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A comparison of traditional methods of osteological cutmark analysis versus the implementation of new-age technology in the field of anthropology

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Abstract

Bone cutmark analysis is a practice that has been performed by forensic researchers and medical examiners around the world. The traditional method of gathering information for this type of analysis is to draw a detailed picture or take a photo of the bone which can be analyzed for pattern, coloration and orientation of each individual lesion and then the mark itself is measured with non-digital Vernier (hand) calipers or a ruler. In recent years, forensic anthropologists have been using DSLR cameras and digital calipers to record these findings as well as detailed field notes to determine the condition and tool which may have been used on the bone. In this study, the Dino Lite Premier microscope was used to test its precision, accuracy, and applicability in this type of analysis. The Dino Lite microscope is a handheld microscope which can be connected to one's laptop and transported into the field with the capacity to magnify 200x. This experiment takes the original method of non-digital hand calipers and photography and compares it to the use of digital calipers as well as the Dino Lite digital microscope. There are seven bone types examined including a control bone, two burnt bones, two weathered bones, and two frozen bones, four separate cutmark types made by four different implements are compared . Upon measuring, the results were input into a table and the averages and degrees of variance were calculated in order to assess precision and accuracy. This Dino Lite Premier microscope proved to be both precise and accurate and therefore applicable to the process of bone cutmark analysis in the field. A DSLR camera and observational notes should also be take in the field as well in order to construct a detailed, in-situ, recollection of the bones in the lab.

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Introduction

Bone cutmark analysis is a series of observations made on a bone presenting with cutmark-like lesions. This sort of analysis is conducted in the archaeological field by biological anthropologists and bioarchaeologists at excavation sites where human and faunal remains are uncovered that demonstrate cutmarks, as well as in the forensic field by forensic anthropologists and medical examiners in recent cases to determine cause of death, manner of death, and mechanism. The process of data recovery and analysis has been altered over time depending on the field in which it is being used, however, it has remained fairly stable in the general attributes: a depiction of relevant finds (by sketch or photography), a series of measurements, and a detailed description in the form of field notes to discuss the overall appearance of the bone.

There are various conditions which can alter the appearance of a bone including the weather it has endured, how long it has been exposed to the elements of natural weathering, burning, freezing, being waterlogged, and being submerged in water over long periods of time. All of these conditions will alter the appearance of the bone regardless of if it has been cut, but how these conditions change the cutmark and the ability for a researcher to analyze it is the question which will be considered during this case study along with the applicability of newer technology to aid in analysis.

Cutmarks must be analyzed by forensic experts in order to determine the timing of trauma relative to death, if it is related or indicative to the cause of death, as well as if the cutmark was performed as part of a cultural or religious ceremony. The determination of whether the bone is human or faunal also plays into this analysis but for the sake of this study the we will disregard this differentiation. Improvements on the processes and accuracy of the osteological cutmark analysis used by anthropologists is important because if the tool used to perform the cut is discovered, it could reveal new information regarding the culture and social practices of the group being studied. As for other fields of anthropology, this improvement could lead to a more accurate understanding of cause, mechanism and manner of death in more recent forensic cases.

With technology rapidly changing the toolkits of scientists across the board, the implementation of new technology in the field of biological and forensic anthropology has brought a change to the methodology of cutmark analysis. Traditionally, the tools used to measure the length, width- and when possible- depth of a cutmark on bone were non-digital hand calipers and rulers, which were then switched to digital calipers in recent years deeming non-digital (referred to from this point on simply as "hand") calipers nearly obsolete (Appendix A, Fig 2). Now, there is a rise in technology that can be transportable, this includes the Dino Lite microscope. The Dino Lite microscope, while not specifically made for use in the field of anthropology, is a transportable microscope which can allow for high resolution and specific measured photos of cutmarks. The Dino Lite version used here was the Premier model which has an amplification of 200x, for this project we used 20x magnification (Appendix A, Fig. 3). Potentially, this technology could replace the DSLR cameras and hand calipers used in cutmark analysis. This technology has the potential to help anthropologists take a closer look at small impurities and measure specific attributes of a cutmark which otherwise may have gone unnoticed. The purpose of this study is to compare the applicability and accuracy of the traditional methods of osteological cutmark analysis to the methods which involve the use of new technology such as the Dino Lite microscope. In this pilot case study, faunal femurs and tibia are used to simulate the long bones of humans which are often found containing cutmarks in the archaeological record and in various forensic cases. By using data retrieved via the Dino Lite microscope along with that from the traditional methods, it will be possible to determine the use and practicality of the Dino Lite microscope as an addition or substitution to the tools traditionally used in osteological cutmark analysis.

Methods

All Bones

The bones used in this experiment are deer leg bones including the femur and tibias which were obtained from the Richmond Meat Packers in Richmond, Michigan. When they were received, they were "fresh" bones in that they had small bits of flesh still attached at the ends and parts of the shaft, some bones were also still articulated at the joints. Fresh bone means that collagen content is still intact and the bone itself is holding moisture in the form of lipids. If these bones were "dry" or had been removed from the animal for some time, the collagen would be dried out and the bone itself would be more brittle. Having fresh bones changes the morphology of the cutmarks because instead of the splintering and shattering of dry bone there will be a rolling of the collagen during cutting as it will be more likely to hold itself together. In the field, the cutting of fresh bone makes the determination of timing difficult as it can appear perimortem but may have taken place post-mortem whereas the cutting of dry bone would be determined post-mortem more readily. In order to deflesh the bones, they were placed in a barn with an industrial fan in order to dry the flesh, after the dried flesh was peeled off, they soaked in a bath with Dawn dish soap for 2 weeks in order to degrease. The last step was to boil them in hot water for 1 hour to remove the remaining flesh. This process was found during research into the defleshing of animal bones via taxidermy sites and zoological/museum practice; this study specifically follows a modified version of the method outlined in a study by Karr et al from 2015 called "Bone degradation and environment: understanding, assessing and conducting archaeological experiments using modern animal bones" (Karr, L. P., & Outram, A. K. (2015). Bone degradation and environment: understanding, assessing and conducting archaeological experiments using modern animal bones. *International Journal of Osteoarchaeology, 2015.).* All of the bones were dried out again from the boiling water and were marked for cutting.

Black tape was put around the shafts of the bones which would be cut before going under an assigned condition such as weathering, burning, or freezing. An additional color was placed below the black tape which would identify the bones for their specific conditions: yellow being frozen, red being burnt, and green being weathered. Once the bones were labelled and arranged, the pre-condition cut bones were cut using a serrated knife, an un-serrated knife, a pick axe-type tool, and a hand saw. These cutmarks were made in the order of un-serrated closest to the tape marking then pick axe-type, saw, and serrated knife. These tools were chosen to represent many different blade types and cutmarks, the pick axe represents a blunt force/ sharp force object, the serrated knife is a more dull sawing motion, the saw itself represents the sawing motion of a more industrial tool, and the un-serrated blade is meant to represent a cutmark more like a sharpened rock or bone.

Control Bone

The control bone was cut immediately after the defleshing and photos and notes were taken as soon as the cuts were made. The first set of measurements were taken right away and the others were taken over a period of one month (Appendix B, Fig. 1).

Burnt Bone

The burnt bones were burnt using a propane blow torch which can reach a maximum of 2237 degrees Fahrenheit. They were as evenly burnt as possible through a sweeping motion from end to end across the front of the bone. For the pre-condition cut bone, the burns were evenly spread throughout the areas where the bone was cut and observations on the cutmarks were made before and after the torching. The post condition cut bone was cut in the same manner and order but knowing that the pick axe would likely break the bone in half, the bone was allowed to cool for one hour before implementing the cutmarks. (Appendix C, D.)

Weathered Bone

The weathered bones were placed outside in a wooded area in Armada, Michigan under a small crate with a cinderblock on top in order to prevent scavengers from removing it from the area. The bone which was pre condition cut was cut in the same order as the burnt bones and placed outside with the post-condition bone which had not yet been cut. These bones remained under their outdoor crate for 4 weeks from the beginning of February through the end. These bones saw temperatures from the mid-teens to the fifties, snow, wind, melt-off, rain, and sunshine. The post-condition bone was removed on the last day and cut in the same manner as the other and notes were taken on the condition the bone was in as well as the condition the pre-condition cut bone was in in order to draw conclusions on the effects of being left to the elements for prolonged time. (Appendix E, F.)

Frozen Bone

The frozen bones were wrapped in Saran wrap and placed in a normal kitchen freezer for five days. During the five days the bones were not removed from the freezer and the pre-condition cut bone was cut days in advance of the freezing. After the five days, photos were taken of the bones and cutmarks were made in the post-condition cut bone which were in the same fashion as the pre-condition cut bone. The cutmarks were made in the post-condition bone immediately after the removal from the freezer. (Appendix G, H.)

Measurements

Measurements were taken three separate times with hand calipers, digital calipers and the microscope. The three sets of measurements were then averaged and the average was used to compare to the other methods. To control for error, these measurements were confirmed with an additional person also taking measurements in order to confirm the accuracy of the numbers which would be used to average. The hand calipers measured in inches so it was necessary to also convert those numbers after their average was taken. In order to keep the measurements ordered the numbers were placed in a spreadsheet and the averages color coded with respect to the tool used- orange as the un-serrated knife, yellow as the pick axe, green as the saw and blue as the serrated knife. For the microscope measurements, three separate photos were taken and measured using the software to produce the numbers found in the tables in the Results portion of this report.

Photography

The camera used to take the photos was a Canon Rebel XSi with a 17-40mm lens. This lens was chosen in order to produce the best photos of the bones as a whole which would be used for observation notes later and as a reference to the pre-condition cut bones after the condition had been implemented.

Observational Notes

Observational notes were taken on each bone at every step in the process noting the coloration, porousness, and the flaking if necessary. This information can be found in the Results section of this report. The purpose of observing the bone cutmarks both pre-condition cut and post-condition cut is to evaluate if the microscope and/or the traditional methods can be used to determine the timing of the cuts in bone with reference to the condition they had been put under.

Results

Measurements

Data Tables

Table 1: Control Bone Measurements

Measurement Tool	**Cutmark**	**Length**			**Average Length (mm)**	**Range of Variance (mm)**	**Width**			**Average Width (mm)**	**Range of Variance (mm)**
Hand Caliper (in)	**Un-serrated**	0.25	0.3	0.3	7.197	1.27	0.025	0.025	0.025	0.635	0.0
	Pick Axe	0.3	0.275	0.325	7.62	0.635	0.075	0.1	0.125	2.54	1.27
	Saw	0.4	0.375	0.4	9.948	0.635	0.075	0.05	0.075	1.963	0.635
	Serrated	0.275	0.325	0.325	7.832	1.27	0.025	0.025	0.025	0.635	0.0
Digital Caliper (mm)	**Un-serrated**	7.33	6.36	6.59	6.76	0.97	0.75	0.72	0.62	0.697	0.13
	Pick axe	7.88	7.50	7.34	7.573	0.54	2.12	1.55	1.73	1.8	0.57
	Saw	10.63	10.09	9.86	10.19	0.77	1.94	1.69	1.64	1.757	0.3
	Serrated	8.71	7.93	7.57	8.07	1.14	0.87	0.63	0.75	0.75	0.24
Microscope (mm)	**Un-serrated**	7.79	7.897	7.501	7.729	0.396	0.5	0.5	0.396	0.456	0.104
	Pick axe	6.947	5.658	5.474	6.026	1.473	1.763	1.395	1.474	1.544	0.368
	Saw	10.978	10.054	10.448	10.493	0.924	1.342	1.079	1.184	1.202	0.263
	Serrated	7.184	7.212	7.447	7.281	0.263	0.632	0.579	0.447	0.553	0.185

	Table 2: Pre-Condition Burnt Bone Measurements										
Measurement Tool	**Cutmark**	**Length**			**Average Length (mm)**	**Range of Variance (mm)**	**Width**			**Average Width (mm)**	**Range of Variance (mm)**
Hand Caliper (in)	**Un-serrated**	0.35	0.325	0.35	8.676	0.635	0.025	0.025	0.025	0.635	0.0
	Pick Axe	0.3	0.3	0.3	7.62	0.0	0.1	0.125	0.1	2.752	0.635
	Saw	0.45	0.425	0.425	11.006	0.635	0.075	0.05	0.075	1.693	0.635
	Serrated	0.40	0.325	0.35	9.102	1.905	0.025	0.025	0.025	0.635	0.0
Digital Caliper (mm)	**Un-serrated**	9.21	9.09	9.18	9.16	0.12	0.75	0.72	0.51	0.66	0.24
	Pick axe	8.64	7.84	7.58	8.02	1.06	3.72	3.27	3.67	3.553	0.45
	Saw	12.18	11.16	11.5	11.61	1.02	2.12	1.87	1.65	1.88	0.47
	Serrated	10.77	8.75	9.15	9.557	2.02	0.81	0.67	0.8	0.76	0.14
Microscope (mm)	**Un-serrated**	8.448	8.632	8.316	8.465	0.316	0.632	0.763	0.605	0.667	0.158
	Pick axe	6.870	6.527	6.579	6.659	0.343	1.316	1.185	0.974	1.158	0.342
	Saw	10.503	10.123	9.192	9.939	0.976	1.737	1.474	1.737	1.649	0.263
	Serrated	10.901	9.527	9.975	10.134	1.374	0.744	0.553	0.660	0.652	0.191

