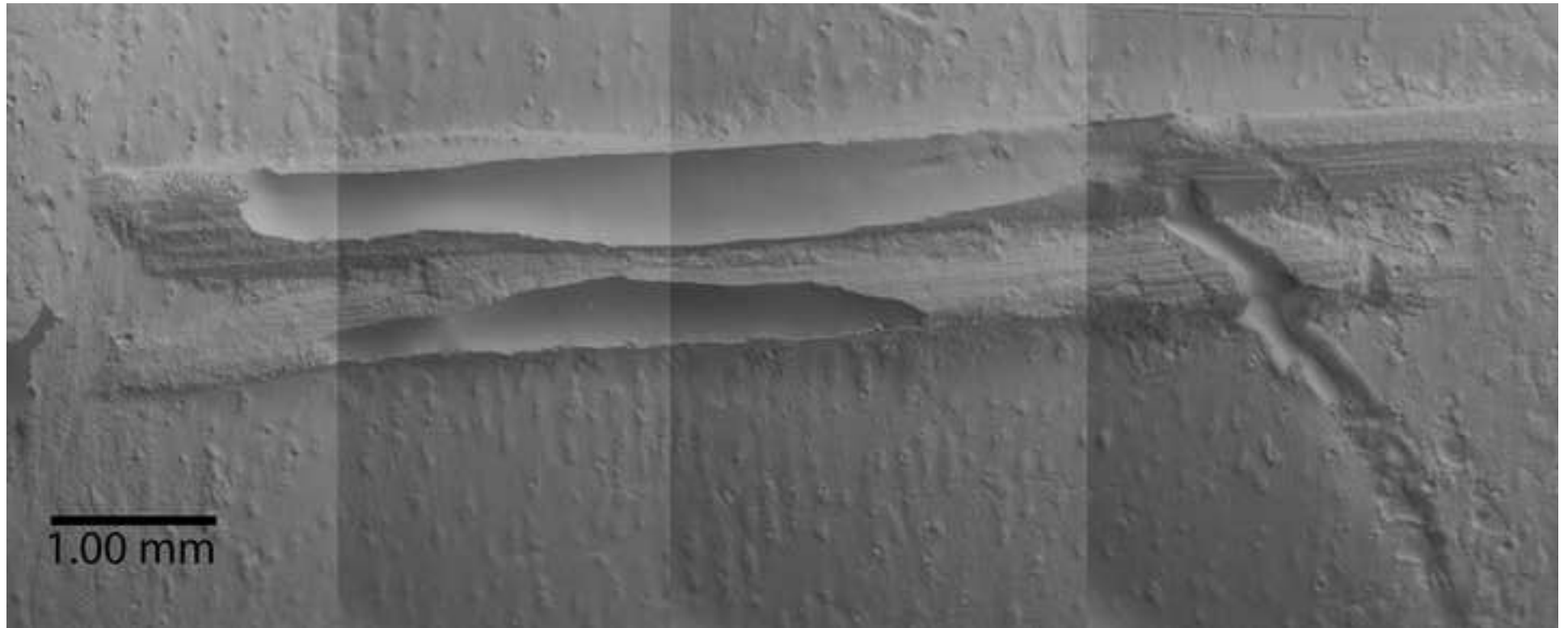


SEM composite micrograph (x30) of kerf number 7 in modern bone  
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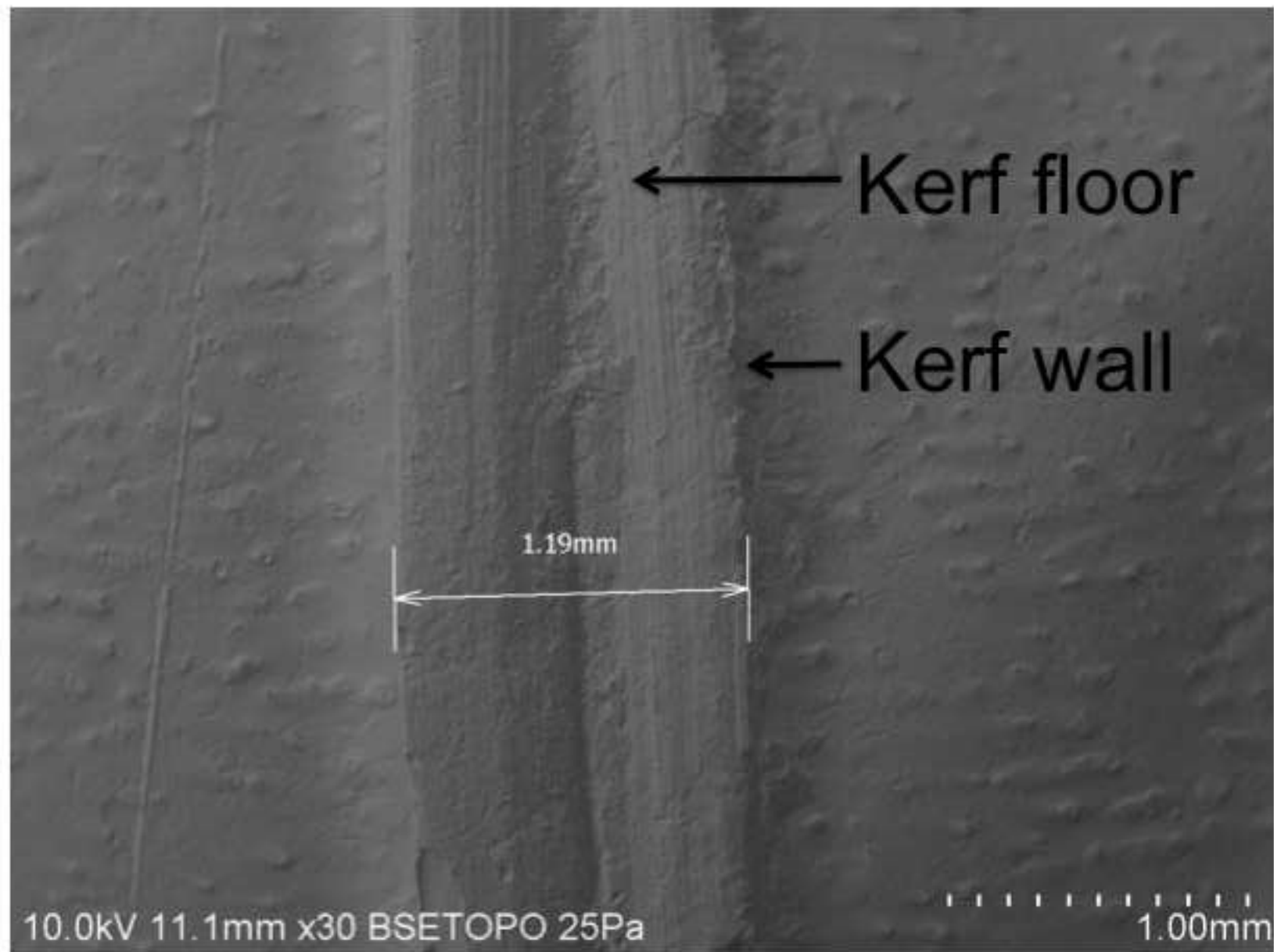




Composite SEM micrograph showing 'gaps' created by air pockets i  
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SEM micrograph showing the saw mark characteristics and the kerf  
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Reconstructed cranium of burial 90 from Stanground South, Peterb  
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SEM micrograph showing extensive tool mark trauma on a cranium f  
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