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**TECHNICAL NOTE**

**ANTHROPOLOGY**

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# The Effects of Corrosive Substances on Human Bone, Teeth, Hair, Nails, and Soft Tissue*

**ABSTRACT:** This research investigates the effects of household chemicals on human tissues. Five different human tissues (bone, tooth, hair, fingernails, and skin/muscle/fat) were immersed into six different corrosive agents. These agents consisted of hydrochloric acid, sulfuric acid, lye, bleach, organic septic cleaner, and Coca-Cola® soda. Tap water was used as a control. Tissue samples were cut to consistent sizes and submerged in the corrosive liquids. Over time, the appearance, consistency, and weight were documented. Hydrochloric acid was the most destructive agent in this study, consuming most tissues within 24 h. Sulfuric acid was the second most destructive agent in this study. Bleach, lye, and cola had no structural effects on the hard tissues of the body, but did alter the appearance or integrity of the hair, nails, or flesh in some way. The organic septic cleaner and tap water had no effect on any of the human tissue tested during the timeframe of the study.

**KEYWORDS:** forensic science, forensic anthropology, acids, bone, teeth, soft tissue

Remains of three individuals were recovered from three separate 50-gallon metal drums in a desert area west of Phoenix, Arizona. Based on the condition of the bodies, the use of an unknown corrosive agent to obfuscate identity was suspected. Multiple white plastic safety seals commonly used to secure containers of corrosive substances were found in conjunction with each of the decedents. The large number of safety seals suggested the use of a chemical agent that was easily acquirable. Two of the three individuals were nearly completely consumed by the agent while one had extensive marring of the soft tissue and skeleton consistent with some type of corrosive substance. This study began as an attempt to determine the possible agent used, but was later expanded to test a variety of corrosive agents and their effect on human bone and tissue after a literature search turned up few publications on the effects of chemical substances on human remains.

Many different techniques are used to obtain a positive identification of human remains and use more than one type of tissue to do so. Attempts to hide the identity of a victim and prevent positive identification are frequent and may include dismemberment, removal of fingers to thwart identification through fingerprints, destruction or removal of teeth, disfigurement of the face, burning of the body, and even dissolution in various household chemicals. Household corrosive substances that may be used to disfigure a body include easily obtainable items, such as drain cleaners, septic tank cleaners, other cleaning products, pool chemicals, and rust dissolvers. Because of the fact that methods of positive identification involve both hard and soft tissues, scientists must strive to understand how corrosive substances affect all of the various types of tissue that compose the human body.

Much of our understanding of how corrosive agents affect human dentition comes from medical and dental studies of bulimia (1,2), workplace safety (3–5), and restorative dentistry (6). Few publications describe the effects of chemicals on the human skeleton, dentition, and skin. Notable exceptions include the analysis of the Romanovs by Maples (7) and King and Wilson (8), in which dental remains, skeletal remains, and soil samples suggest exposure to a corrosive agent. Later, interviews of the offenders revealed that sulfuric acid was likely the corrosive substance used to mask their identity. Furthermore, a study by Ubelaker and Sperber (9) described a case where dental fragments were damaged by a chemical agent tentatively identified as sodium hydroxide. Mazza et al. (10) placed human teeth in hydrochloric acid (also known as muriatic acid), sulfuric acid, nitric acid, and the combination of hydrochloric acid and nitric acid (known as *aqua regia*). The authors observed that hydrochloric acid, nitric acid, and *aqua regia* completely dissolved the teeth in 14, 12, and 17 h, respectively. Sulfuric acid had not completely dissolved the teeth at 90 h. Until a recent study by Cope and Dupras (11) on the effects of household chemicals on human teeth, no published studies quantified the destruction of human tissues caused by corrosive agents (see also [12] for a study using pigs). Cope and Dupras (11) subjected 16 human teeth to a total of eight readily available household products, each containing differing concentrations of hydrochloric acid, sulfuric acid, phosphoric acid, and sodium hydroxide (the pellet form of sodium hydroxide was not available at consumer stores, but the authors were still able to obtain it). After each tooth was submerged in the chemical, both quantitative and qualitative descriptions were recorded at regular intervals. The research

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described in the current study provides quantitative and qualitative data on the effects of several common household corrosive agents on human bone, teeth, hair, nails, and soft tissue (skin, muscle, fat, and fascia).