	Table 3: Post-Condition Burnt Bone Measurements										
Measurement Tool	**Cutmark**	**Length**			**Average Length (mm)**	**Range of Variance (mm)**	**Width**			**Average Width (mm)**	**Range of Variance (mm)**
Hand Caliper (in)	**Un-serrated**	0.35	0.325	0.325	8.466	0.635	0.025	0.05	0.05	1.058	0.635
	Pick Axe	0.425	0.425	0.425	10.795	0.0	0.1	0.075	0.075	2.116	0.635
	Saw	0.45	0.425	0.475	11.43	1.27	0.075	0.05	0.05	1.481	0.635
	Serrated	0.275	0.275	0.25	6.773	1.27	0.025	0.025	0.025	0.635	0.0
Digital Caliper (mm)	**Un-serrated**	10.06	9.96	9.67	9.897	0.39	0.75	1.58	1.14	1.157	0.83
	Pick axe	11.59	11.21	11.34	11.38	0.38	3.12	2.57	2.11	2.6	1.01
	Saw	11.3	10.41	11.19	10.967	0.89	2.12	1.67	1.69	1.827	0.45
	Serrated	7.48	6.72	7.23	7.143	0.76	0.81	0.93	0.87	0.87	0.12
Microscope (mm)	**Un-serrated**	8.739	8.344	8.424	8.502	0.395	1.105	1.054	1.342	1.167	0.288
	Pick axe	7.663	7.742	7.896	7.767	0.233	1.474	1.421	1.069	1.321	0.405
	Saw	9.211	8.895	8.951	9.019	0.316	0.816	1.079	1.105	1.0	0.289
	Serrated	6.591	6.316	6.527	6.478	0.275	0.711	0.711	0.685	0.702	0.026

	Table 4: Pre-Condition Weathered Bone Measurements										
Measurement Tool	**Cutmark**	**Length**			**Average Length (mm)**	**Range of Variance (mm)**	**Width**			**Average Width (mm)**	**Range of Variance (mm)**
Hand Caliper (in)	**Un-serrated**	0.35	0.35	0.325	8.676	0.635	0.025	0.025	0.025	0.635	0.0
	Pick Axe	0.225	0.225	0.225	5.715	0.0	0.075	0.05	0.075	1.693	0.635
	Saw	0.375	0.3	0.325	8.466	1.27	0.075	0.05	0.05	1.481	0.635
	Serrated	0.4	0.35	0.325	9.102	1.905	0.05	0.025	0.025	0.847	0.635
Digital Caliper (mm)	**Un-serrated**	10.65	8.95	8.69	9.43	1.96	0.77	0.75	0.81	0.777	0.06
	Pick axe	6.69	5.77	5.98	6.147	0.92	2.05	1.42	1.39	1.62	0.66
	Saw	8.85	8.44	8.82	8.703	0.41	1.88	1.69	1.73	1.767	0.19
	Serrated	10.72	9.45	9.77	9.98	1.27	1.18	0.76	0.83	0.923	0.42
Microscope (mm)	**Un-serrated**	7.105	7.106	7.343	7.185	0.238	0.553	0.658	0.422	0.544	0.236

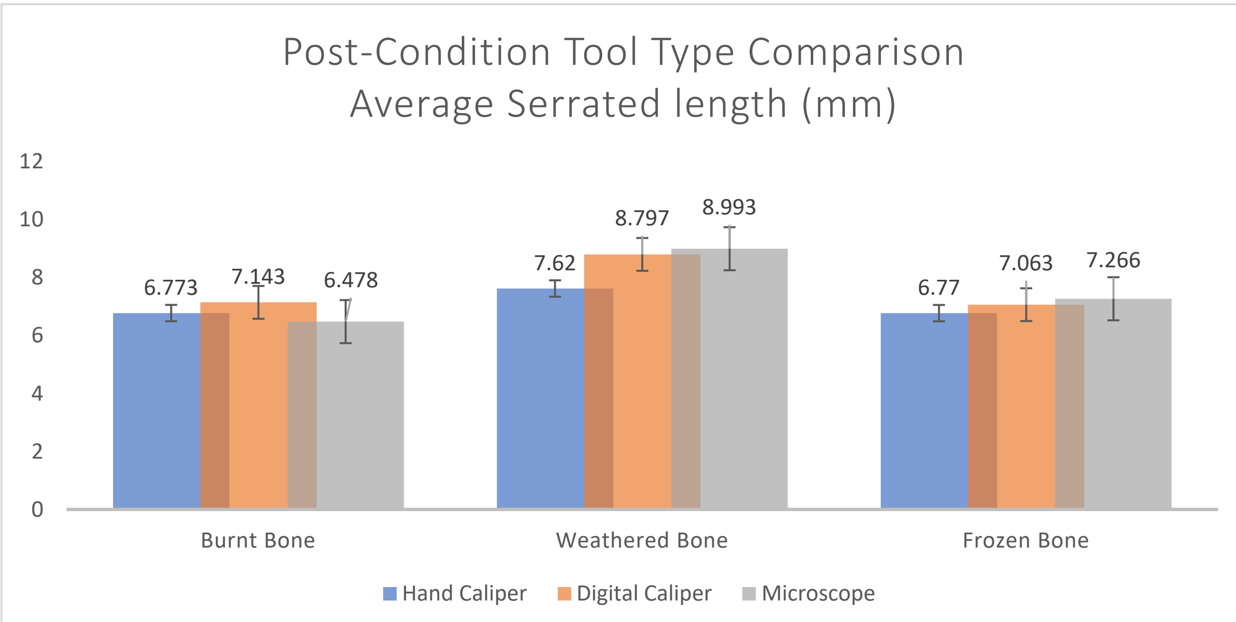
Table 5: Post-Condition Weathered Bone Measurements											
Measurement Tool	Cutmark	Length			Average Length (mm)	Range of Variance (mm)	Width			Average Width (mm)	Range o Varian (mm)
Hand Caliper (in)	**Un- serrated**	0.225	0.225	0.2	5.503	0.635	0.025	0.025	0.025	0.635	0.0
	Pick Axe	0.225	0.2	0.175	5.08	1.27	0.125	0.1	0.075	2.54	1.27
	Saw	0.225	0.25	0.275	6.35	1.27	0.075	0.05	0.05	1.481	0.635
	Serrated	0.325	0.275	0.3	7.62	1.27	0.025	0.025	0.025	0.635	0.0
Digital Caliper (mm)	**Un-serrated**	6.8	5.83	6.56	6.397	0.97	0.66	0.63	0.69	0.66	0.06
	Pick axe	6.54	6.52	6.55	6.537	0.03	3.1	1.75	2.36	2.403	1.35
	Saw	6.84	6.89	6.62	6.783	0.27	2.27	1.86	1.72	1.95	0.55
	Serrated	9.01	8.45	8.93	8.797	0.56	0.57	0.8	0.7	0.69	0.23
Microscope (mm)	**Un-serrated**	5.667	5.737	5.868	5.757	0.201	0.421	0.474	0.501	0.465	0.08
	Pick axe	3.239	3.474	3.526	3.413	0.287	1.185	1.237	1.495	1.306	0.31
	Saw	6.475	6.533	6.747	6.585	0.272	1.320	1.553	1.632	1.502	0.312
	Serrated	9.211	8.874	8.895	8.993	0.337	0.58	0.5	0.5	0.527	0.08
	Pick axe	5.606	5.290	5.158	5.351	0.478	1.027	0.947	1.079	1.018	0.132
	Saw	8.292	8.453	8.478	8.408	0.186	1.397	1.320	1.448	1.388	0.128
	Serrated	8.895	8.053	8.186	8.378	0.842	0.316	0.474	0.527	0.439	0.211

Table 6: Pre- Condition Frozen Bone Measurements											
Measurement Tool	Cutmark	Length			Average Length (mm)	Range of Variance (mm)	Width			Average Width (mm)	Range of Variance (mm)
Hand Caliper (in)	**Un-serrated**	0.275	0.275	0.25	6.773	1.27	0.025	0.025	0.025	0.635	0.0
	Pick Axe	0.275	0.25	0.25	6.561	0.635	0.075	0.075	0.075	1.905	0.0
	Saw	0.4	0.4	0.425	10.371	0.635	0.05	0.075	0.05	1.481	0.635
	Serrated	0.475	0.375	0.35	10.16	3.175	0.025	0.025	0.025	0.635	0.0
Digital Caliper (mm)	**Un-serrated**	6.95	6.49	6.92	6.787	0.46	0.64	0.54	0.57	0.583	0.1
	Pick axe	7.03	7.57	7.37	7.323	0.54	1.85	1.55	1.58	1.66	0.3
	Saw	11.43	11.76	10.38	11.19	1.38	1.64	1.62	1.49	1.583	0.15
	Serrated	11.24	11.28	11.03	11.183	0.25	0.84	0.67	0.7	0.737	0.17
Microscope (mm)	**Un-serrated**	7.424	7.448	7.554	7.475	0.13	0.421	0.526	0.477	0.475	0.105
	Pick axe	5.922	6.0	6.132	6.018	0.21	1.237	1.289	1.291	1.272	0.054
	Saw	10.711	10.819	10.486	10.672	0.333	1.056	0.974	0.953	0.994	0.103
	Serrated	10.849	10.926	10.792	10.856	0.134	0.606	0.579	0.658	0.614	0.079

Table 7: Post-Condition Frozen Bone Measurements											
Measurement Tool	Cutmark	Length			Average Length (mm)	Range of Variance (mm)	Width			Average Width (mm)	Range of Variance (mm)
Hand Caliper (in)	**Un-serrated**	0.25	0.25	0.225	6.136	0.635	0.025	0.025	0.025	0.635	0.0
	Pick Axe	0.225	0.25	0.225	5.926	0.635	0.05	0.05	0.05	1.27	0.0
	Saw	0.35	0.35	0.35	8.89	0.0	0.075	0.05	0.05	1.48	0.635
	Serrated	0.25	0.3	0.25	6.77	1.27	0.025	0.025	0.025	0.635	0.0
Digital Caliper (mm)	**Un-serrated**	6.91	6.7	6.71	6.773	0.21	0.36	0.37	0.35	0.36	0.02
	Pick axe	5.68	5.95	5.38	5.67	0.57	1.28	1.26	1.02	1.187	0.26
	Saw	8.4	8.52	8.84	8.587	0.44	1.87	1.29	1.65	1.603	0.58
	Serrated	6.94	7.46	6.79	7.063	0.67	0.79	0.81	0.53	0.815	0.28
Microscope (mm)	**Un-serrated**	5.975	5.792	5.553	5.773	0.422	0.289	0.289	0.263	0.280	0.026
	Pick axe	5.342	4.921	5.369	5.211	0.448	1.448	1.263	1.21	1.307	0.238

	Saw	8.485	8.553	8.737	8.592	0.252	1.211	1.369	1.448	1.343	0.237
	Serrated	7.295	7.529	6.974	7.266	0.555	0.342	0.447	0.474	0.421	0.132

Table 8: Average Range of Variance	
Measurement Tool	**Average Range of Variation (mm)**
Hand Caliper	*0.658*
Digital Caliper	*0.5589*
Microscope	*0.3205*



Graph 1:

Comparisons of the Average Length of the Serrated Knife cutmarks with respect to the averages and deviances for all Post-condition bones. This provides another view of the information displayed in the tables above.

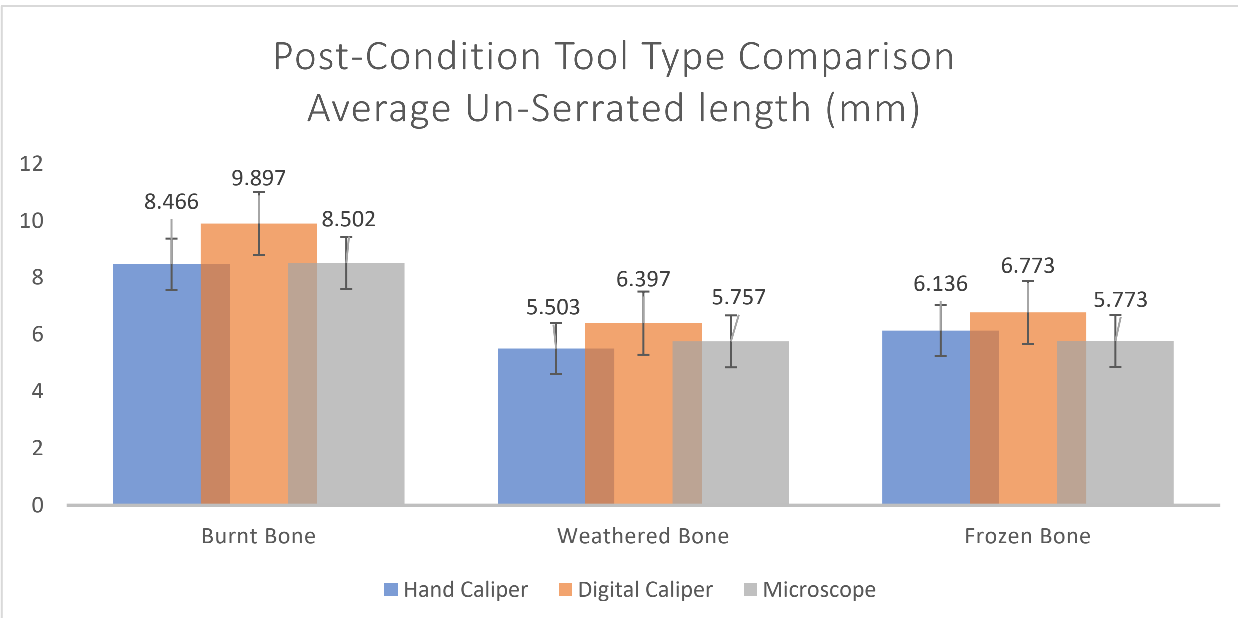
Observational Notes

Control Bone

The cutmarks made on the control bone are small and do not fully transverse the shaft. They are shallow and have shavings on the ridges which were likely displaced by the tool used to cut them (Appendix B, Fig 2).

