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A Study of the Effectiveness of a Common Household Chemical for Maceration

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A STUDY OF THE EFFECTIVENESS OF A COMMON HOUSEHOLD CHEMICAL FOR
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ABSTRACT

Maceration is often a necessary component when working on a forensic case. Since it is not very common to get a case with fully skeletonized remains, the soft tissue must be removed for the forensic anthropologist to start their assessment. There are varying maceration techniques, but the goal is the same: to remove the soft tissue without damaging the bone.

The main purpose of my research is to examine a common household chemical, Drano® Max Gel, to determine its effectiveness for maceration. I tested two diluted solutions of Drano® Max Gel, 25% and 12.5%, both heated and unheated, to determine which concentration and temperature could remove the soft tissue without damaging the bone. The results indicate that unheated solutions are not effective for maceration; tissue did not dissolve and, instead, became more difficult to remove. Both heated solutions were effective at removing tissue; however, bones macerated in the 25% solution showed more cortical damage than those macerated in the 12.5% solution. This research could be the starting point in developing a new maceration technique that is not only safe for bone, but is also effective and works quickly. Continued research using Drano® Max Gel can help create a better understanding of the chemical, its effect on bone, and its potential use for maceration in a forensic context.

CHAPTER ONE: INTRODUCTION

Forensic anthropology is defined as "the scientific discipline that focuses on the life, the death, and the postlife history of a specific individual, as reflected primarily in their skeletal remains and the physical and forensic context in which they are emplaced" (Dirkmaat et al. 2008:47). As part of their job, forensic anthropologists try to determine a biological profile of the deceased. This biological profile includes age, sex, ancestry, and stature. Determining whether any pathology or trauma is present on the remains is also important. All of these facts can help the forensic anthropologist, and the police, learn the manner of death of the individual and his or her identity.

On occasion, when a forensic anthropologist first encounters human remains, the decomposition process may not be in an advanced stage. The remains could be fresh, dried out/mummified, or mostly skeletonized with some tissue still present. To be able to get to the bones to assess the biological profile, the tissue must be removed, and the bones cleaned. Medical examiners and forensic anthropologists are often faced with this task (Mann and Berryman, 2012). This process is called maceration. The purpose of maceration is to soften the skin, tendons, muscles, and ligaments so they can be easily removed without damaging the bone, or altering evidence of perimortem trauma (Mann and Berryman, 2012). Many different maceration techniques are available; some are extremely effective, but slow, and some are faster but not quite as effective. The most common techniques among forensic anthropologists include simmering in hot water, using dish detergent (with or without enzymes) or diluted bleach under a vented fume hood, or using dermestid beetles (Mann and Berryman, 2012).

One of the more important aspects of maceration is that the technique used is safe. The person administering the maceration technique needs to be protected from any harmful

chemicals, but the bone needs to be protected as well. In particular, the DNA of the deceased can be lost if the bone is damaged during maceration. Additionally, several types of evidence that the bone itself may hold can be lost if the bone is damaged. Such evidence includes information crucial for determining the identity of the deceased through the biological profile (if it is not already known), whether or not any ante-, peri- or postmortem trauma is present, and the manner of death. This information also may allow law enforcement agents to identify a suspect (if a homicide occurred) by association with the victim, if she or he is positively identified. Therefore, maceration is an important initial step in the many processes undertaken during a forensic case.

Household chemicals have been shown to impact human hard and soft tissues (Hartnett et al., 2011). Understanding their effects on bone can be helpful in finding a maceration technique. A wide variety of household chemicals are available at any grocery or hardware store around the country. Depending on what chemical one is buying, some are very inexpensive. The purpose of this research is to investigate whether a readily available household cleaning agent can be used safely and effectively for maceration. Specifically, heated and unheated diluted solutions of Drano® Max Gel were used to macerate partially defleshed pig humeri and tibiae. Once the tissue was sufficiently removed by the solution alone, the specimens were evaluated for damage associated with maceration.

CHAPTER TWO: LITERATURE REVIEW

Interest in maceration from an anthropological standpoint began in the 19th century with the collection of skulls from cemeteries for the purpose of craniometric studies (Steadman et al., 2006). Today, maceration is used to prepare specimens for many different purposes including curation, display, or research of museum or anatomical collections, as well as in forensic contexts. As such, museum curators, comparative anatomists, zooarchaeologists, anthropologists, and human skeletal biologists have helped maceration methods transform over the years.

One of the more remarkable maceration endeavors involved the thousands of individuals in the anatomical collections frequently used by anthropologists for research. The Hamann-Todd collection at the Cleveland Museum of Natural History, and the Terry and Huntington collections at the Smithsonian Institution, are all comprised of donated cadavers from the 20th century; thus all individuals had to be macerated. The method used with these collections was devised by Dr. Robert J. Terry, and is still being used today (Steadman et al., 2006). His maceration technique involves stripping the soft tissue from the bone, placing the bone in hot water for 72 hours, allowing the bone to dry, then treating it with benzene vapors to remove some of the fats. Dr. Terry strongly believed that removal of all the fats would cause the bone to become brittle and unstable (Steadman et al., 2006). Similar maceration techniques are used today in preparing specimens for anatomical collections derived from human decomposition facilities (e.g., the anthropological research facility at the University of Tennessee, Knoxville, among others).

Several variables can influence what method of maceration is used, including the amount of decomposition that has occurred and any time constraints associated with a forensic case (Mann and Berryman, 2012). Many current maceration techniques are some derivation of

Terry's original method. They generally start with removal of the soft tissue manually, which is then followed by soaking the defleshed remains in some kind of solution (which may or may not have chemical agents and which may or may not be heated). Some techniques include additional manual removal of soft tissues by gently scraping the bone using ronguers, perino picks, or some other instrument; other methods let the solution do the work. Finally, some techniques involve a final degreasing step to remove the fats (Nawrocki, 1997).

Well known maceration techniques include microwaving, boiling water, a combination of Palmolive® and meat tenderizer, and hot water and bleach, to name a few (Lee et al. 2010). These techniques can also vary by adjusting the temperature of the solution (either hotter, colder, or keeping at room temperature). Steadman and colleagues (2006) studied the effectiveness of 11 different maceration techniques that are commonly used. These methods include mechanical removal of flesh, soaking in room temperature bath or hot water, boiling, microwaving, soaking in bleach, hydrogen peroxide, Ethylenediaminetetraacetic (EDTA) acid and papain, meat tenderizer and Palmolive®, detergent/sodium carbonate, and detergent/sodium carbonate followed by degreaser. Each of these techniques was tested, then scored based on odor, soft tissue texture, ease of flesh removal, and resulting bone quality (Steadman et al., 2006).

Steadman and colleagues' (2006) research demonstrated that each maceration technique had slightly different results as well as benefits and challenges. Procedures that lacked heat or were only heated slightly (i.e., room temperature water, bleach, hydrogen peroxide, and EDTA/papain) were generally slower at removing soft tissues than hot and boiling techniques, some taking up to two months for maceration to complete. The resulting bones were fairly clean and white, although some exfoliation of the cortical bone was noted (Steadman et al., 2006). Alternatively, techniques using elevated temperatures (i.e., hot water, boiling water, microwave,

Adolph/Palmolive) quickened soft tissue removal, and completed the process in a matter of hours. However, these methods generally were more malodorous and did not necessarily produce better bone quality (Steadman et al., 2006). Individually, the Adolph/Palmolive method had some advantages over other hot water solutions by showing more soft tissue breakdown and ease of cleanup. The microwave technique also proved to be very effective by completing the process in only five to twenty minutes (Steadman et al., 2006). In summary, results from this study suggest that methods of maceration with heat are more effective in removing tissue in a timely manner, a fact which is important in a forensic context.

The point of maceration is to remove all soft tissue efficiently and effectively, while not damaging the bone. Using bleach as a maceration agent has been a topic of controversy over the years because of the potential for damage to the bone. Bleach acts by oxidizing the protein bond in bone, making it effective for removing soft tissues such as muscles, tendons, and ligaments. Bleach is especially effective for removing tissues from small sections of bone, such as the clavicle and the pubic symphysis (Mann and Berryman, 2012). However, bleach also has been shown to damage the cortical bone. In general, oxidizing agents often cause flaking on the surface of bone which, in turn, destroys any evidence (both macroscopically and molecularly).

Nawrocki (1997) details the procedures typically used for cleaning "dirty bones" and biohazard specimens, as well as for boiling or chemically degreasing bones. "Dirty bones" refer to archaeological or ancient remains. In such cases, the bones are cleaned with a soft bristle brush, such as a toothbrush, and warm water. These remains are often encased in mud, which can be removed with wooden chopsticks (wood is less destructive on bone when compared to metal implements). The bones then air dry on newspaper or screens (Nawrocki, 1997). Conversely, biohazard specimens generally are cleaned with a bleach solution of one cup of

bleach to one gallon of water. Nawrocki cautions against over-boiling the remains in bleach as doing so could damage the cortical surface (Nawrocki, 1997). Boiling often is the fastest form of maceration, and involves the following four steps: 1) manually removing as much skin, tendons, muscles and ligaments as possible, 2) putting the bones in a metal pot and covering completely with water, 3) adding up to a cup of a powdered enzyme-active borax and bringing to a boil, and 4) scraping off any remaining tissue with chopsticks. Boiling should be limited to one to two hours then followed by letting the solution simmer for six to eight hours if necessary (Nawrocki, 1997). In any context where the remains will be stored or curated for an indefinite period of time, chemical degreasing is a necessary step. The bones typically are soaked for a few days, or even weeks, in two to three cups of household ammonia per gallon of water. The remains then are air dried on paper for approximately two days (Nawrocki, 1997).