## Materials and Methods

Six commonly available chemical substances and a control (tap water) were tested. These chemical substances (Table 1) included hydrochloric acid (muriatic acid), sulfuric acid, household lye (caustic soda), bleach, a 100% natural active bacteria and enzyme product (Rid-X®, Reckitt Benckiser Group, Slough, Berkshire, U.K.), and a cola soft drink (Coca-Cola®, The Coca-Cola Company, Atlanta, GA). Two-ounce round glass jars were filled with approximately one ounce of the chemical liquid or in the case of the dry chemicals, with a mixture of the powder and approximately one ounce of water.

A nonpathological human femur from a European (White) man, 49 years of age at death, was purchased from a medical research company (International Institute for the Advancement of Medicine) and was cut into one-inch sections along the shaft. The femur was harvested less than a week prior to the commencement of the research and kept cold but not frozen. The tissue was procured from the adherent skin, muscle, fascia, and connective tissue on the donated femur. The hair was procured from a beauty salon and represents cut hair. The fingernails were obtained from a manicurist and represent cut distal tips. Pulled teeth were donated by a forensic odontologist. The teeth were similarly sized adult molars and incisors harvested by an oral surgeon during normal orthodontic procedures and selected for their uniformity to one another and their unfractured, unrestored state.

Once the samples of each tissue were procured, they were weighed on a digital scale accurate to 1/10 of a gram, photographed, and placed into a two-ounce round jar. The scale was cleared, calibrated, and set to zero prior to each weight. A sample of each type of tissue was immersed into one ounce of each corrosive agent. The start time was noted for each specimen. During the course of the experiments, the specimens were removed at regular half-hour to hour long intervals from the liquid, weighed, measured, and photographed. Once a specimen ceased to change over a period of 24 h or was deemed to be "unrecognizable as human tissue," the experiment was stopped. Descriptive data including the type of specimen, weight, size, agent tested, and a brief description were recorded in a standard spreadsheet. Observations were made at specified intervals depending on the agent under consideration. For example, the hydrochloric acid consumed most human tissue types very rapidly so observations were made at half-hour intervals until the specimens were no longer present. Initially, two trials of muriatic acid were completed to ensure that there was consistency in the observed changes. The results of these two tests were indistinguishable. The remaining acid trials were only performed once for each type of tissue. Each specimen jar was maintained in a fume hood in a laboratory setting with an ambient temperature of 75°. The specimens were not disturbed during the course of the individual experiment, and additional amounts of the chemicals were not added to the jars after the experiments had started. The specimens were agitated once they were no longer recognizable to determine whether there were portions remaining.

TABLE 1—*Products used in the experiment with their corresponding active agent and concentration.*

| Product Name | Dominant Agent | Concentration (%) |
|---|---|---|
| Transchem muriatic acid | Hydrochloric acid | 31.45% |
| VWR scientific concentrated sulfuric acid | Sulfuric acid | 95–98% |
| Rooto® household lye | Sodium hydroxide | 100% |
| Waxie® bleach | Sodium hypochlorite | 5.25% |
| Rid-X® | Bacteria and enzymes | N/A |
| Coca-Cola® | Phosphoric acid | Unknown |
| Tap water (control) | Water | 100% |

## Results

The effects of each chemical agent on the different types of biological tissues are outlined below. Hydrochloric acid was the most destructive agent tested in this study, followed by sulfuric acid. There was no structural or weight change in any of the tissues after being submerged for 1 month in tap water (the control) or the organic septic treatment (Rid-X®), and therefore, no further results will be presented for these two agents.