The un-serrated cutmark is precise and looks like it has no deviating paths from the main cut. One end of the mark is slightly wider than the other. When viewed with the microscope, ridges can be seen in the middle of the cutmark which show that there was a sawing motion with multiple passes. This was nearly impossible to see with the naked eye. If can also be seen that the ridges are in fact flakes of bone that have built up on the edges of the cutmark (Appendix B, Fig. 3)

The pick axe cutmark is rough and covers a wide area. There is frayed bone on either end as well as on the ridges in the middle of the area. It is difficult to see where an individual cut mark begins and ends for measurement purposes. Under the microscope, individual cutmarks can be more easily identified, they are still a little ambiguous but overall, more identifiable (Appendix B, Fig 4).



Graph 2:

Comparisons of the Average Length of the Un-serrated Knife cutmarks with respect to the averages and deviances for all Post-condition bones. This provides another view of the information displayed in the tables above.

The saw mark is wider than the others and there is deviance from the main cutmark suggesting that it was an inaccurate sawing motion to begin. The mark itself is almost bowtie shaped with the ends flaring out a little more than the middle. Under the microscope, it is easy to see the edges and the membrane of the bone that was left over from defleshing has been stripped away at the edges (Appendix B, Fig. 5).

The serrated knife cutmark is the hardest to identify, it is shallow and has a pathway of marks leading to it showing a sawing motion. This cut mark was easier to be examined under the microscope, it shows the multiple ridges inside the main cutmark and allows the observer to identify the ridge ends easier (Appendix B, Fig. 6).

Burnt Bones

The burnt bones both exhibit a blistering look where the outer layer of the bone has begun to peel away. They are blackened and browned where the outer layer has stripped away and have large linear cracks running from end to end (Appendix C, Fig 1-3).

On the pre-condition cut bone the cutmarks were all more rounded after the burning, they also blacked at the edges rather than throughout the mark. Flakes were removed from the edges of the cutmarks of all tools and cracks ran through the centers (Appendix D).

The un-serrated cutmark on the pre-condition cut bone looks uniform while the post-condition cut looks more like the saw mark from the others, it is wider and has many flakes missing from the edges (Appendix D, Fig. 3). Under the microscope the post-condition bone cutmark from the un-serrated knife shows the impurities of the edges which suggests large flaking likely due to the heat drying the bone out (Appendix C, Fig. 3). This observation could not be made without the high-resolution photo.

The pick axe cutmark on the pre-condition cut bone was dryer looking after the condition than it was originally, it also now has a large crack running through it (Appendix D, Fig. 4). The coloration is dark around the outside with a layer of a more honey colored ring then a lighter colored center. The post-condition cut bone cracked in half with the pick axe so its measurements were mostly approximations (Appendix C, Fig 4). There is still a ridge which can be identified for the length but the width is tricky due to the two halves now being separate. Color wise, the blackened portion of the bone flaked off on impact of the pick axe. Under the microscope it is possible to see the patterning of the flaking from the post-condition impact which helps have a more detailed idea of the tool used. The fracture pattern is ridged and sharp which aligns with the drying out of the bone pre-cutmark.

The saw cutmark on the pre-condition bone is the characteristic bowtie shape discussed on the control bone (Appendix D, Fig. 5). The main difference is the coloration- it is not blackened- and the roundedness of the edges of the mark itself. Before the burning, the cutmark was sharper at the edges, now it is rounded and more continuous with the inside of the marking. The post-condition bone is much harder to identify (Appendix C, Fig. 5). From the naked eye it looks as though the outer layer has just been stripped away and the burnt areas has flaked off, however, there is a pathway of saw-motion like scrapes. Under the microscope it is easier to see the edges of the cutmark which helps to identify the length and width. This was one mark that truthfully needed the microscope to identify the main mark.

The serrated knife cutmark on both bones appears to be thin, the post-condition bone has flakes missing of the blackened layer (Appendix C, Fig. 5). In the center of the post-condition bone cutmark there is a "polished" appearance possibly due to the sawing motion. The pre-condition cutmark doesn't look as polished but the overall look is comparable to the control bone (Appendix D, Fig. 5). Under the microscope it is more easily observed that there were multiple passes due to the multiple ridges in the middle of the cutmark on both pre- and post-condition. It is also easier to identify the flaking patterns of the post-condition cutmark through the microscope and see the depth of the flakes.

Weathered Bones

The weathered bones show some discoloration- they appear pale and dull in comparison to the control bone and as compared to their condition before being placed outside (Appendix E, F). There are also sections of dark splotches and the appearance of drying out. The grease which may have been left from the defleshing process now looks like it has been concentrated into the ends of the bone which look greasy and more yellow than the other sections of the bone.

The pre-condition bone's un-serrated cutmark is identical to that of the control bone but the area surrounding it looks more matte in color than the control (Appendix E, Fig. 3). The edges are still sharp and one end is still slightly larger than the other which suggests an inequality in pressure and that the motion was applied form one side rather than directly down and across. The post-condition un-serrated cutmark was hard to identify with the naked eye and required the addition of wood marker. This cutmark looked uniform and frayed at the edges but overall identical to the pre-condition. The microscope allowed easier identification of the ends of the cutmark and also showed the fraying pattern in the post-condition cutmark (Appendix F, Fig. 3). It also allowed for a better view of the pattern within the cutmark which shows the multiple ridges.

The pick axe cutmarks on both bones were wide and large frayed portions around the outside and throughout the middle of the cutmark. It was hard to identify the individual cutmarks with the naked eye but through the addition of wood marker and the use of the microscope I was able to pick out a possible individual cutmark to measure. The microscope also revealed that there were sections within the cutmark which had pilled or began raising out of the bottom. The changes in temperature could have caused this (Appendix E, F).

The saw marking on the pre-conditioned bone had a series of smaller sawing motion marking leading to it. The smaller markings seem to have only scraped away the outer layer but failed to produce larger and deeper marks. On the post-condition bone, the cutmark looks more precise but less deep (Appendix F, Fig 5; Appendix E, Fig. 5). It still has a fraying of layers around the perimeter of the cut but less of a deviance from the main cutmark. Upon using the microscope, it can be observed that the pattern is not parallel but more cross-hatched within and around the main cutmark. This observation can help determine the directionality of the cutmarks.

The serrated knife cutmark on the pre-condition bone has deviant markings around it showing imperfect sawing motion and fraying around the perimeter of the cutmark rather than flaking. This shows that it is not necessarily dried out. The post-condition bone appears to lack the deviant markings but had the same fraying (Appendix F, Fig 6). Under the microscope the fraying looks more hair-like than the pre-conditioned bone (Appendix E, Fig 6). This may indicate that the bone was drier when cut.

Frozen Bones

The frozen bones appear to be more of a yellow-green color which is different than the other conditions. There is also a general difference on the coloration of the cutmarks between the pre-condition and post-condition bones. The pre-condition bones appear to have almost bleached color cutmarks while the post-condition bones look more bone-colored even at the bottoms of the troughs of the cutmarks. This is a notable difference due to how dramatic it looks in comparison between pre- and post-condition (Appendix G, H).

The un-serrated cutmark on the pre-condition bone is precise and appears to have only slight fraying at the perimeter of the cutmark but sharp ridges (Appendix G, Fig. 5). The post-condition one resembles this but looks slightly shallower (Appendix H, Fig. 3). The shallowness could just be due to a smaller amount of pressure being applied at the time of cut or it could be a show that the bone was harder to cut into when frozen. Under the microscope both the pre-condition and post-condition cutmarks appeared to align with the observations made through the traditional method. Nothing shocking was observed which changed the observation written pre- microscopic view.

The pick axe markings were both wide and irregular in shape, the pre-condition cutmark was far lighter in color in a very dramatic way and it was also larger in general (Appendix G, Fig 1-4). The post-condition marking was still irregular but showed more fraying at the edges and looked a bit more slice-like (Appendix H, 1-2). Under the microscope it was apparent that the pre-condition bone was drier than the post-condition one (Appendix G, Fig. 6; Appendix H, Fig. 4). This observation could not have been positively made by the naked eye alone.

The saw cutmark on both bones exhibited the bowtie appearance with the ends slightly flaring wider than the center (Appendix G, Fig. 7; Appendix H, Fig. 5). The pre-condition bone had a white cutmark and showed markings surrounding the main cutmark clearly while the post condition bone had markings around the main cutmark which were only confirmed after the microscope was used. While multiple ridges on the inside of the main cutmark could be seen on the post-condition bone, the microscope revealed their presence on the post-condition bone.

The serrated cutmarks both show the deviant markings and fraying but it is clearer on the pre-condition bone than the post-condition bone because of the coloration of the cutmarks (Appendix G, Fig. 8; Appendix H, Fig. 6). The pre-condition cutmark appears drier due to its high degree of fraying on the outside of the markings (Appendix G, Fig. 8). The microscope allows the viewing of the intricate ridge patterns in the middle of the main cutmarks on both the pre-condition and post-condition bones which could not be observed with the naked eye beforehand (Appendix H, Fig. 6).

Discussion

The measurements from each tool (hand calipers, digital calipers and microscope) were taken three separate times and those three measurements were averaged to produce a number which could be compared to the other sets of data for each individual cutmark (See Tables 1-7). The primary observation when reviewing the data is that the pick axe cutmark measurements- both in length and width- were inconsistent throughout regardless of the tool being used to measure them, with the same tool and with the measurement comparisons between different tool types. This could be because of the shape of the cutmark itself or because of the tool's accuracy. It is unlikely that the latter is true though due to the overall consistent results produced between trials with the hand calipers and the microscope.

Inconsistencies relating to measurements found in the microscope stills may have been due to human error given the fact that the beginning and termination of each cutmark is determined on a case by case basis by the observer. Overwhelmingly, the three tools did not come out to the same conclusions regarding majority of the measurements. With the hand calipers, it is hard to find much room for variance as they are approximations in inches rather than millimeters as opposed to the digital calipers and microscope, however, the microscope is the most accurate and precise based on the multiple measurement trials and an average range of variance calculated in Table 8. Table 8 shows that the microscope had the least amount of deviance between trials in comparison to the other tools. This lower deviance indicates that it is more suitable for this type of measurement with the range and view as well as the measuring tool itself.

The other likely cause for deviance is the fact that the width and length of the cutmark is left to interpretation by the person measuring the mark. I ran into this issue when comparing my measurements to that of the person assisting with the project. We struggled to come to similar conclusions with our measurements but realized after the fact that we were interpreting the beginning and end of the cutmark differently which was causing a large deviation in our resulting measurements. To mitigate this problem, we used a wood marker to mark the beginnings and ends of each mark as well as the areas we were considering to measure the widths. Seemingly, we did not run into this issue as often with the microscope, the photos were so high resolution that it was easier to identify the ridges which would mark the boundaries of each cutmark and we had little dispute over the areas that should be measured.

The other important step in cutmark analysis is the observation of overall condition which traditionally takes place in the field notes of an anthropologist and is then reaffirmed through the reference to photos taken in the field. When observational notes were being taken, they were originally taken only as naked eye accounts of one cutmark at a time and arranged by the condition of the bone- burnt, weathered, or frozen. Accounts of comparison to the control bone as well as between pre-condition and post-condition were recorded. These notes reflected comparisons between the pre- and post- condition marks without the use of the microscope, using the pictures of the cutmarks taken with the microscope, and based on these records a second set of observational notes were compiled. For this report, these observations were combined to include both sets and provide a more detailed and comprehensive record of the observations made in general.

Overall, the research methods could be improved by the inclusion of more trials. If the project were to be reproduced, it would be advisable to include measurements of multiple digital calipers as well as multiple hand calipers in order to produce a more all-encompassing set of data for these tools. By using the different sets of calipers, it would also be easier to see the precision of the instrument itself rather than just a single tool/model.

Conclusion

While the traditional methods of cutmark analysis have been used for many years, the recent boom in scientific technology may provide a new avenue for analysis which can allow for more detailed notes and measurements. The Dino Lite microscope allows for the cutmarks on bone to be examined more closely and in a higher resolution. These higher resolution photos allow for anthropologists to obtain a more detailed view of the patterns and features of a cutmark which may lead to a better understanding of the condition and tool which the bone has been modified by. However, the microscope does not totally overshadow the use of the traditional methods of cutmark analysis in the realm of observational data as it can only capture a small, hyper-focused photo rather than one which encompasses the bone as a whole. While the traditional methods of measurement may not be as precise as the Dino Lite microscope, they are by no means inaccurate. How exact can a measurement be in reality? The use of the Dino Lite microscope is definitely a worthy addition to the toolkit though due to the fact that it can provide a new and precise view of the cutmark being analyzed which otherwise may not have been able to be observed.

Another positive to using this technology is that it can be transported into the field which allows for microscopic images to be taken in situ which has never been available before. The benefit of capturing these images in situ is that the accuracy of the depiction of the scene can be preserved for documentation. There is one aspect of cutmark analysis that no one has seemed to solve though, how do we accurately measure the depth of small cutmarks? With the rise in new technology, perhaps we can create a new method for identifying depth.