Fenton and colleagues (2003) detail a fast, safe, and inexpensive non-bleaching maceration method that was developed at the former Human Identification Laboratory at the University of Arizona. Their technique involves the use of standard household chemicals and a three-ingredient procedure that has evolved over 30 years (Fenton et al., 2003). The three ingredients are water, a powdered detergent (e.g., Alconox, Tide, Cheer) at 20 cc per 2 liters of water, and a powdered sodium carbonate (e.g., Arm and Hammer Washing Soda) at 20 cc per 2 liters of water. A degreasing step can be employed when necessary and involves household ammonia at 150 milliliters per 2 liters of water (Fenton et al., 2003). The remains are put into the water-detergent-carbonate solution over low heat and may require several changes of the solution during the procedure. After each heating episode, the remains must be rinsed in water and any remaining soft tissue manually removed (Fenton et al., 2003). If curating the remains, they should then be placed in the water-ammonia solution over low heat for several cycles (Fenton et

al., 2003). Fenton and colleagues (2003) believe that their method of maceration is safe for the technician in that no volatile compounds or noxious fumes are involved, and safe for the remains in that the use of non-bleaching chemicals will not consume calcium in the bone. The remains produced by this technique are in excellent condition, making this a method that can be easily used in an archaeological or forensic context, and one that makes analysis, documentation, and curation simple (Fenton et al., 2003).

A study by Mairs and colleagues (2004) looked at various detergents as possible maceration agents. Using 44 defleshed pig hind and forelimbs, they tested nine detergents, in capsule form, including Persil Performance, Bold 2-in-1 Aqua, Daz, Vanish, Sunfresh Surf, Ariel, Persil, Non-Biologic, Fairy Non-Biologic, and Ariel Non-Biologic (Mairs et al., 2004:278). They then compared the results of the various detergents with five other techniques including manual cleaning, enzymatic maceration, "cooking" (i.e., heating), water maceration, and insect consumption.

Mairs and colleagues' (2004) results indicated that manual cleaning, which involves the use of a scalpel, forceps, and a firm brush or scouring pad, is especially effective when cleaning long bones. However, manual cleaning can be difficult, and may lead to damage, when more delicate skeletal elements, such as cervical vertebrae, are being cleaned (Mairs et al., 2004). Water maceration, both heated ("cooking") and unheated, involves natural bacterial decomposition. When the water is not subjected to heat, this technique takes more time. While cooking is a very quick maceration technique, it can often cause damage to the bone. Enzymatic maceration uses chemicals such as papain, which can be hazardous to the user, but can be effective, often removing soft tissue within 24 to 48 hours.

With regard to the various detergents, Mairs and colleagues (2004) found that, after four days in the solutions at room temperature, there were no real changes in soft tissue. After three days of heating the solutions to approximately 104 degrees Fahrenheit, the periosteum of bones soaked in the Bold 2-in-1 and Surf solutions could be removed with a scouring pad. The seven remaining detergents loosened the soft tissue, but not to the extent that it could be manually removed easily. After two days at approximately 140 degrees Fahrenheit, the Persil Performance, Daz, and Ariel solutions had the best results: only small amounts of soft tissue were present and they could be removed with light scrubbing (Mairs et al., 2004). All detergents created a neutral or slight perfumed smell. In conclusion, this study found that detergent capsules are not only effective at removing soft tissue, producing good bone quality, and removing any odor, but they are also convenient in that they can be carried into the field and purchased from almost any store.

Lee and colleagues (2010) evaluated the effect maceration had on DNA amplification. Though not the sole purpose of the study, they do report the effectiveness of different maceration techniques for cleaning bones. Using human tibiae, fibulae, and a femur from amputated limbs obtained from a local hospital, they investigated nine maceration techniques including mechanical removal (control), hot water bath, boiling, microwaving, bleach, hydrogen peroxide, EDTA/papain, meat tenderizer/Palmolive®, detergent/sodium carbonate, and detergent/sodium carbonate plus a degreaser (Lee et al., 2010). With regard to the speed of maceration, their results were similar to other studies. That is, they found that the techniques involving heat cleaned the bones faster, often within a matter of minutes or hours when compared with the techniques that lacked heat. They also found that techniques involving heat generally had better

bone quality as well. Techniques using meat tenderizer/Palmolive® and boiling in plain water also removed the soft tissue quickly and did not damage the bone (Lee et al., 2010).

Being able to collect DNA from skeletal remains from a forensic context can be a vital part of the case. DNA is useful not only for establishing a positive identification, but also for helping law enforcement with other aspects of the case (such as identifying perpetrators). While the main goal of maceration is to clean the bones so they can be examined, one must be careful to select a technique that does not destroy any DNA that may be available. Lee and colleagues (2010) found that maceration techniques do indeed have an impact on the successful extraction and subsequent analysis of DNA.

With regard to DNA, Lee and colleagues (2010) found that microwaving, as a maceration technique, had the highest success rate on the ability to recover and amplify nuclear DNA (nDNA). Microwaving was also extremely successful for macerating, in that it required a very short amount of time while also not damaging the bone. Techniques using meat tenderizer/Palmolive and boiling in plain water also removed the soft tissue quickly, did not damage the bone, and were successful approximately 50% of the time at amplifying nDNA. Hot water had the least successful rate of amplification despite the fact that the quality of the remains still appeared to be good (Lee et al., 2010).

In a similar study, Rennick and colleagues (2005) looked at three maceration techniques and the effect each had on collecting DNA from human and non-human bones. For this study, they used bone samples from cows, sheep, and pigs, as well as from humans. The three solutions they tested included a control of purified water, a 25% household bleach solution, and 20cc of detergent/carbonate in water (Rennick et al., 2005). Their results were varied. The bone boiled in bleach had a whiter appearance compared to a more beige color of those boiled in the control

and detergent/carbonate solution. Along with a whiter appearance; however, the bone boiled in bleach flaked more easily, while the other bones were more solid. For DNA extraction, the pig samples, which were boiled in water, yielded the most DNA (Rennick et al., 2005). Overall, they concluded that bleach is very effective at removing the soft tissue; however, it degrades the bone too much (including decalcification, destruction of proteins, and cortical damage) to be useful in forensic contexts (Rennick et al., 2005).

Corrosive Chemicals

Many household chemicals that are readily available, such as drain and septic tank cleaners, pool chemicals, rust dissolvers, and other cleaning products, could potentially destroy tissues in a body. The caustic effect of such agents was demonstrated in a recent study by Hartnett and colleagues (2011). To test which chemicals have the greatest effect on soft tissue and bone, researchers studied six chemicals (including hydrochloric acid, sulfuric acid, household lye, bleach, a 100% natural active bacteria and enzyme product, and a cola soft drink) along with a control of tap water. Samples tested included a nonpathological femur of a 49 year old white male (purchased from a medical research company), soft tissue from the femur (including skin, muscle, fascia, and connective tissue), fingernails from a manicurist (cut distal tips), hair from a beauty salon (cut), and pulled teeth from a forensic odontologist. The teeth consisted of similarly sized adult molars and incisors (Hartnett et al., 2011). Each sample was then soaked in two ounce glass jars which contained the varying chemical solutions.

Results from this study showed that hydrochloric acid has a profound effect on soft tissue and bone compared to the other products, with sulfuric acid coming in second. Hydrochloric acid consumed all tissue, except for hair and nails, within 24 hours, and bone was dissolved completely in less than 20 hours (Hartnett et al., 2011). Sulfuric acid, on the other hand,

consumed the bone and teeth over a period of several days causing "bubble-like" formations on the surface of the bones after immediate immersion in the acid (Hartnett et al., 2011). Remains submerged in the other three chemicals had less radical effects. Bone and tissue samples submerged in bleach remained unchanged, structurally, after one month, but the bones and teeth became whiter (Hartnett et al., 2011). Lye appeared to dissolve the fats in the flesh and the contents of the marrow cavity, but did not change the overall structure or color of the bone. An interesting side effect of the lye was that once the remains were submerged in the lye, the jar containing the solution became too hot to be touched with bare hands (Hartnett et al., 2011). Lastly, the remains in the cola drink were not altered in density or integrity, although they were darkened in color (Hartnett et al., 2011).

In summary, Hartnett and colleagues (2011) found that, when compared to the other five chemicals, hydrochloric acid had the capability of completely destroying either portions of or an entire human body if a large enough quantity was obtained to fully submerge the remains (Hartnett et al., 2011). While the other chemicals did not have such a drastic effect on the bone, they nevertheless caused some damage or changes to the bone and/or marrow cavity.