Hydrochloric acid completely consumed all biological tissue samples, except hair and nails, in 24 h or less. The rate of loss was steady over the course of the experiment. Bone was completely dissolved in less than 20 h (Figs 1 and 2). While submerged in hydrochloric acid, the bone initially became porotic and pitted with eroded edges. The bone then became soft and gelatinous with scalloped edges and toward the end of the experiment appeared amorphous. Because hydrochloric acid was so destructive to the small bone sample, a larger bone sample—the entire proximal end of the male femur—was tested. The proximal end of the femur was nearly consumed by the hydrochloric acid in 19 h, but was not completely consumed until 23 h (Fig. 3). The process of dissolution of the large piece of femur followed the same pattern as the initial one-inch bone sample. Teeth were completely dissolved in 19 h (Figs 4 and 5). Bubbles formed inside the jar immediately after the tooth was placed inside. The enamel became pitted, and dark spots were observed. The tooth began to lose mass before any change in size was observed. The roots and crown became translucent and gelatinous and were indistinguishable from each other. Closer to 19 h, the tooth became amorphous, clear, and broke apart into pieces. Nails were present, but unrecognizable as nails after 14 days. At the outset, the nails sank and turned a slight purple color around the edges. Hair clumped together first, but then turned yellow and separated into stubble-like pieces after 8 days. The muscle, fascia, and fat separated into pieces because each type of tissue was dissolving at different rates. Fat globules formed on the surface first, and the remaining tissue was the consistency of gelatin. The muscle turned a darker color, and the contents of the jar became cloudy. The tissue became stringy and then was completely consumed in <6 h.

Sulfuric acid consumed the bone and the teeth over a period of several days while making the bone and teeth soft and viscous with "bubble-like" formations on the surfaces immediately exposed to the acid. Bone lost its integrity and became gelatinous in 1 day and was completely dissolved in 6–7 days (Figs 6 and 7). White residue was noted in the bottom of the jar during observation. Teeth were completely consumed in 10 days (Figs 8 and 9). The crown of the tooth broke down before the roots and resembled a mushrooming bullet. A white paste was also observed in the bottom of the jar. Nails were present but unrecognizable as nails after 14 days, while hair and flesh were consumed in <5 h. All tissues were observed to turn a darker, brownish-yellow color.

The bone segment and teeth that had been submerged in bleach remained structurally unchanged after 1 month. Both the bone and teeth, however, became whiter. Bleach consumed the hair in 8 min, the fingernails in 6 h, and the flesh in 6 h. When subjected to the