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Appendices

Appendix A

Tools

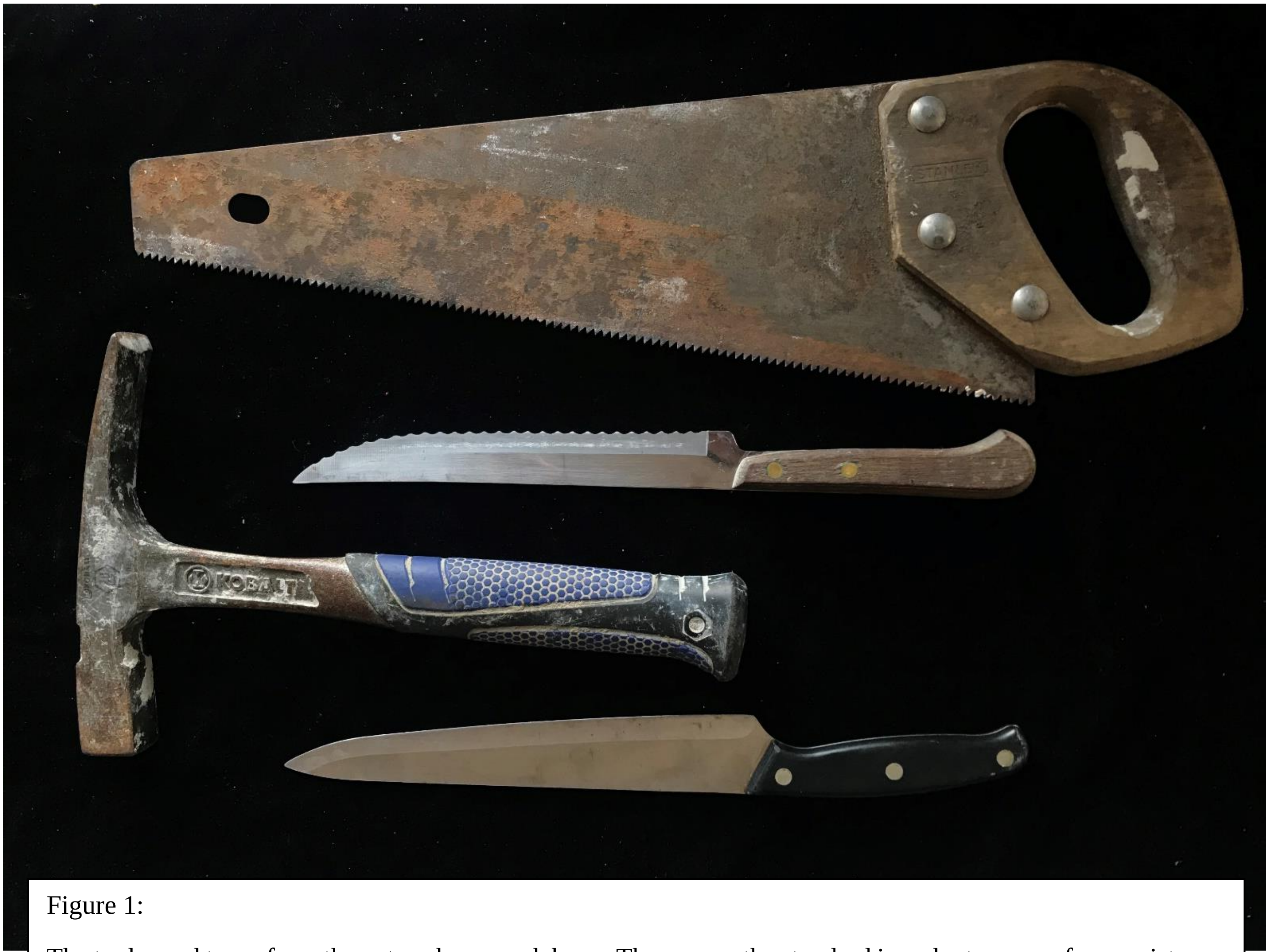

Figure 1:

The tools used to perform the cutmarks on each bone. These were the standard in order to assure for consistency in the markings found on each bone. These tools were used in order to observe how different cutting methods can be viewed, measured, and documented and whether the different types of serrated edges or un-serrated edges could be distinguished through the analytical method used. It was found that the serrated could be distinguished from the un-serrated as well as the pick axe be distinguished but the differences between the saw and the serrated knife were more ambiguous.

Figure 2:

These are the two sets of calipers used, the calipers on the left are Vernier hand calipers which measure in inches while those on the right are digital calipers set to measure in millimeters.

Figure 3:

This is the Dino Lite Premier digital microscope. This microscope has the capacity to zoom up to 200x, for this project it was only used at 20x magnification.

Appendix B

Control

Figure 1:

This is the DSLR digital camera documentation of the control bone. This bone was defleshed and cut immediately in order to use as a reference when looking at the effects of the conditions which other specimens were put under. The cutmarks are in the order of un-serrated, pickaxe, saw, and serrated when moving from top to bottom of the photo.

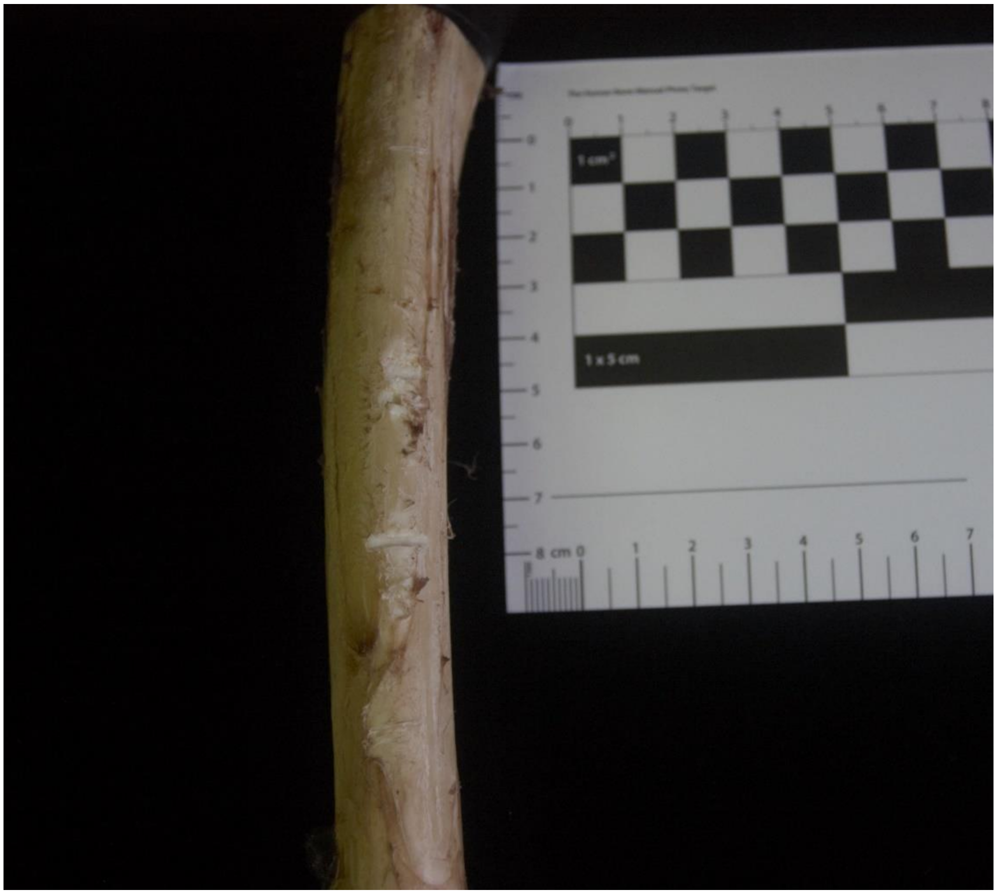

Figure 2:

This is a secondary documentation of the bone from the DSLR digital camera, this photo was used along with the naked eye observations, in order to take observational notes.

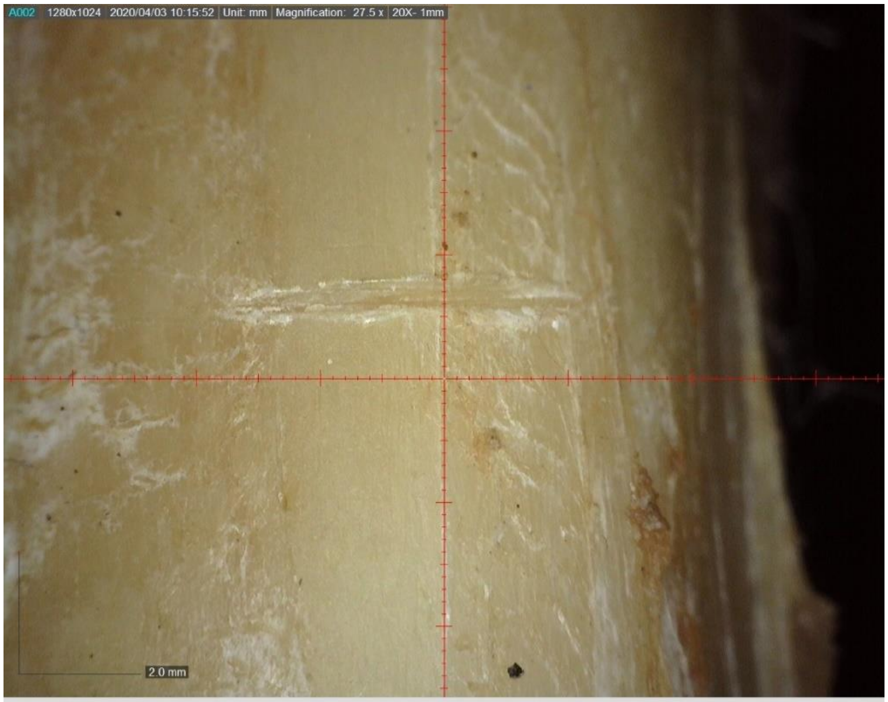

Figure 3:

This is the Dino Lite still of the un-serrated cutmark on the control bone. It is visible that the edges of the cutmark are exhibiting rolling which is likely on bone with collagen still intact. It is also possible to see the membrane bubbling and stretching from the defleshing process.

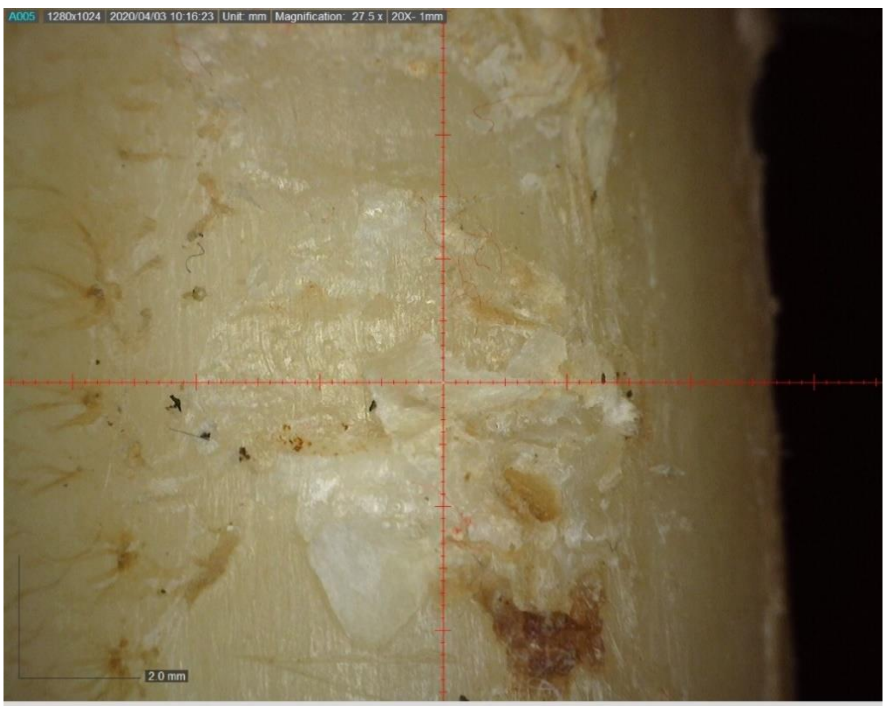

Figure 4:

A Dino Lite still of the pickaxe cutmark on the control bone. This mark exhibits flaking and some striation marks from impurities on the surface of the pick axe.

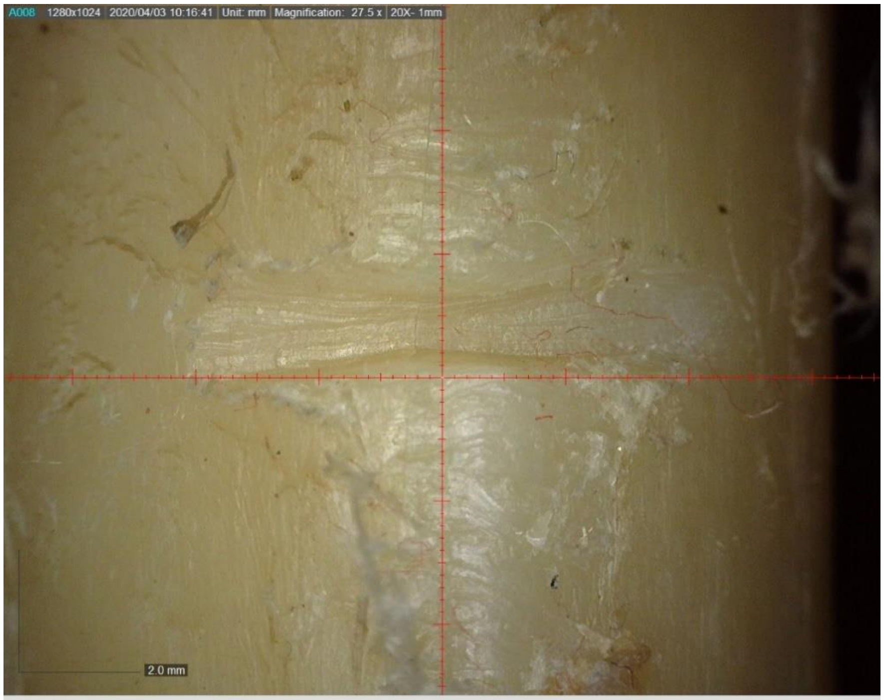

Figure 5:

A Dino Lite still of the saw cutmark on the control bone. This shows striations from the serrated edge leading to the main cutmark. It has a distinctive bowtie configuration with flaring ends.