Lastly, the results of a previous study I completed for a class assignment indicated that pure Drano® has the ability to completely remove soft tissue from bone (Wyatt and Roberts, 2011). For this study, two fully fleshed human hands, from one set of remains, were submerged in five quart plastic containers, which were filled with pure Drano® Max up to the level of the proximal metacarpals. The plastic containers were then wrapped in transparent plastic bags and secured to the wrist with twist ties. The remains were checked after three days. Results showed that all tissue was completely removed and the bones had become disarticulated. However, despite the effectiveness of Drano® Max in removing the tissue, the bone was damaged in the

process. The cortex was heavily bleached, and the cortical layer of the bone was flaking slightly. The amount and types of damage were not evaluated (Wyatt and Roberts, 2011).

Dermestid Beetles

Dermestidae, a family of *Coleoptera*, have been used for maceration since 1922 (Sommer and Anderson, 1974). Other common names for Dermestid beetles (*Dermestes maculatus*) include larder beetles, hide or leather beetles, carpet beetles and khapra beetles. There are approximately 500-700 Dermestid beetle species worldwide. Dermestid beetles are often used by museum curators who have a large amount of small to medium sized specimens that need to be cleaned inexpensively, completely, and without any damage (Sommer and Anderson, 1974). Larder beetles (*Dermestes haemorrhoidalis*) are often seen in a forensic context, but they can also be used for maceration for museum curation. Dermestid beetles are necophagous insects, commonly found indoors on dry human remains (Charabidze et al., 2014). After mating, the females lay 10 to hundreds of eggs in cavities in the tissue. The larvae feed on the surface, but before each individual moults, it burrows into the tissue. After approximately seven to eight moults, the larvae have reached an appropriate weight for metamorphosis and begin to build pupation chambers (Charabidze et al., 2014:162).

Insect consumption of soft tissues (primarily dermestid beetles) is the preferred method when small, delicate skeletal remains are involved. Dermestid beetles can potentially remove soft tissue in as little as 24 hours, but constant supervision is usually required. Once all the soft tissue has been consumed, if the skeletal remains are not promptly removed, the beetles may digest the bone (Mairs et al., 2004).

In one study, Charabidze and colleagues (2014) used larder beetles to deflesh seven human mandibles and maxillae. After 22 days, they found total removal of soft tissue, leaving bare and

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clean bones. They concluded that use of larder beetles, compared to dermestid beetles, requires little human involvement, with only the placing and removing of bone needed (Charabidze et al., 2014).

Two techniques using dermestid beetles are available: the cotton-bed technique and the formalin inhibition technique. Both techniques are effective for tissue removal in different ways. The cotton bed technique works well to reduce the amount of debris accumulated from the beetles and allows the observer to view the maceration in progress. The formalin inhibition technique works well when dealing with skeletons or elements with multiple, tiny components, such as dolphin skulls and bird feet (Sommer and Anderson, 1974). Sommer and Anderson (1974:296) found that maceration through dermestid beetles is efficient and very useful for delicate vertebrates.

The cotton-bed technique involves using a 70 to 80 millimeter layer of cotton bedding in a box or container. The remains are placed on top of a framed mesh screen, which has openings approximately six millimeters wide. The cotton layer lies beneath the screen, and provides an area for the beetle larvae to pupate. The cotton layer will also keep the beetle droppings and debris from accumulating on top of the mesh screen and, thus, obscuring the view. This allows the beetles, and their work on the remains, to be clearly viewed at all times (Sommer and Anderson, 1974:292).

The formalin inhibition technique is used when certain items need to remain articulated or be disturbed as little as possible during the maceration process. For example, a dolphin dentition (which is composed of numerous small teeth) would be better kept intact, rather than reconstructed after maceration. Therefore, a thin layer of formalin is applied to the area surrounding each tooth to keep the teeth in place. Usually, at least three or four coats of formalin

need to be applied to keep the teeth firmly in place during beetle maceration (Sommer and Anderson, 1974). The remains are then placed in a container with the beetles for maceration.

According to Russell (1947:286-287), there are five steps that must be followed for keeping dermestid beetles alive and healthy for maceration purposes. As compared to the techniques followed by Sommer and Anderson (1974), these steps involve 1) preventing sawdust from drying on the bones; 2) keeping arsenic, salt or formalin off the bones; 3) keeping flies away from the specimens; 4) quickly drying the bones, either naturally or artificially, to prevent the growth of mold; and 5) removing the brains from all skulls before drying. Humid air will often cause the growth of mold, which can potentially kill the beetles (Russell, 1947:287). Following these steps to prepare remains prior to placement in the containers with the beetles will allow the best results possible from using dermestid beetles for maceration.

Research has shown that using dermestid beetles to macerate the skeleton can be a very efficient technique. Hefti and colleages (1980) completed a study comparing rat bones cleaned by dermestid beetles with those cleaned by hand. One leg (femur, tibia, fibula) of a rat carcass was cleaned by hand, while the remainder of the carcass was cleaned using dermestid beetles (Hefti et al., 1980). Before being placed in a cage with the beetles, the skin and intestines were manually removed. After approximately 24-48 hours, the skeleton was free of soft tissue, with only the ligaments still holding the bones in place. The dry weight of the long bones cleaned by hand was higher than those cleaned by the beetles. This result was explained by the presence of connective tissue around the trochanters of the femur on the manually cleaned remains (Hefti et al., 1980). Hefti and colleagues (1980:47) found that dermestid beetles are able to effectively clean skeletons in a short amount of time; however, the beetles must be carefully observed during the process. Macroscopic lesions were found on the bones when the remains were left

with the beetles for several days and the beetles were deprived of another source of food (Hefti et al., 1980). This result can be prevented by keeping a close watch on the beetles during maceration, providing an alternative adequate source of food other than the remains being macerated, or removing the skeleton immediately when the cleaning process is complete.

Summary

In summary, multiple maceration techniques are available to clean and prepare skeletal remains for use in many contexts (Table 1). For forensic cases, ideal maceration techniques involve those that can effectively remove the soft tissue in a timely manner, without damaging the bone, either macroscopically or at the molecular level. The current research will further explore the use of Drano® Max as a maceration agent as well as its impact on cortical bone.

Table 1. Summary of Maceration Techniques

Method/Detergent	Relative Speed of Tissue Removal	Damage to Bone Surface	Study
Mechanical removal	Slow	Possible	Steadman et al. (2006); Mairs et al. (2004); Lee et al. (2010)
Soaking in room temperature bath	Slow	No damage	Steadman et al. (2006)
Soaking in hot water bath	Fast	No damage	
Boiling	Fast	Studies report contradicting results	Steadman et al. (2006); Mairs et al. (2004); Lee et al. (2010)
Microwaving (keep bone moist w/ water)	Fast	No damage	Steadman et al. (2006); Lee et al. (2010)
Soaking in bleach	Slow	Some exfoliation/flaking of cortical bone; porosity	Steadman et al. (2006); Lee et al. (2010); Rennick et al. (2005); Hartnett et al. (2011)
Hydrogen peroxide (3%) w/ water	Slow	Some exfoliation of cortical bone	Steadman et al. (2006); Lee et al. (2010)
EDTA acid and papain w/ water	Slow	Dark stains (could obscure cut marks)	
Meat tenderizer and Palmolive® w/ water	Fast	Studies report contradicting results	
Detergent/sodium carbonate w/ water	Slow	Loss of bone density, slight exfoliation of cortex	

(Table 1 continued)

Method/Detergent	Relative Speed of Tissue Removal	Damage to Bone Surface	Study
Detergent/sodium carbonate followed by degreaser	Slow	Some damage possible	Steadman et al. (2006); Lee et al. (2010)
Boiling in bleach (1 c. bleach to 1 c. water)	Fast	Over-boiling can cause damage to cortical surface	Nawrocki (1997)
Water, powdered detergent, powdered sodium carbonate (low heat)	Fast	No damage	Fenton et al. (2003)
Detergent (Bold 2-in-1, Surf)	Slow	No damage	Mairs et al. (2004)
Detergent (Persil Performance, Daz, Ariel)	Fast	No damage	
Dermestid Beetles	Slow/Fast	Requires constant supervision; beetles can digest the bone	Mairs et al. (2004); Hefti et al. (1980)
Larder Beetles	Slow	No damage	Charabidze et al. (2014)
Hydrochloric acid w/ water	Fast	Dissolves bone	Hartnett et al. (2011)
Sulfuric acid w/ water	Fast	Dissolves bone	
Household lye w/ water	Fast	Dissolves bone marrow, does not change structure of the bone	
100% natural active bacteria and enzyme product w/ water	N/A	No damage (color change)	
Cola soft drink w/ water	Slow	No damage (color change)	
Drano® Max	Fast	Cortex heavily bleached, cortical flaking	Wyatt and Roberts (2011)

CHAPTER THREE: MATERIALS AND METHODS

The purpose of the current study is to determine if Drano® Max Gel can be used safely and effectively for maceration. Drano® Max Liquid, which was used in the 2011 pilot study, could not be found for purchase. Drano® Max Gel consists of two bases: sodium hydroxide and sodium hypochlorite. Health hazards associated with Drano® Max Gel include chemical burns, skin irritation, and severe damage to the digestive tract if ingested. Drano® Max Gel has a pH level of 11.5-13.4, which can be compared to a basic solution, such as sodium hydroxide (Manufacturer's Department Technical Support, 2005:2). Although Drano® Max Gel is a stable product, if mixed with other chemicals, it could potentially produce chlorine gas (Manufacturer's Department Technical Support, 2005:3).

Skeletal samples used in this study consisted of partially defleshed pig (*Sus scrofa*) humeri, and articulated tibia and fibulae. Pigs are biochemically and physiologically similar to human remains and, therefore, are often used as a proxy for humans, especially in decomposition studies (Haglund and Sorg, 2006). Adult pigs were used in this study because the larger size not only more closely approximates that of adult humans, but also facilitates examining damage to cortical bone. Specimens were obtained from local butchers, as well as from Guillory's Grocery in Pine Prairie, Louisiana, and Cruse Meat Processing in Concord, North Carolina. No animals were killed specifically for this study.

Originally, 50% and 25% solutions of Drano® Max Gel were going to be tested for their effectiveness in maceration. Prior to beginning the experiment, a test round was completed using those two concentrations in both heated and unheated solutions (the remainder of the solution was tap water). Prior to submerging in the solutions, as much soft tissue as possible was manually removed from the skeletal elements. For the 50% solution (both heated and unheated),

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a femur and tibia/fibula (articulated) were used. The size of the two samples was approximately the same. For the 25% solutions, a femur and tibia/fibula were also used, and were also approximately the same size. From these initial tests, it was determined that the 50% solution was too strong, ultimately causing damage to the cortical surface of the bone. The 25% solution showed better results, so the Drano® Max Gel solutions tested in the remainder of the study were changed to 25% and 12.5% concentrations.

The skeletal elements tested in the experimental rounds included articulated tibia/fibulae and humeri (femora could not be obtained). Each solution tested was both heated and unheated. The effectiveness of the solutions for maceration, as well as any associated skeletal damage, was documented at regular 30 minute intervals. Each concentration was tested twice, with the second round serving as a validation round.

Before being placed in the solution, as much tissue as possible was manually removed from each element using scalpels and scissors; periosteum, cartilage, and tissue at origins and insertions were left in place. Specimens were then photographed to document their initial condition. For the 25% unheated solution, tibiae/fibulae were used, while humeri were used for the heated solution. Elements were placed in two stainless steel pots and covered with the solution. The pot with the unheated solution was placed underneath a fumehood and left uncovered. The pot with the heated solution, also uncovered, was placed on a burner underneath a fumehood, brought to a boil, then reduced to a simmer. At 30 minute intervals, specimens were removed from each solution, photographed, and the condition of the soft tissue and any damage to cortical bone was documented using the criteria discussed below. This process continued until the bone was completely free of tissue, or until tissue could be scraped off with light pressure from fingertips (no instruments were used for cleaning). At the end of each day, the bones were

removed from the solution, then replaced when the experiment resumed the following day. The same procedure was followed for the 12.5% solution, using tibiae/fibulae for the unheated solution and humeri for the heated solution.

The scoring system used in this study to document the condition of the bone was revised slightly from the one created by Steadman and colleagues (2006). This system provides criteria for documenting changes in soft tissue texture, ease of flesh removal, and bone quality. Soft tissue texture was scored based on how the remaining tissue felt when palpated, while ease of flesh removal was scored based on how adherent the tissue felt to the bone when pulled slightly. A category for bone greasiness was added to assess the condition of the bone once maceration was complete. Table 2 presents the qualitative criteria and corresponding numerical score within each of the four categories.

Once all tissue appeared to be gone, specimens were removed from the solutions and placed underneath a fumehood to dry. The category of bone quality continued to be scored, along with the category bone greasiness, at one, two, four, and eight weeks post removal. These latter observations documented any destruction to the bone that occurred after maceration was complete.

My hypotheses and expectations for this experiment are as follows: 1) heated solutions will macerate more quickly than unheated solutions, 2) the 25% solutions will macerate more quickly than the 12.5% solutions, and 3) the 25% solutions will result in greater cortical damage than the 12.5% solutions. Ultimately, the safety and effectiveness of the Drano® Max Gel solutions will be determined by the length of time it takes for the bone to be completely free of tissue and the amount of damage to the bone surface.

Table 2. Maceration Scoring System[1]

Soft Tissue Texture:	Ease of Flesh Removal:	Bone Quality:	Greasiness:
1. Soft tissue is firm and/or quite solid; may feel tougher or more rubbery than when first submerged	1. Adherence to bone is quite strong with little or no flesh removal possible without damaging the bone	1. Brittle, fragile, easily broken	1. The bone is wet with grease which may even be dripping
2. Soft tissue is more malleable, but still solid	2. Adherence to bone is moderately strong although large portions can be easily removed; the core of flesh close to the bone is still adherent	2. No cortical erosion but bone is lighter in weight and porous	2. Greasiness on bone is evident, but is not as thick
3. Soft tissue is considerably softer and looser than when the experiment began; very malleable	3. Adherence to bone is minimal; flesh falls off as bones are removed from solution or is easily removed with fingertips	3. Softer, more pliable than normal bone but no cortical damage	3. Greasiness is less evident; may not be present at all
4. Soft tissue is nearly liquefied and floats on the surface with little or no connection to bone		4. Cortex eroding and/or flaking but bone will not easily fracture	
		5. Strong, normal bone texture and quality	

[1]Adapted from Steadman et al. (2006)

CHAPTER FOUR: RESULTS

Results for all of the round 1 experiments are presented in Table 3 and graphically depicted in Figure 1. The post-maceration results are presented in Table 4 and Figure 4. For 12.5% unheated, with ease of flesh removal, the tissue was minimally adhered to the bone (score 3) for the first six and a half hours. After the first six and a half hours, the tissue was more difficult to remove and became more adherent to the bone. For two hours (6.5-8.5), this category was given a score of 2. After eight and a half hours, this category was scored as 1. For soft tissue texture, texture was given a score of 2 and was very malleable for the first five hours. The texture became more solid and firm as time progressed and was scored as a 1 (Figure 2). For bone quality, some slight porosity was noted on the bone surface and the shaft had the appearance of being bleached. However, the specimen never showed flaking or cortical damage and was consistently given a score of 5.

After a total of 16.5 hours, the bone was removed from the solution due to a lack of change in soft tissue texture or ease of flesh removal in the previous eight hours. The tissue that remained on the bone was concentrated around the proximal and distal ends (Figure 3).

For the post-maceration assessment (Table 4, Figure 4), bone quality remained the same for as long as data were collected (8 weeks); therefore, the score never changed from 5. Also, the remains never displayed greasiness and were scored as a 3 for the entire post-maceration period. However, a change was noted in the color: after the specimen had been out of the solution for four weeks, the bleached-white discoloration became less evident (Figure 5).

Table 3. Results for round 1

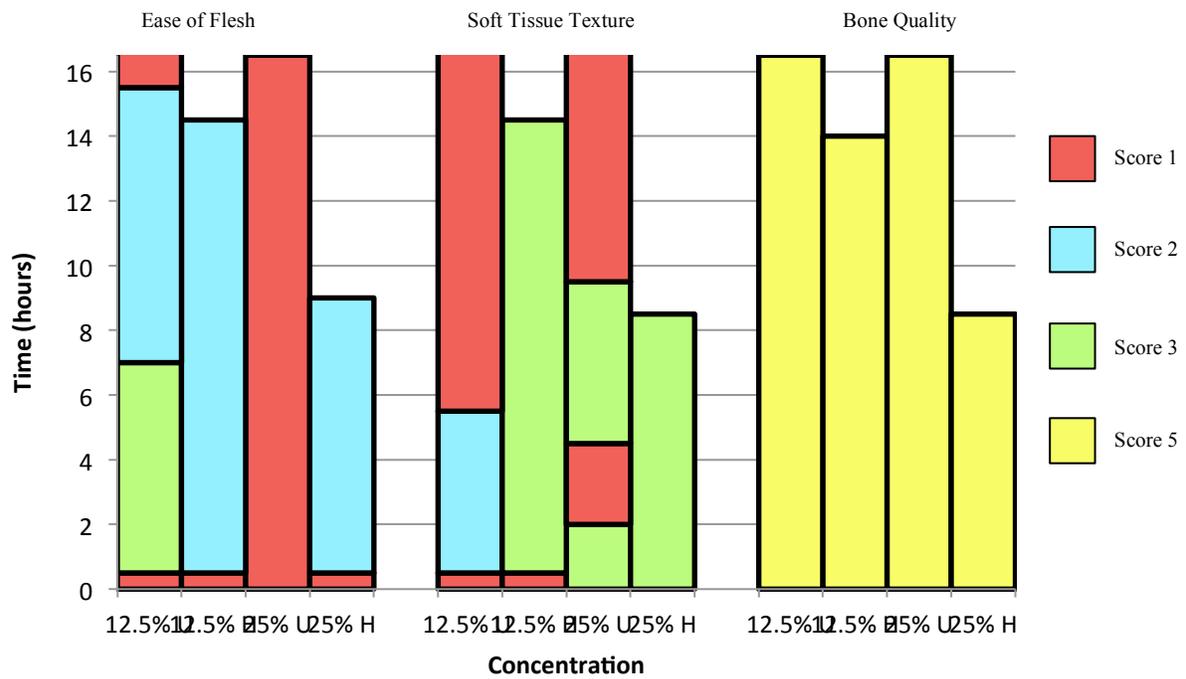| Concentration/Round	Time (weeks)	Bone Quality	Greasiness
12.5% unheated, round 1	1-8	5	3
12.5% heated, round 1	1-8	5	3
25% unheated, round 1	1-4	5	2
	4-8	5	3
25% heated, round 1	1-4	5	3
	4-8	4	3

Figure 1. Round 1 graphed results.