Figure 6:

A Dine Lite still of the serrated edge knife on the control bone. This shows cutmarks leading to the main abrasion and flaking of the membrane.

Appendix C

Burnt Post-Condition

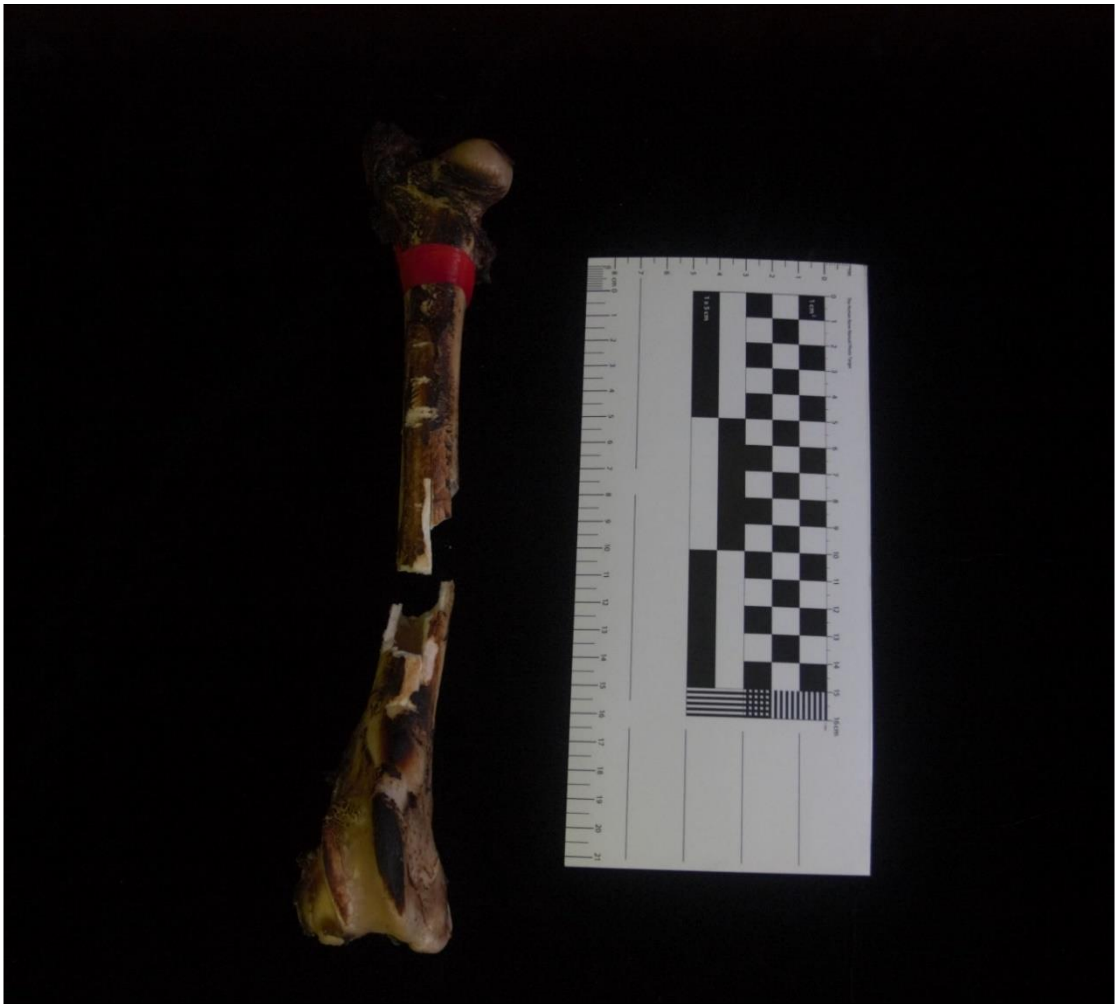

Figure 1:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Post-condition burnt bone. This bone was burnt, then cut with all four instruments before being observed. There was a large crack created by the pick axe which is best viewed in its entirety.

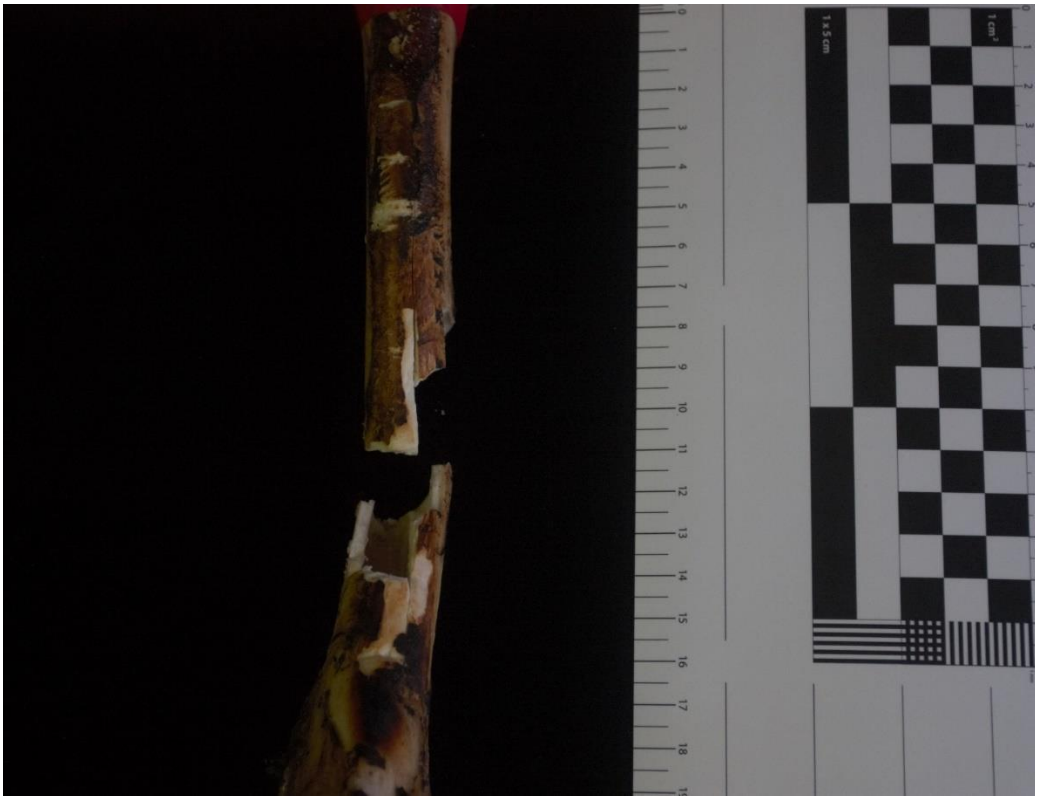

Figure 2:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Post-condition burnt bone. This bone was burnt, then cut with all four instruments before being observed.

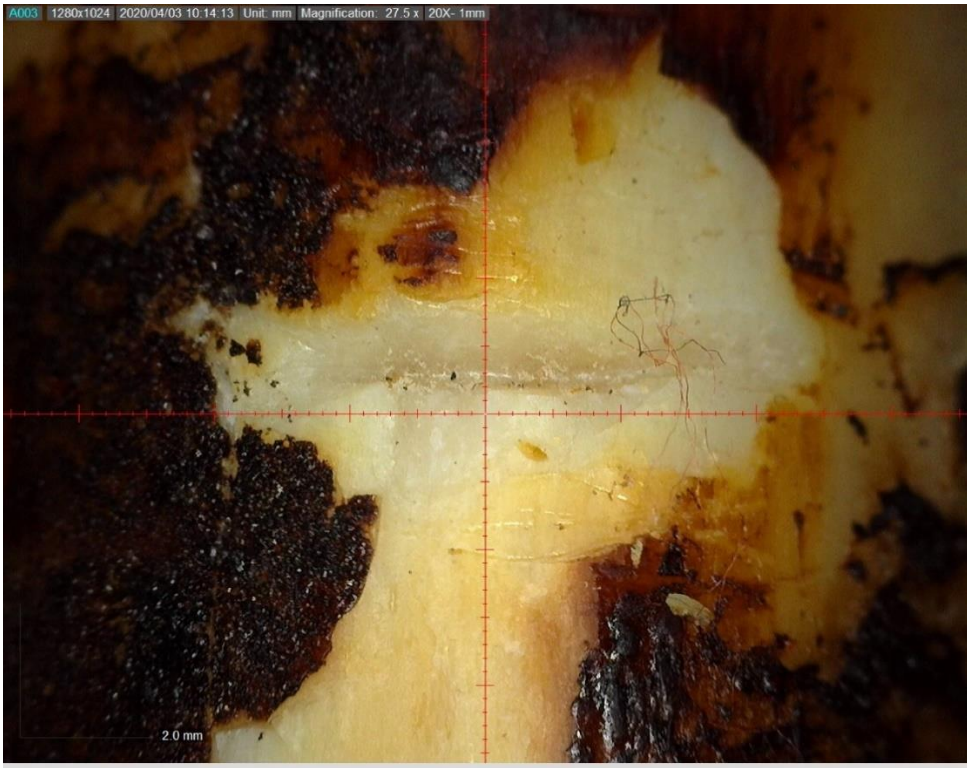

Figure 3:

This is the Dino Lite still of the un-serrated cutmark on the post-condition burnt bone. It is visible that there is discoloration at the middle of the cutmark. It is also possible to see the membrane flaking from the burning process.

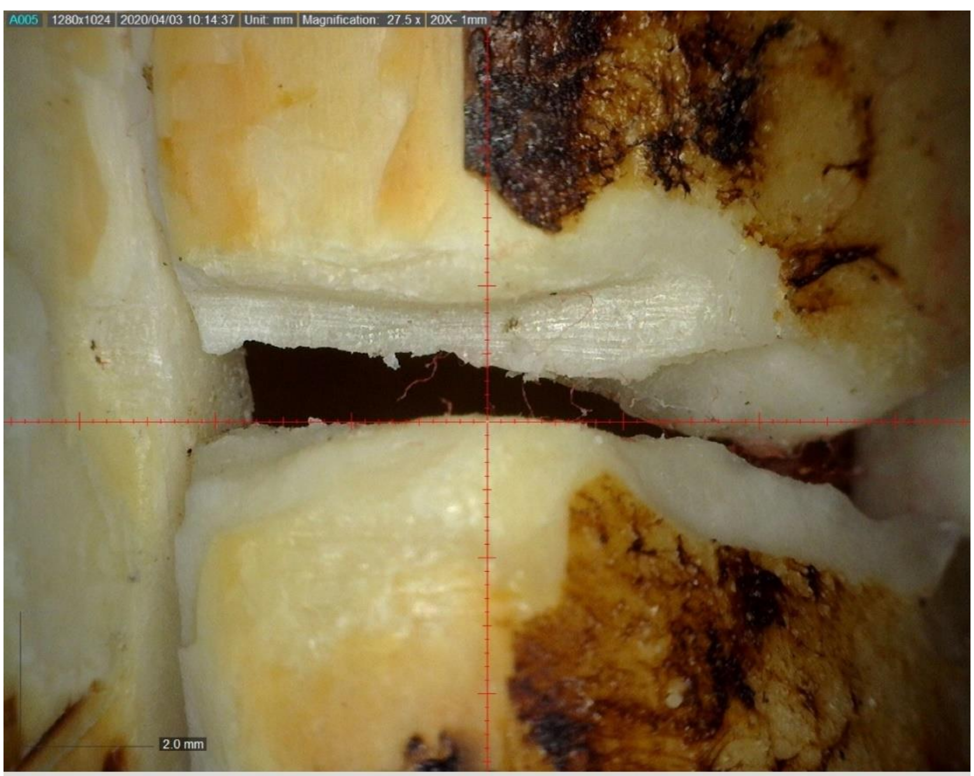

Figure 4:

A Dino Lite still of the pickaxe cutmark on the post-condition burnt bone. This mark exhibits flaking and some striation marks from impurities on the surface of the pick axe. The blunt force caused a large break in the bone during this process.

Figure 5:

A Dino Lite still of the saw cutmark on the post-condition burnt bone. This shows striations from the serrated edge leading to the main cutmark. It has no distinctive bowtie configuration like the control bone but shows flaking of the membrane around the edges.

Figure 6:

A Dine Lite still of the serrated edge knife on the post-condition burnt bone. This shows bubbling and flaking of the membrane.

Appendix D

Burnt Pre-Condition

Figure 1:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Pre-condition burnt bone. This bone was cut with all four instruments and then burnt before being observed. There was a large crack running down the middle due to the burning process which is best viewed in its entirety.