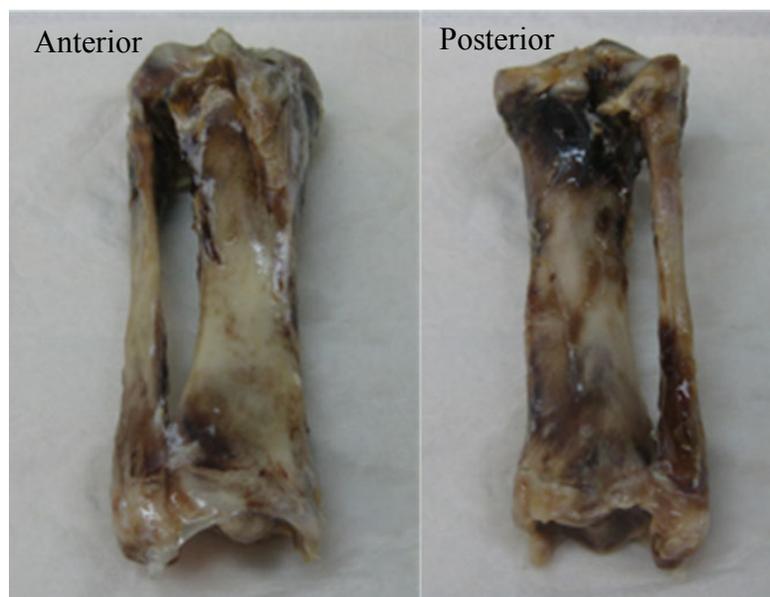Figure 2. Tibia/fibula after 5 hours in the 12.5% unheated solution.

Figure 3. Tibia/fibula after being removed from the 12.5% heated solution.

Table 4. Round 1 post-maceration results

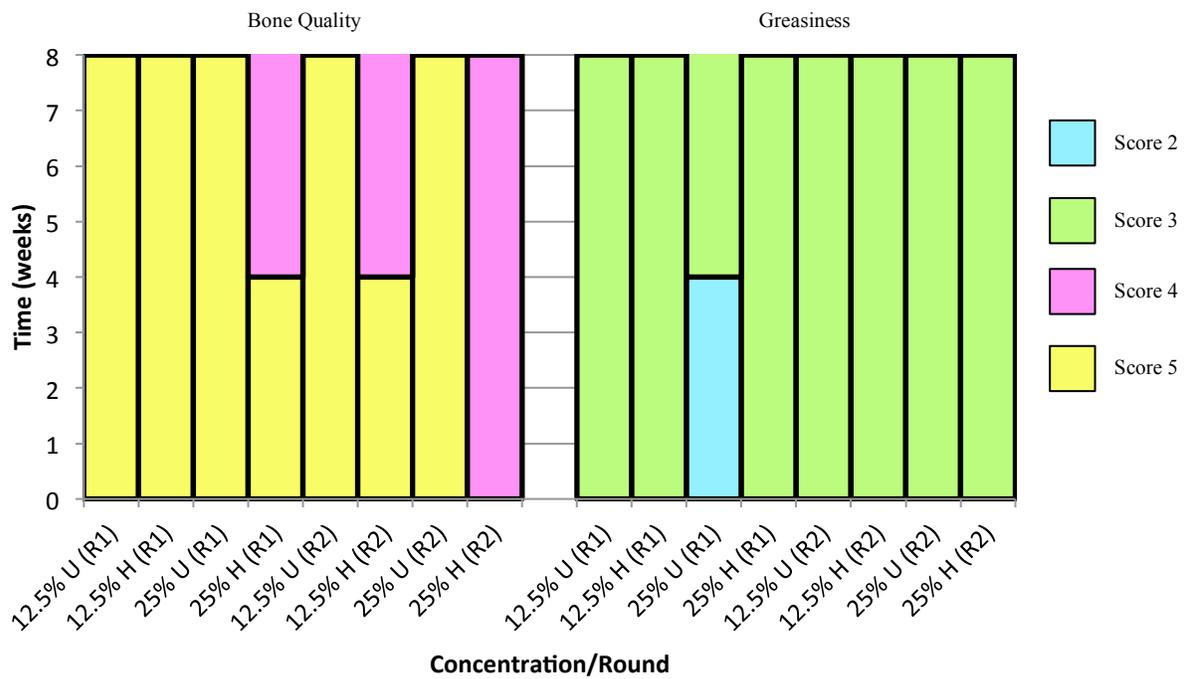| Concentration/Round	Time (weeks)	Bone Quality	Greasiness
12.5% unheated, round 1	1-8	5	3
12.5% heated, round 1	1-8	5	3
25% unheated, round 1	1-4	5	2
	4-8	5	3
25% heated, round 1	1-4	5	3
	4-8	4	3

Figure 4. Post-maceration results from round 1 and 2.

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Figure 5. Tibia/fibula after 4 weeks removed from the 12.5% unheated solution.

For 12.5% heated, with ease of flesh removal, the tissue remained moderately adhered (score 2) the entire time the humerus was in the solution. For soft tissue texture, the tissue was considerably softer and very malleable after being placed in the solution, and was scored as a 3. For bone quality, the shaft had the appearance of being bleached, although no cortical damage was noted. Therefore, this category was given a score of 5 (Figure 6). The humerus was removed after a total of 14 hours in the solution because all soft tissue had been dissolved.

For the post-maceration assessment, bone quality remained the same (score 5) and the humerus never displayed greasiness (score 3). As with the tibia/fibula from the unheated solution, after the humerus had been out of the solution for four weeks, the bleached-white discoloration became less evident (Figure 7). No flaking was noted on the specimen at any time during the post-maceration period.

Figure 6. Humerus after 2.5 hours in the 12.5% heated solution.

Figure 7. Humerus after 4 weeks removed from the 12.5% heated solution.

For 25% unheated, with ease of flesh removal, the tissue remained very adherent to the bone (score 1) the entire time in the solution. Soft tissue texture was considerably soft and malleable for the first five hours (score 3), although an anomaly in texture was noted at two to two and a half hours. This anomaly corresponded with the re-submersion of the specimen after a

period of time outside of the solution with resumption of the experiment. At five hours, the texture became quite firm and solid and was given a score of 1 (Figure 8). The shaft had the appearance of being bleached, but no cortical damage was noted, so bone quality was given a score of 5 for the duration of the round.

After a total of 16.5 hours, the bone was removed from the solution due to a lack of change in soft tissue texture or ease of flesh removal. As with the 12.5% solution, the remaining tissue was concentrated around the proximal and distal ends.

For the post-maceration assessment, bone quality remained the same (score 5). Unlike what was found with the lower concentration solution, the tibia/fibula did display some greasiness up to four weeks after being removed from the solution and was given a score of 2. By eight weeks post-maceration, the greasiness had become less evident and therefore was scored as a 3 (Figure 9). A bleached-white appearance was evident upon removal from the solution, but had lessened by eight weeks after removal.

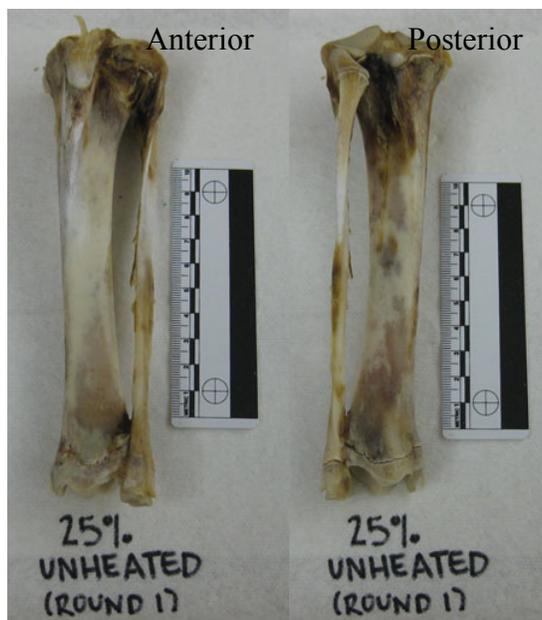Figure 8. Tibia/fibula after 5 hours in the 25% unheated solution.

Figure 9. Tibia/fibula after 8 weeks removed from the 25% unheated solution.

For 25% heated, the tissue remained moderately adhered to the bone the entire time, so ease of flesh removal was given a score of 2. Also, the soft tissue texture consistently was given a score of 3 for being very soft and malleable. The humerus had the appearance of being bleached, but bone quality was given a score of 5 because no flaking or other cortical damage was noted (Figure 10). The humerus was removed from the solution after a total of eight and a half hours because all the soft tissue had been dissolved.

For the post-maceration assessment, bone quality remained the same (score 5) for the first four weeks after removal from the solution. However, by eight weeks out of the solution, slight cortical flaking was noted. Therefore, the bone quality was scored as a 4. Similar to other specimens, the bleached-white discoloration present upon initial removal became less evident by eight weeks post-maceration (Figure 11). The humerus never displayed any evidence of greasiness (score 3).
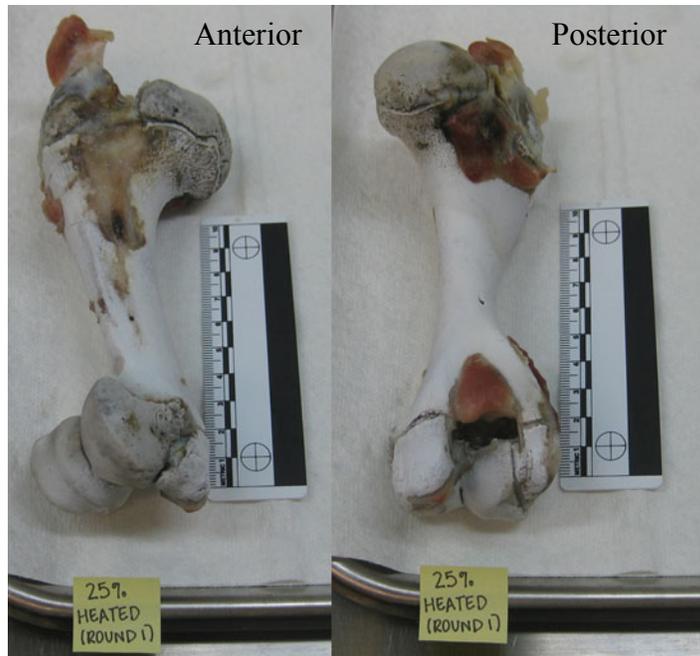
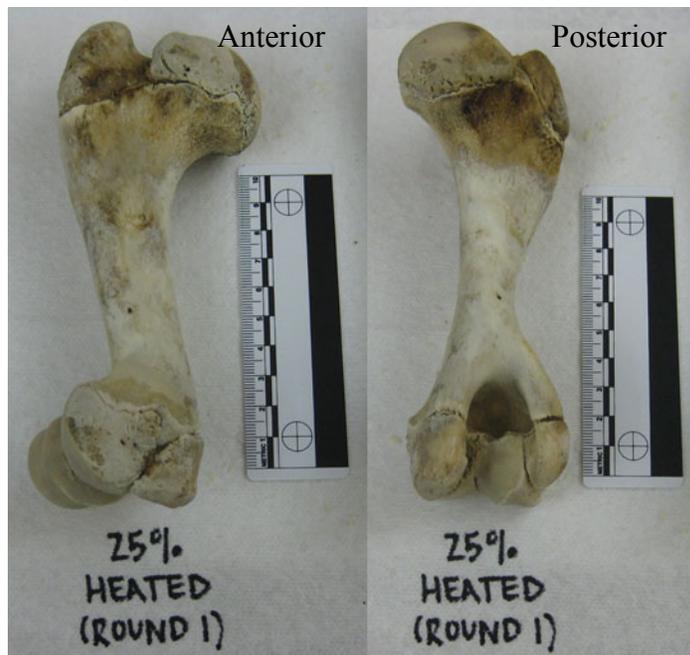Figure 10. Humerus after 1 hour in the 25% heated solution.

Figure 11. Humerus after 8 weeks removed from the 25% heated solution.

Results for all of the round 2 experiments are presented in Table 5 and graphically depicted in Figure 12. The post-maceration results for round 2 are presented in Table 6 and Figure 4. For 12.5% unheated, the tissue remained strongly adhered to the bone so ease of flesh removal was given a score of 1 for the entire period. For soft tissue texture, texture was given a score of 3 and was very malleable for the first five hours, after which it became more solid and firm as time progressed (score 1) (Figure 13). For bone quality, some slight porosity was noted on the bone surface and the shaft had the appearance of being bleached. The specimen never showed flaking or cortical damage, so it was consistently given a score of 5.

After a total of 16.5 hours, the bone was removed from the solution due to a lack of change in soft tissue texture or ease of flesh removal. As with other specimens in unheated solutions, the remaining tissue was concentrated around the proximal and distal ends.

Table 5. Results for round 2

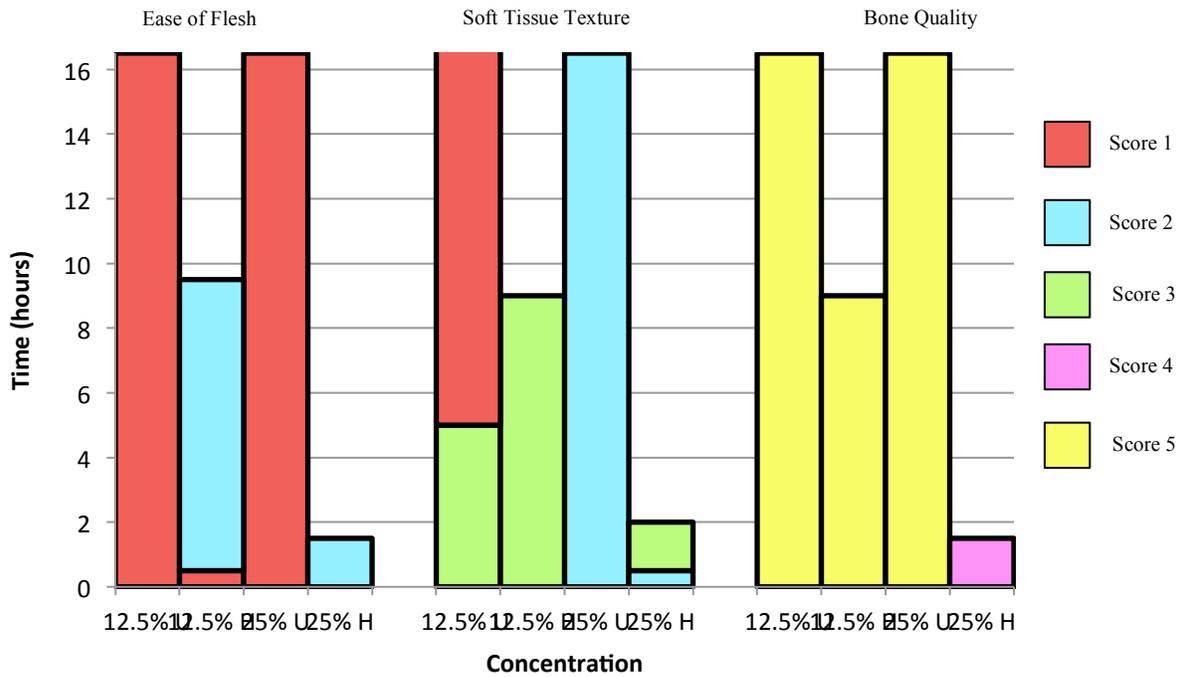| Concentration/Round	Time (hours)	Ease of Flesh Removal	Soft Tissue Texture	Bone Quality
12.5% unheated, round 2	0-5	1	3	5
	5-16.5	1	1	5
12.5% heated, round 2	0-0.5	1	3	5
	0.5-9	2	3	5
25% unheated, round 2	0-16.5	1	2	5
25% heated, round 2	0-0.5	2	2	4
	0.5-1.5	2	3	4

Figure 12. Round 2 graphed results.

For the post-maceration assessment (Table 6, Figure 4), bone quality remained the same (score 5), and after four weeks, the bleached-white discoloration was less evident (Figure 14). The remains never displayed evidence of greasiness (score 3).

Table 6. Round 2 post-maceration results

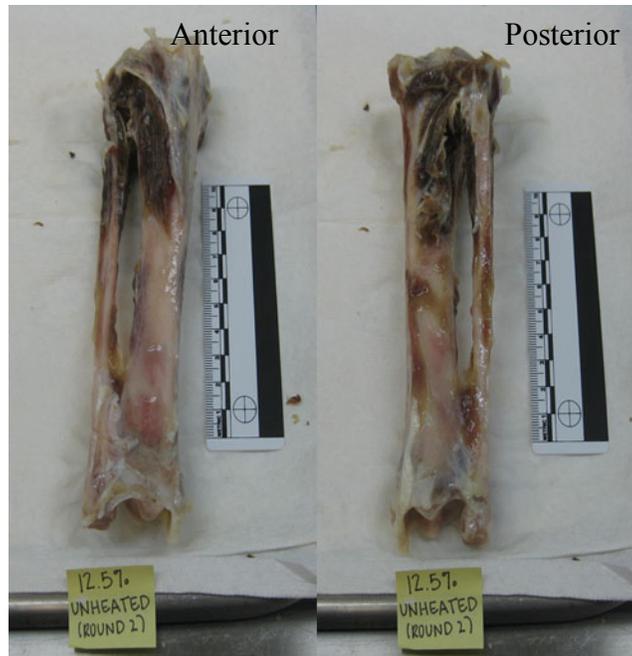| Concentration/Round	Time (weeks)	Bone Quality	Greasiness
12.5% unheated, round 2	1-8	5	3
12.5% heated, round 2	1-4	5	3
	4-8	4	3
25% unheated, round 2	1-8	5	3
25% heated, round 2	1-8	4	3