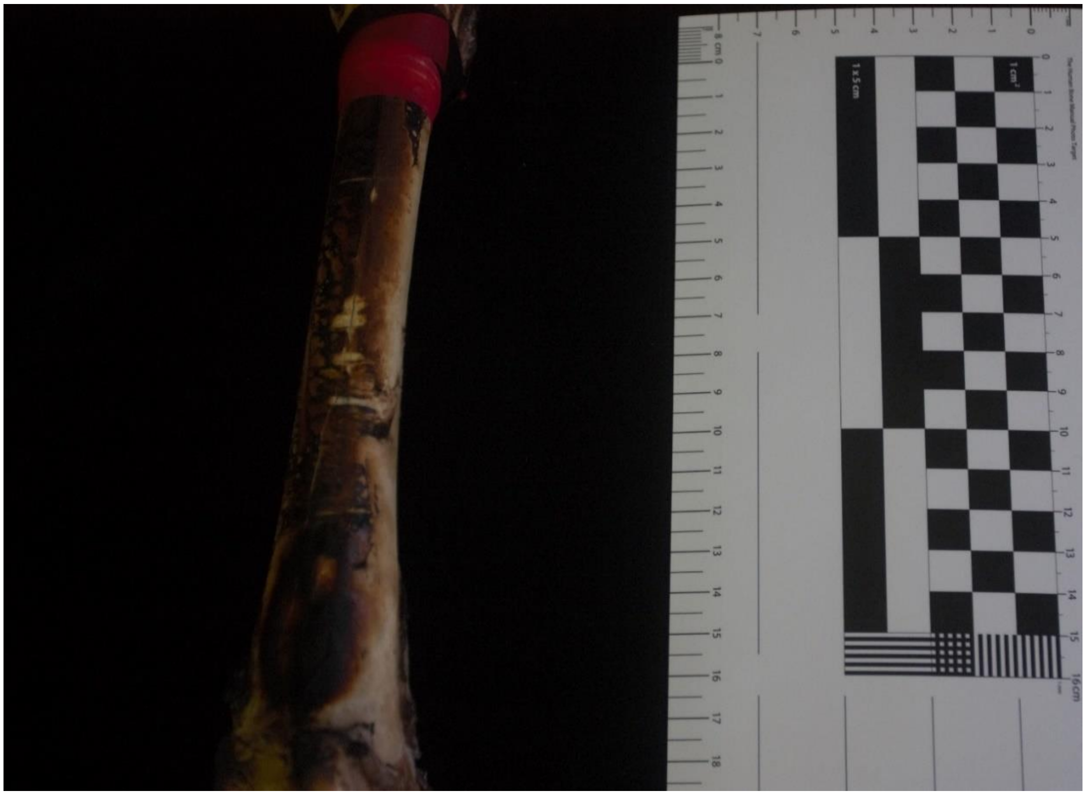

Figure 2:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Pre-condition burnt bone. This bone was cut with all four instruments and burnt before being observed.

Figure 3:

This is the Dino Lite still of the un-serrated cutmark on the pre-condition burnt bone. It is visible that there is discoloration at the middle of the cutmark. It is also possible to see the membrane flaking and bubbling from the burning process.

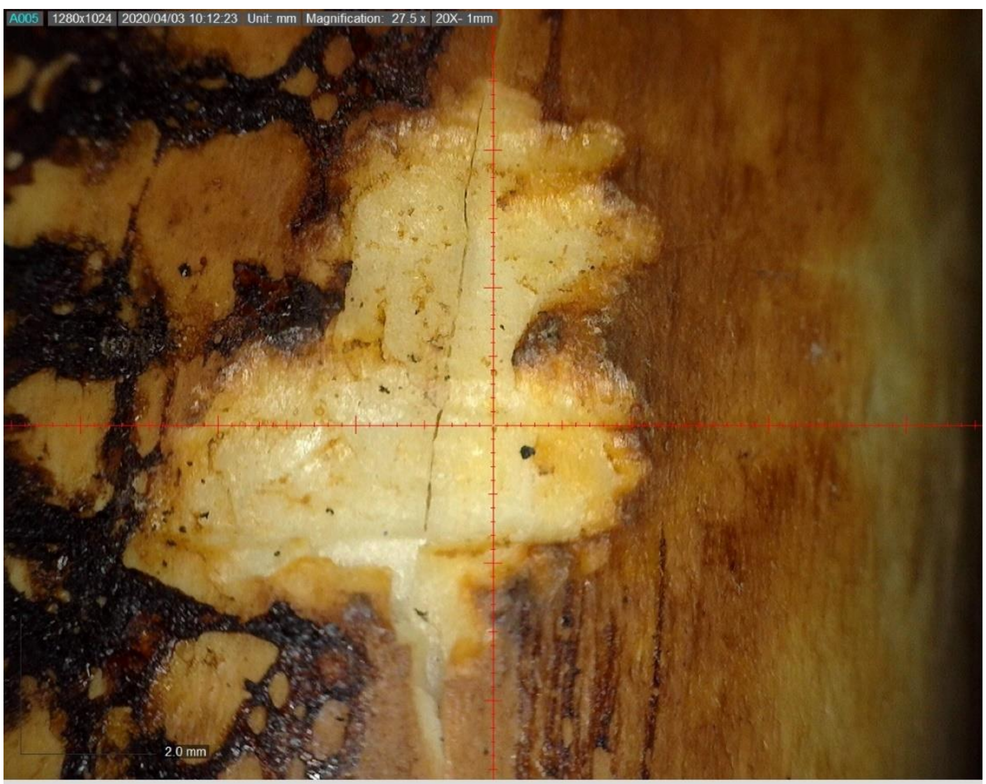

Figure 4:

A Dino Lite still of the pickaxe cutmark on the pre-condition burnt bone. This mark exhibits flaking and some striation marks from impurities on the surface of the pick axe. There is a large chunk splintered off at the base of the cutmark.

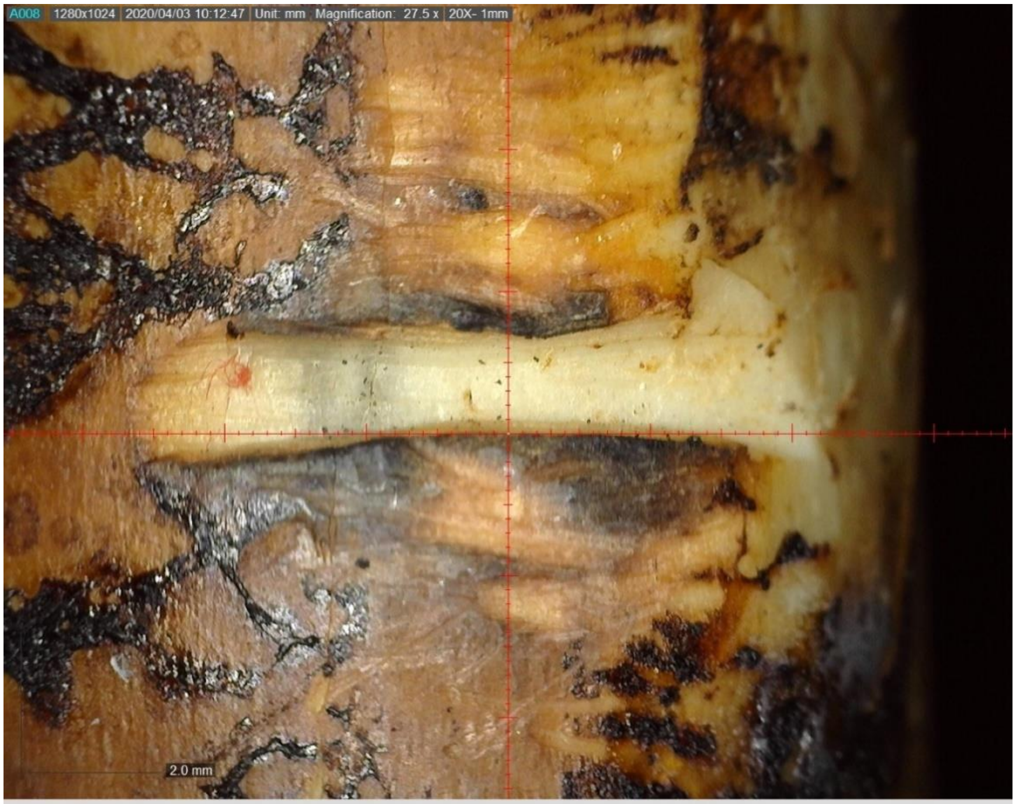

Figure 5:

A Dino Lite still of the saw cutmark on the Pre-condition burnt bone. This shows striations from the serrated edge leading to the main cutmark. It has a distinctive bowtie configuration with flaring ends. The inside of the cutmark is discolored lighter despite the burning process.

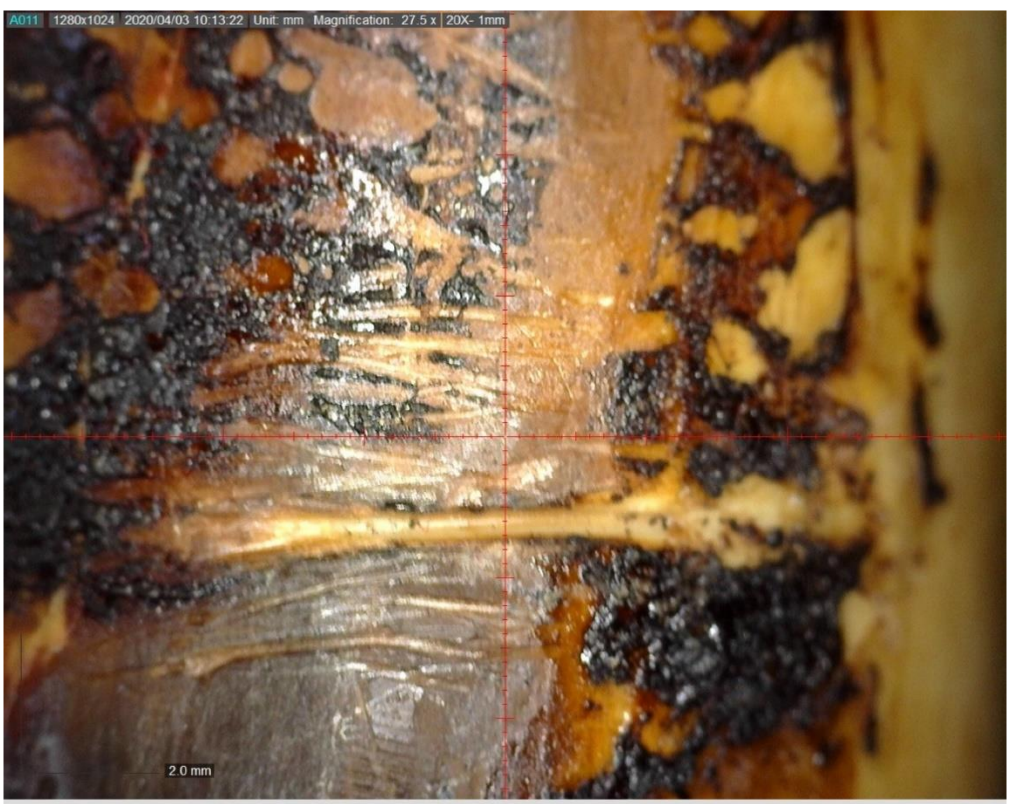

Figure 6:

A Dine Lite still of the serrated edge knife on the pre-condition burnt bone. This shows cutmarks leading to the main abrasion and bubbling and flaking of the membrane.

Appendix E

Weathered Pre-Condition

Figure 1:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Pre-condition weathered bone. This bone was cut with all four instruments and left outside in the weather conditions of the month of February 2020 in Armada, Michigan before being observed. There was a degree of discoloration over time which was able to be observed through comparison to the control bone.

Figure 2:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Pre-condition weathered bone. This bone was cut with all four instruments and weathered through being exposed to the elements before being observed.

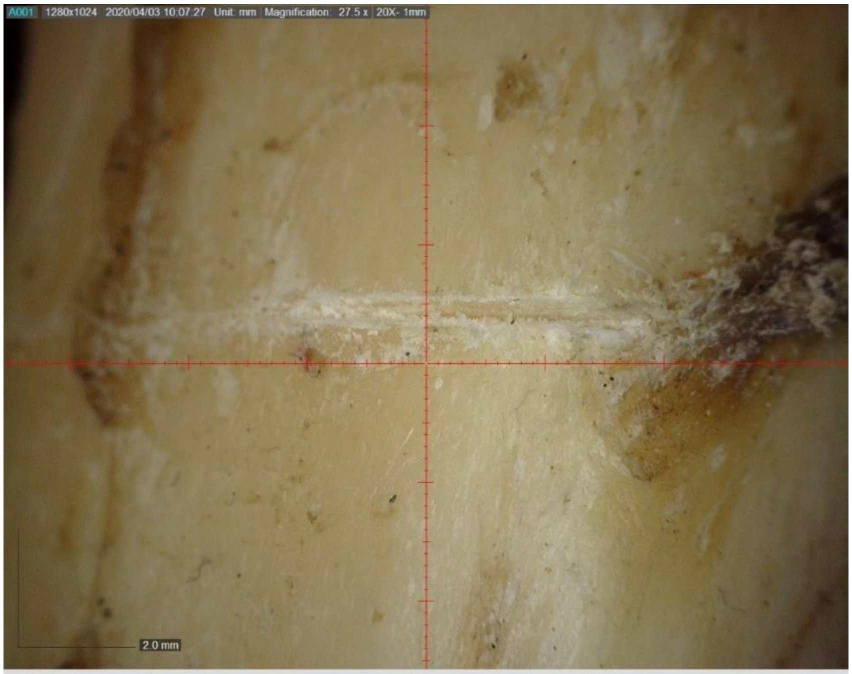

Figure 3:

This is the Dino Lite still of the un-serrated cutmark on the pre-condition weathered bone. The edges of the cutmark exhibit a rolling pattern similar to that of the control bone but with small bits flaking off and appearing drier overall.