Figure 13. Tibia/fibula after 5 hours in the 12.5% unheated solution (round 2).
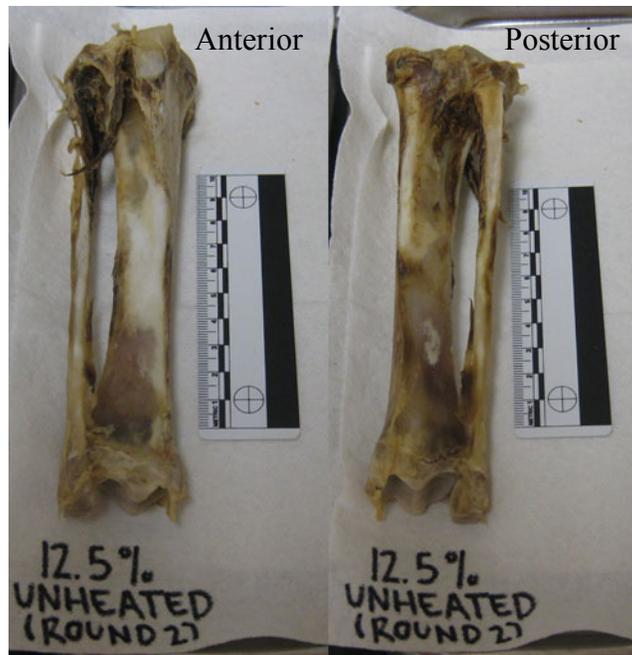

Figure 14. Tibia/fibula after 4 weeks removed from the 12.5% unheated solution (round 2).

Ease of flesh removal for 12.5% heated, the tissue remained moderately adhered after the first half hour for the entire time the bone was in the solution (score 2). For soft tissue texture, the texture remained considerably soft and malleable throughout, and was given a score of 3 (Figure 15). For bone quality, the shaft had the appearance of being bleached; however, no flaking or cortical damage was noted so the bone was consistently scored as 5. The humerus was removed after a total of nine hours because all of the soft tissue had been dissolved.

For the post-maceration assessment, some slight cortical flaking was noted after eight weeks out of the solution (score 4) and no greasiness was evident (score 3). After the humerus had been out of the solution for four weeks, the bleached-white discoloration was less evident (Figure 16).
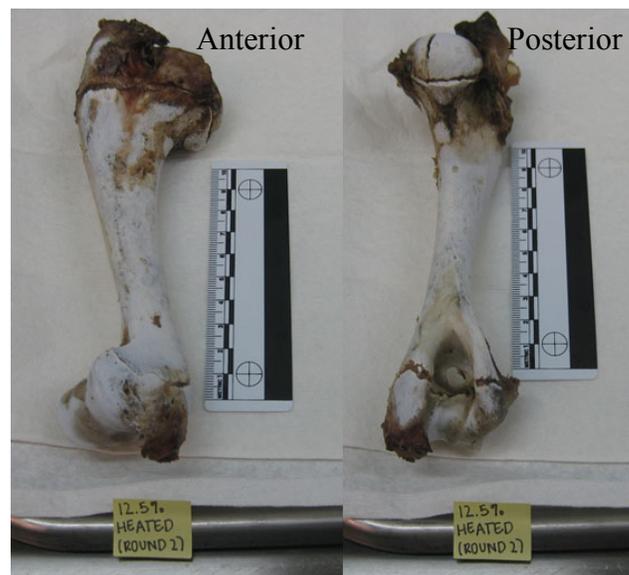

Figure 15. Humerus after 2 hours in the 12.5% heated solution (round 2).
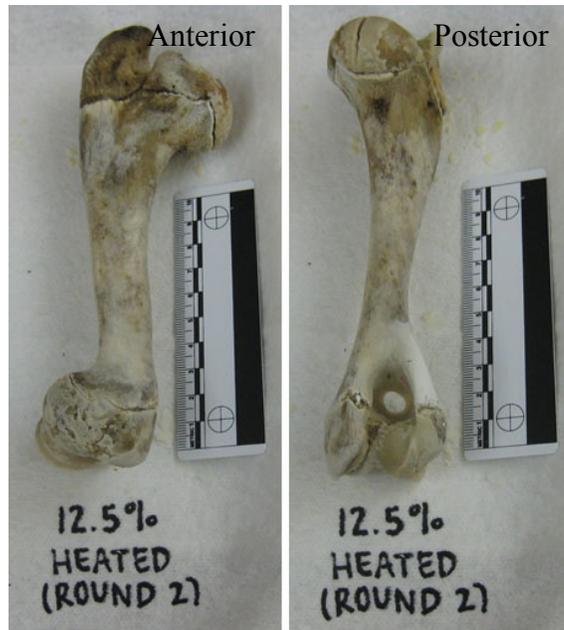
Figure 16. Humerus after 8 weeks removed from the 12.5% heated solution (round 2).

For 25% unheated, with ease of flesh removal, the tissue remained strongly adherent to the bone the entire time the bone was submerged in the solution (score 1). For soft tissue texture, texture was given a score of 2 throughout (soft tissue was malleable, yet still firm). For bone quality, no cortical damage was noted (score 5), but the shaft had the appearance of being bleached (Figure 17).

After a total of sixteen and a half hours, the bone was removed from the solution due to a lack of change in soft tissue texture or ease of flesh removal. All remaining tissue was concentrated around the proximal and distal ends.
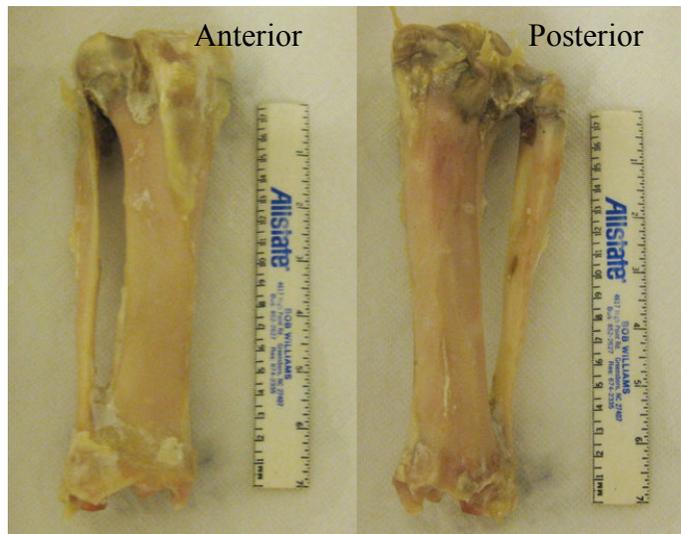
Figure 17. Tibia/fibula after 4 hours in the 25% unheated solution (round 2).

For the post-maceration assessment, bone quality remained the same (score 5), and the specimen never displayed greasiness (score 3) (Figure 18). The bleached-white discoloration was apparent upon removal from the solution; however, unlike other specimens, the discoloration did not diminish during the post-maceration period. No cortical flaking was noted.
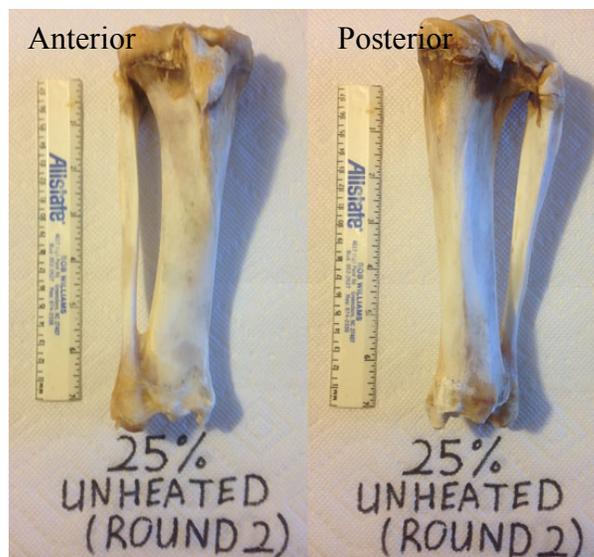
Figure 18. Tibia/fibula after 4 weeks removed from the 25% unheated solution (round 2).

For 25% heated, the tissue remained moderately adherent to the bone so ease of flesh removal was given a score of 2. For soft tissue texture, texture was given a score of 2 and was malleable but still firm, for the first 30 minutes. For the remainder of the time, the soft tissue texture was given a score of 3 (considerably softer and malleable). For bone quality, some slight porosity was noted and the shaft had the appearance of being bleached (Figure 19). The bone did show evidence of flaking and porosity and was therefore given a score of 4. The bone was removed after one and a half hours because all of the soft tissue had been dissolved.


Figure 19. Humerus after 30 minutes in the 25% heated solution (round 2).

For the post-maceration assessment, bone quality showed evidence of cortical flaking and was given a score of 4, and the remains never displayed greasiness (score 3). Also, the bleached-white discoloration on the bone had not diminished by four weeks post maceration (Figure 20).
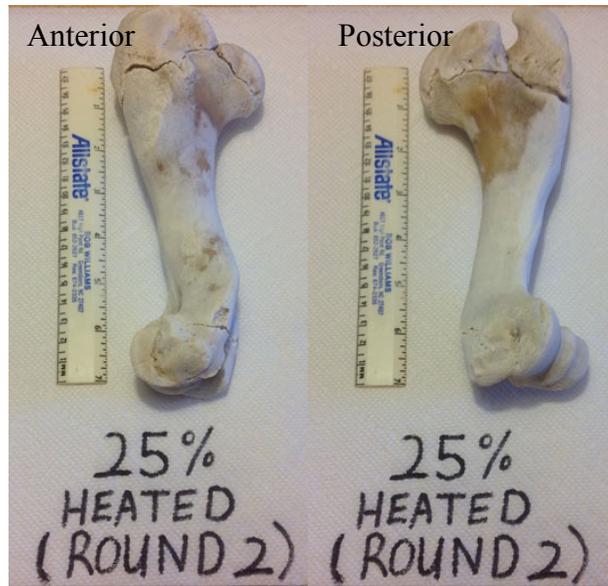
Figure 20. Humerus after 4 weeks removed from the 25% heated solution (round 2).

CHAPTER FIVE: DISCUSSION AND CONCLUSION

This research examined whether or not diluted solutions of Drano® Max Gel would be able to effectively remove soft tissue from bone. Specifically, I hypothesized that 1) a heated solution would macerate more quickly than an unheated solution, 2) the 25% concentration would macerate more quickly than the 12.5% concentration, and 3) the bones macerated in the 25% solution would show more cortical damage than those macerated in the 12.5% solution. The results of this study are summarized in Table 11.

Regarding the first hypothesis, my results showed that the heated solutions, regardless of the concentration of the Drano® Max Gel, completely dissolved all tissue from the specimens in a timely manner. Fourteen hours was the longest time it took for a specimen to be completely free of tissue (12.5% concentration, round 1); one and a half hours was the shortest length of time (25% concentration, round 2). Prior to placing in the solution, the majority of soft tissue had been removed from the specimens, which is a common practice during forensic macerations. This fact likely contributed to the speed in which the tissue dissolved. However, for the unheated solutions, none of the specimens ever became completely clean of tissue. In fact, because no changes occurred in the categories of ease of tissue removal and soft tissue texture for any of the specimens after eight hours, all specimens were pulled from the solution at 16.5 hours. For all these specimens, regardless of the concentration of Drano® Max Gel, tissue not only remained at the proximal and distal ends, but also had become tougher and more adherent over time. In summary, my results provide support for the first hypothesis. That is, heated solutions macerate more quickly and efficiently than unheated solutions. This result is consistent with previous research (Lee et al., 2010; Rennick et al., 2005; Steadman et al., 2006).

Table 7. Summary of results

	Heated Solutions	
Concentration	Round 1	Round 2
12.5%	Clean in 14 hours Tissue dissolved Bleached appearance, diminished over time No cortical flaking No greasiness	Clean in 9 hours Tissue dissolved Bleached appearance, diminished over time Cortical flaking No greasiness
25%	Clean in 8.5 hours Tissue dissolved Bleached appearance, diminished over time Cortical flaking No greasiness	Clean in 1.5 hours Tissue dissolved Bleached appearance, did not diminish Cortical flaking No greasiness
	Unheated Solutions	
12.5%	Bone removed at 16.5 hours Remaining tissue tough and adhered to bone surface Bleached appearance, diminished over time No cortical flaking No greasiness	Bone removed at 16.5 hours Remaining tissue tough and adhered to bone surface Bleached appearance, diminished over time No cortical flaking No greasiness
25%	Bone removed at 16.5 hours Remaining tissue tough and adhered to bone surface Bleached appearance, diminished over time No cortical flaking No greasiness	Bone removed at 16.5 hours Remaining tissue tough and adhered to bone surface Bleached appearance, did not diminish No cortical flaking No greasiness

To assess my second and third hypothesis, I will only consider the heated solutions since the unheated solutions were shown to not be effective for maceration. My second hypothesis, that the 25% solution would macerate more quickly than the 12.5% solution, also generally is supported by my results, though I was not able to assess the differences statistically due to the small sample size. Examining each round individually, for round 1, the 25% solution cleaned the specimen four and a half hours faster than the 12.5% solution. Similarly, for round 2, the 25% solution cleaned the specimen in less than one-third the time it took for the 12.5% solution.

Interestingly, the time it took for maceration to be completed in rounds 1 and 2, for both concentrations, is not consistent. In fact, the time required for the round 2, 12.5% and the round 1, 25% solutions, was very similar (9 and 8.5 hours, respectively). For each concentration and for each round, I attempted to select similarly sized specimens. Therefore, the discrepancy among specimens in the time it took to dissolve tissue may be due to factors other than the concentration of Drano® Max Gel. Such factors might include the freshness of the specimen or the number of times a specimen was removed from and re-submerged in the solutions (discussed more below).

My third hypothesis, that the bones macerated in the 25% solution would show more cortical damage than those macerated in the 12.5% solution, also generally was supported by my results (though again, the differences cannot be assessed statistically). Despite the efficiency with which the bones were cleaned by the heated solutions, all of the bones took on a bleached appearance. This discoloration did diminish during the post-maceration period in three of the four specimens (only round 2, 25% did not diminish). In addition to discoloration, cortical flaking was noted in three of the four specimens; only the round 1, 12.5% showed no cortical damage. Interestingly, only round 2, 25% concentration showed cortical flaking during the heating process. For the other two specimens (i.e., round 1, 25%, and round 2, 12.5%), the cortical flaking did not become apparent until the post-maceration period. As part of the research design, the bones were not rinsed with water after removal from the solution. Therefore, it is possible that if the bones had been rinsed with water after removal from the solution, the cortical flaking could have been stopped. None of the bones displayed any greasiness.

The proposed benefits of using Drano® Max Gel were its availability, economical price, and relative safety. Though no hypotheses were generated, the results of my study also substantiate these practical benefits in terms of safety and clean up. With the former, I used personal protective equipment as needed and followed all safety instructions; I experienced no adverse effects from using the chemical. For the latter, although the color of the solution changed throughout the experimental rounds, clean up was relatively easy. No soft tissue was ever left in the solution (having apparently "dissolved"), allowing the solution to be disposed of as non-biohazardous material, and the containers used were easily cleaned.

Overall, the results for the unheated solutions are fairly consistent in demonstrating their lack of effectiveness for maceration. The heated solutions, however, while showing some effectiveness for maceration, did not yield consistent results between rounds 1 and 2 in the length of time it took for the bones to be completely free of tissue. Factors which may have contributed to the inconsistent results include variation in the freshness of the specimens and the number of times the specimen was removed from the solution then re-submerged during the experimental process.

With regard to freshness, specimens for this experiment were acquired from grocery stores as well as from local butchers who process recently hunted animals. Therefore, while some of the specimens literally were from freshly killed animals, other specimens had been refrigerated or even frozen for some time before they were acquired. Furthermore, all specimens had to be refrigerated (or frozen) from the time I obtained them until the start of the experimental rounds in which they were used. While all frozen specimens were thawed prior to beginning the experiment, this variation in the pre-experimental taphonomy likely affected the way the tissue responded both to the Drano® Max Gel and to the temperature of the solution.

The second factor which likely impacted the results is a consequence of the experimental design of this study. Because my observations of the specimens were made and recorded in 30 minutes intervals, no experimental round ever was completed in a single sitting and no specimen ever was left in the solution unobserved overnight. Thus, the length of time for one round to reach completion varied between one and seven days, depending on the concentration of the solution and the application of heat. At the end of the day, the specimen was removed from the solution and was not re-submerged until the time the experiment could be resumed. This alternating wet and dry condition likely impacted the ease of flesh removal and texture categories in particular. Similarly, the fluctuation between hot and room temperature in the heated experimental rounds could have altered the speed in which the tissue dissolved and may account for the variation not only in the time to reach skeletonization, but also in the amount of cortical damage observed on the bone.

The above confounding factors notwithstanding, I nevertheless achieved good results in this study using Drano® Max Gel in a heated 12.5% solution in terms of the speed of tissue removal (9-14 hours). Further, because no instruments were used to clean the bones once they were placed in the solution, it is possible that, if the bone was taken out of the solution periodically and scraped with a fingernail or wooden implement, the specimen would reach skeletonization in even less time. On the other hand, though the amount of damage to the specimen appeared to be minimal (slight cortical flaking, a bleached appearance that diminishes with time), my observations did not proceed beyond eight weeks. It is possible that, because of the bleaching agent in Drano® Max Gel, degradation of the cortical bone still may occur in the ensuing post-maceration period. Further research using multiple elements at one time, leaving specimens in the solution for longer periods of time (including overnight), actively removing

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tissue using instruments during the soaking process, controlling the temperature of the solution, and observing the remains for a longer post-maceration period will provide further information on this chemical as a maceration agent.

In conclusion, to determine whether or not the method used in this study truly is viable as an option in forensic contexts, research is needed to test whether DNA can be amplified from bones that have been macerated in solutions containing Drano® Max Gel. Since the specimens in this study all appear to have become bleached during the process, it is possible that the ability to collect DNA from remains macerated with Drano® Max Gel will be diminished. Nevertheless, this study demonstrated that Drano® Max Gel used in maceration is inexpensive, safe, and easy to clean. When used in a 12.5% heated solution, it provides an effective method for removing soft tissue from skeletal remains with minimal resulting damage.

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