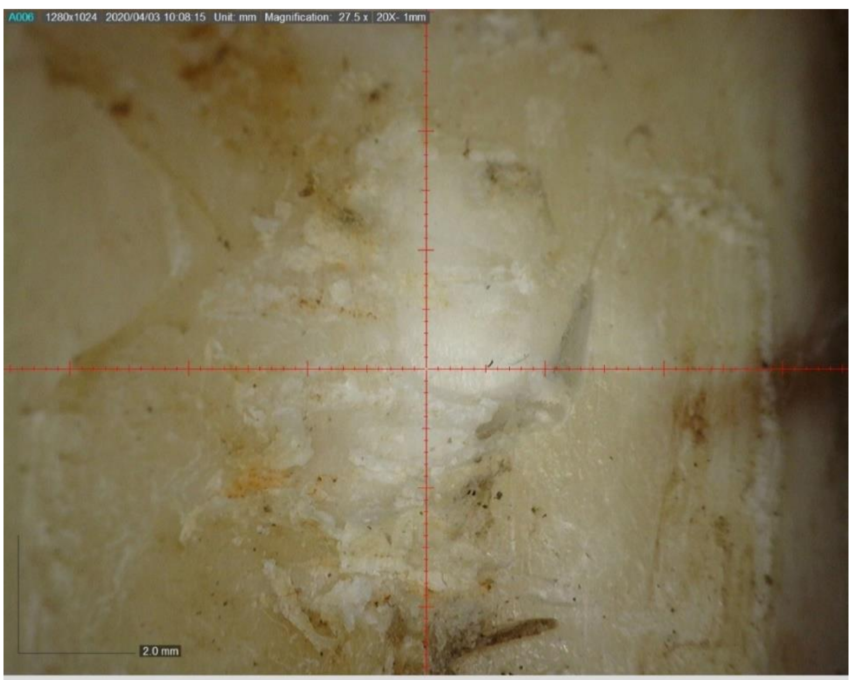

Figure 4:

This is the Dino Lite still of the pickaxe cutmark on the pre-condition weathered bone. The edges of the cutmark exhibit small bits flaking off.

Figure 5:

A Dino Lite still of the saw cutmark on the pre-condition weathered bone. This shows striations from the serrated edge leading to the main cutmark. It has a more squared-off configuration than the other cutmarks.

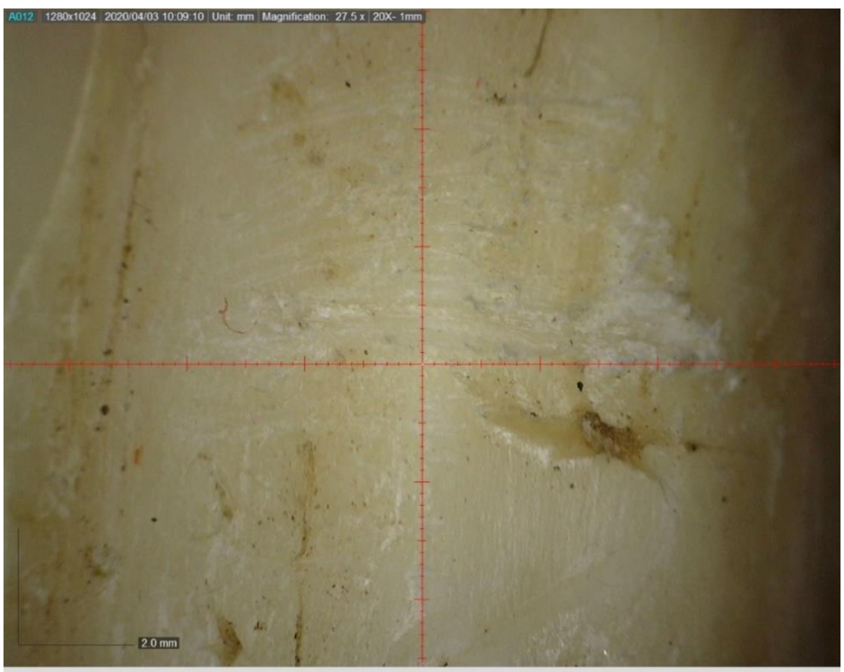

Figure 6:

A Dine Lite still of the serrated edge knife on the pre-condition weathered bone. This shows cutmarks leading to the main abrasion and peeling of the membrane.

Appendix F

Weathered Post-Condition

Figure 1:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Post-condition weathered bone. This bone was outside in the weather conditions of the month of February 2020 in Armada, Michigan before being cut with all four instruments and observed. There was a degree of discoloration over time which was able to be observed through comparison to the control bone.

Figure 2:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Post-condition weathered bone. This bone weathered through being exposed to the elements then cut with all four instruments before being observed.

Figure 3:

This is the Dino Lite still of the un-serrated cutmark on the post-condition weathered bone. The edges of the cutmark exhibit a rolling pattern similar to that of the control bone. It does not appear as dry as the pre-condition bone.

Figure 4:

This is the Dino Lite still of the pickaxe cutmark on the post-condition weathered bone. The edges of the cutmark exhibit small bits flaking off. This cutmark looks dry and appears to have larger flaking bits than the pre-conditioned bone.

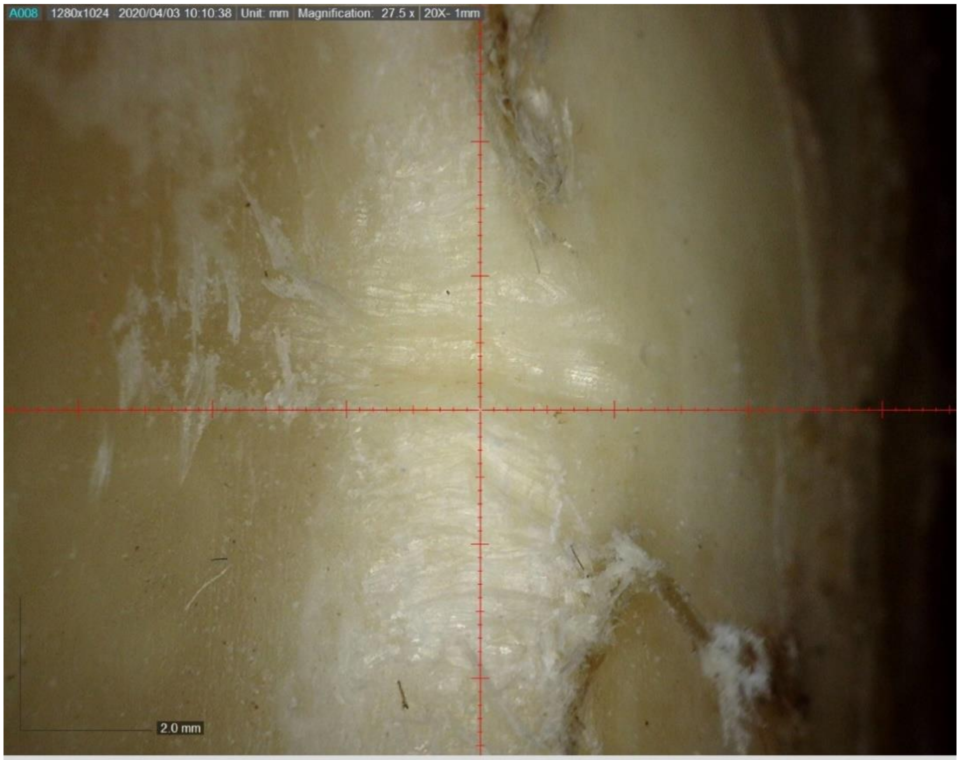

Figure 5:

A Dino Lite still of the saw cutmark on the post-condition weathered bone. This shows striations from the serrated edge leading to the main cutmark. It has an ambiguous configuration compared to the other cutmarks.

Figure 6:

A Dine Lite still of the serrated edge knife on the post-condition weathered bone. This shows cutmarks leading to the main abrasion and discoloration at the deepest point in the cutmark. This photo also shows the degree of discoloration of the bone overall.

Appendix G

Frozen Pre-Condition

Figure 1:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Pre-condition frozen bone. This photo was taken after the cutmarks were made but before the freezing process in order to use the observational notes and photos to compare the effects of freezing on the bone.

Figure 2:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Pre-condition frozen bone. This photo was taken after the freezing process in order to use the observational notes and photos to compare the effects of freezing on the bone.

Figure 3:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Pre-condition frozen bone. This photo was taken before the freezing process.

Figure 4:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Pre-condition frozen bone. This photo was taken after the freezing process.

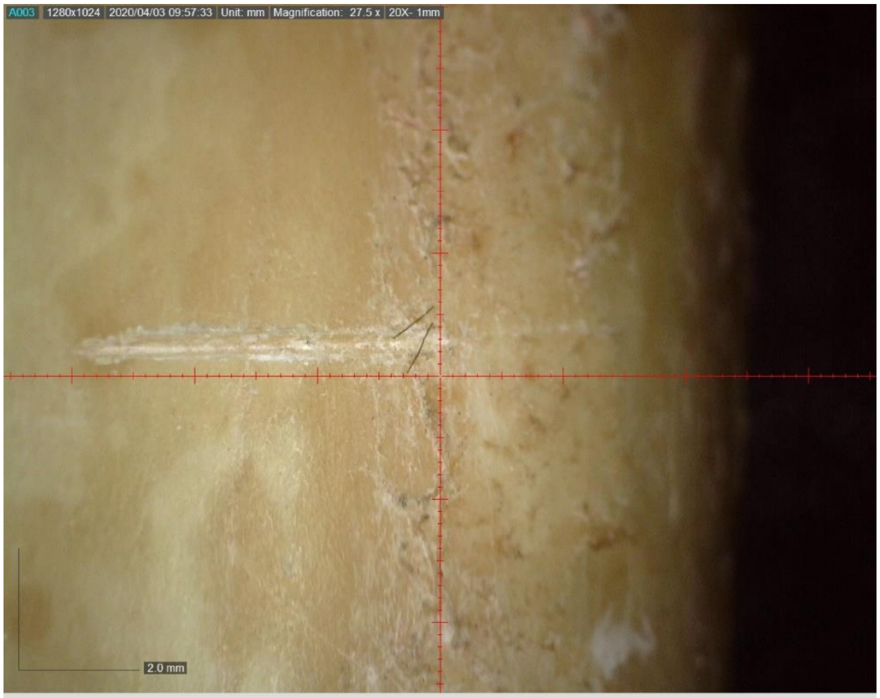

Figure 5:

This is the Dino Lite still of the un-serrated cutmark on the pre-condition frozen bone. The edges of the cutmark exhibit a rolling pattern similar to that of the control bone, but less drastic. It appears drier than the other pre-condition bones.

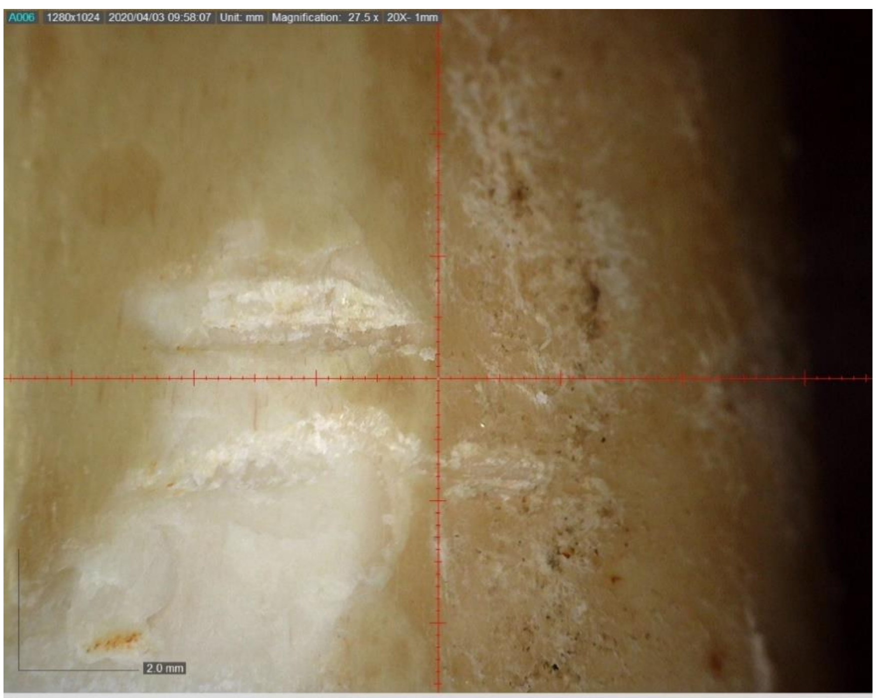

Figure 6:

This is the Dino Lite still of the pickaxe cutmark on the pre-condition frozen bone. The edges of the cutmark exhibit small bits flaking off. This cutmark looks dry and appears to have larger flaking bits in the middle of the cutmark.

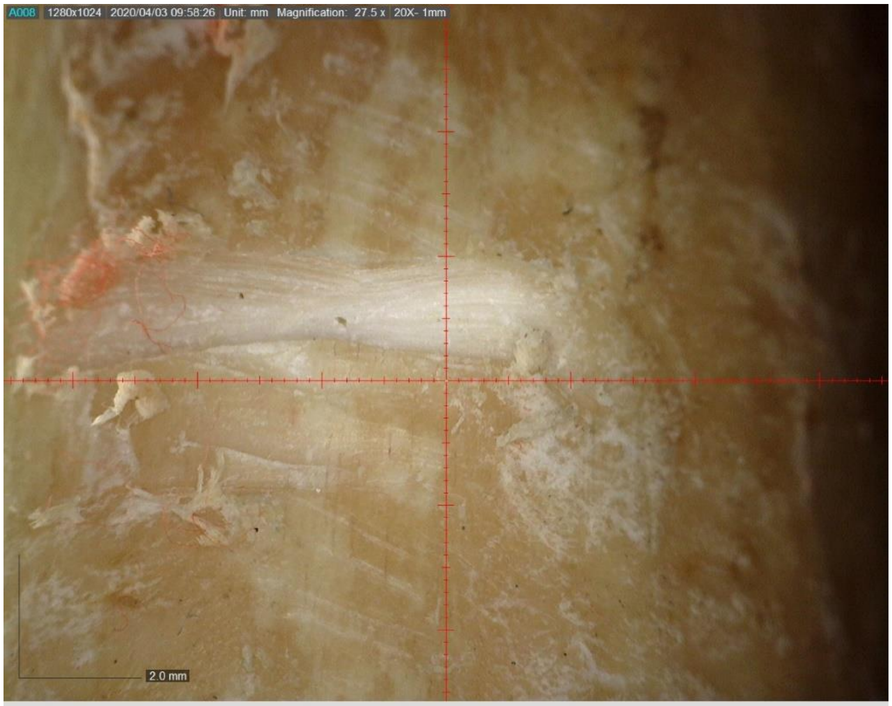

Figure 7:

A Dino Lite still of the saw cutmark on the pre-condition frozen bone. This shows striations from the serrated edge leading to the main cutmark. It has bowtie configuration like the burnt and control bones.

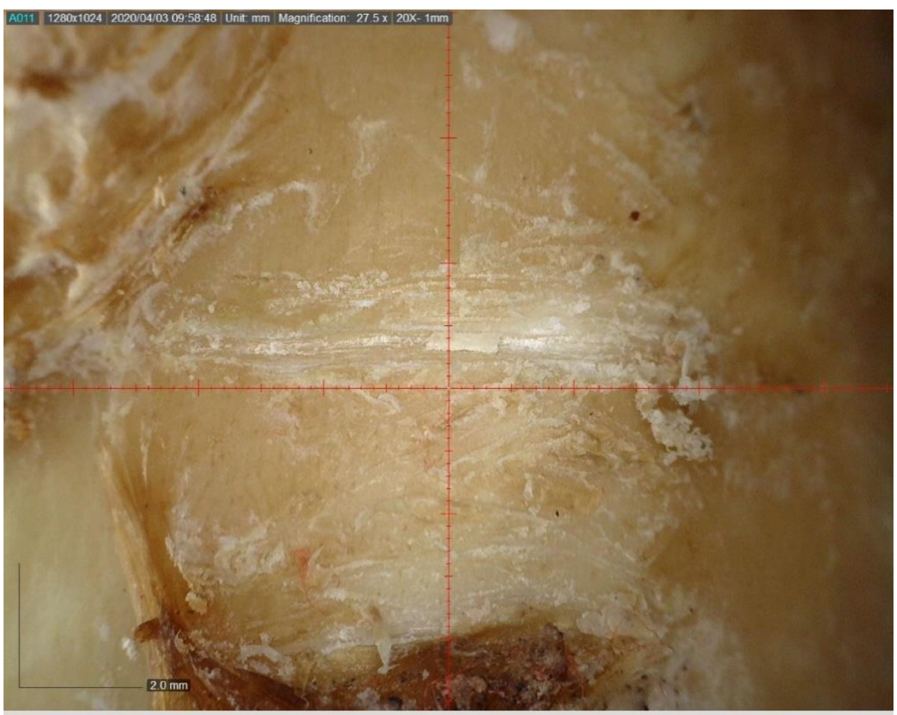

Figure 8:

A Dino Lite still of the serrated edge knife on the pre-condition frozen bone. This shows cutmarks leading to the main abrasion and flaking at the deepest point in the cutmark.

Appendix H

Frozen Post-Condition

Figure 1:

This is the DSLR digital camera photo taken for observational purpose during the traditional method of analysis on the Post-condition frozen bone. This bone was frozen then cut in the same fashion as the other bones.

Figure 2:

This is another photo taken by the DSLR digital camera for observational purpose during the traditional method of analysis on the Post-condition frozen bone. This bone was frozen then cut in the same fashion as the other bones.

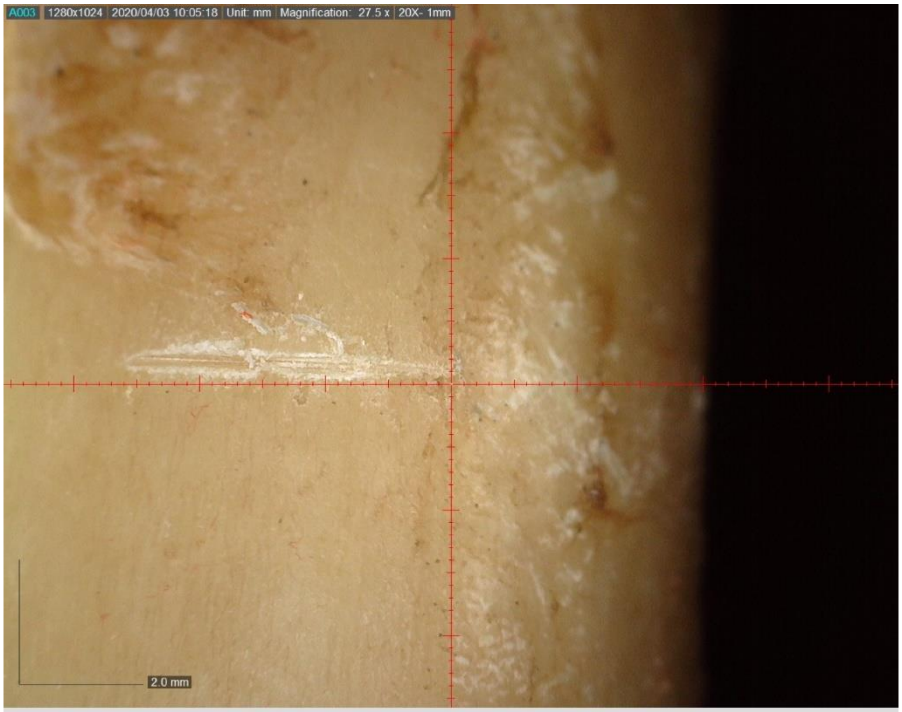

Figure 3:

This is the Dino Lite still of the un-serrated cutmark on the post-condition frozen bone. The edges of the cutmark exhibit a rolling pattern similar to that of the control bone, but less drastic. It appears drier than the pre-condition bone.

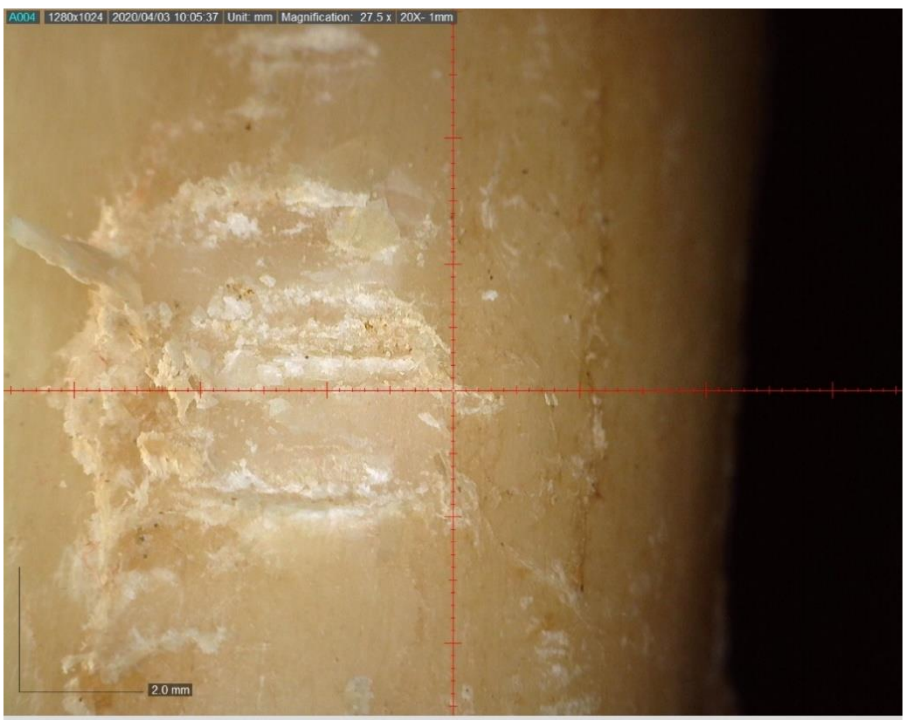

Figure 4:

This is the Dino Lite still of the pickaxe cutmark on the post-condition frozen bone. The edges of the cutmark exhibit small bits flaking off. This cutmark looks dry and appears to have larger flaking bits in the middle of the cutmark. This overall appearance is waxier than that of the pre-conditioned version.

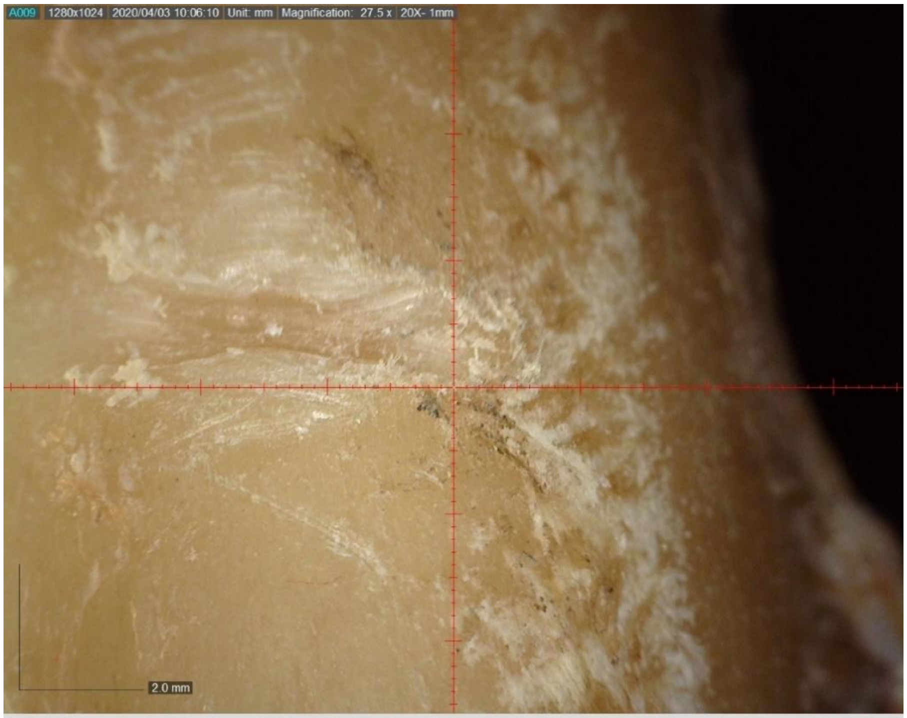

Figure 5:

A Dino Lite still of the saw cutmark on the post-condition frozen bone. This shows striations from the serrated edge leading to the main cutmark. It has bowtie configuration like the burnt and control bones. This also shows discoloration at the pit of the cutmark.

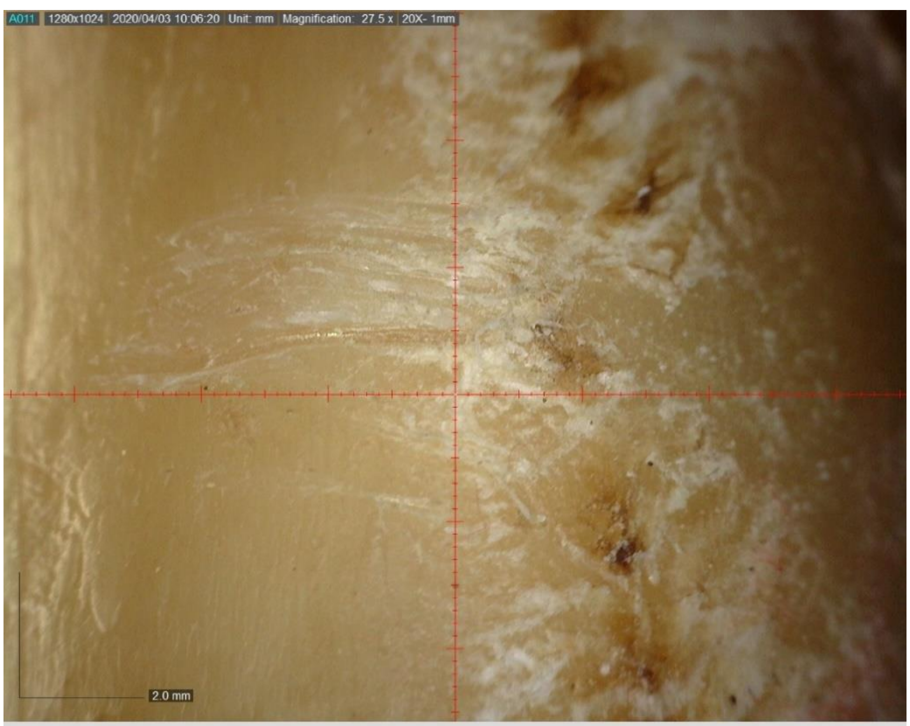

Figure 6:

A Dino Lite still of the serrated edge knife on the post-condition frozen bone. This shows cutmarks leading to the main abrasion and some discoloration at the deepest point in the cutmark.