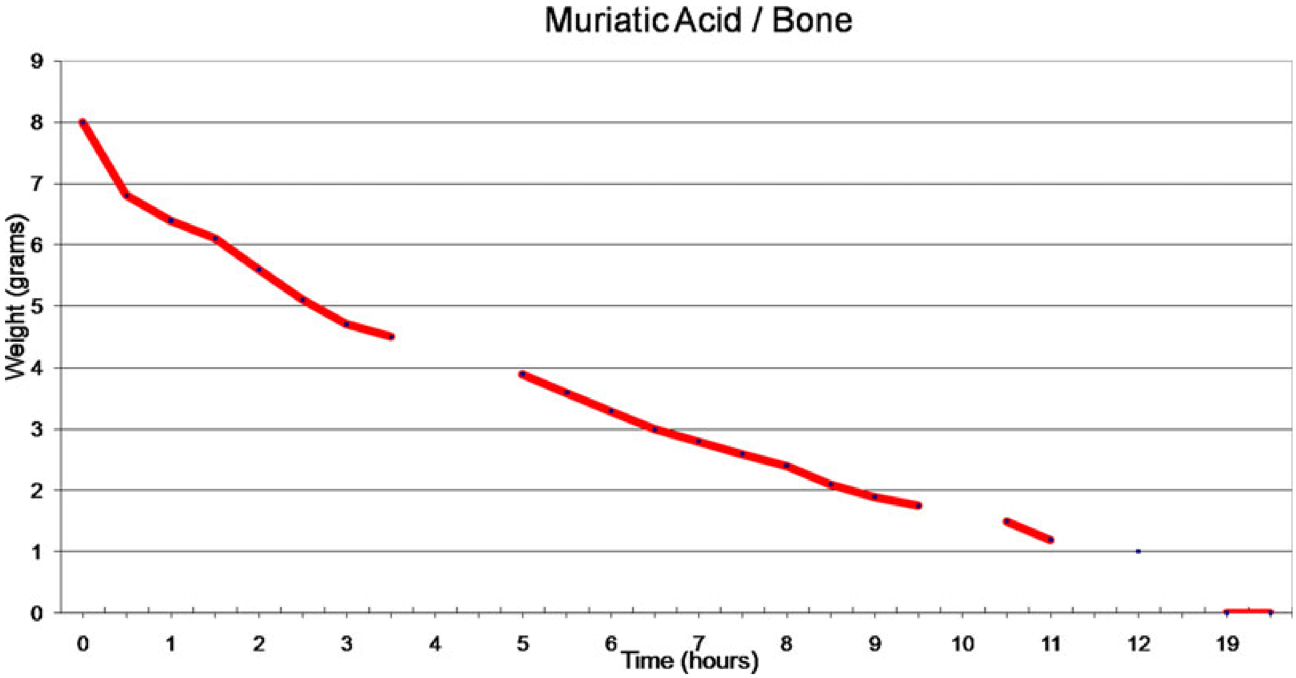


FIG. 1—*Bone weight (in grams) after submersion in muriatic acid over time. Gaps in the line are due to missing data which occurred when an observation was unable to be made at the required interval.*

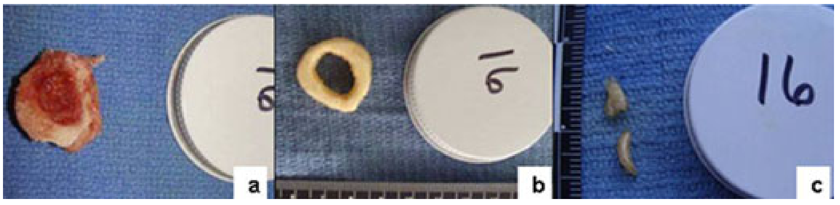


FIG. 2—*Bone segment before submersion in hydrochloric acid (a), after 6 h (b), and after 15 h (c).*

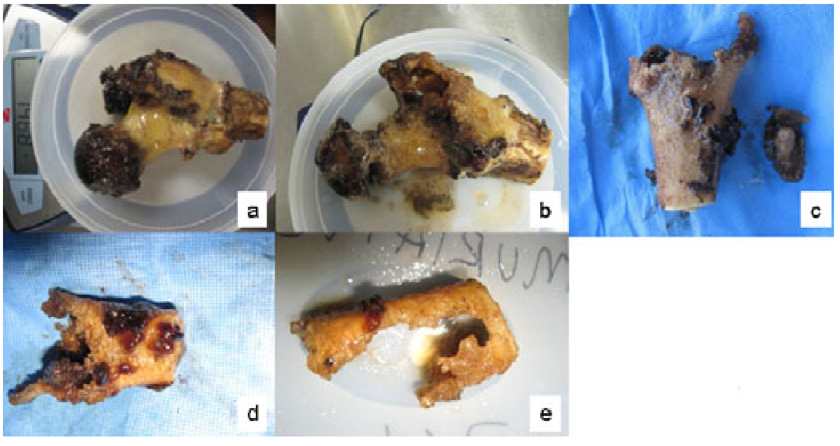


FIG. 3—*Proximal end of the femur prior to submersion in hydrochloric acid (a), after 2 h (b), after 5 h (c), after 8 h (d), and after 19 h (e).*

lye, hair turned yellow and then brown and dissolved in 3 min. The fingernails remained structurally intact, but turned a fluorescent yellow color. Lye appeared to dissolve the fat in the flesh sample, but did not affect the other portions. Also, the lye dissolved the contents of the marrow cavity in the femur sample but did not alter the structure or color of the bone. The teeth remained unchanged. One effect that was observed only with the lye was an increase in temperature of the contents of each jar. Once the lye was combined with each biological tissue sample, the contents and the jar became too hot to touch with bare hands. The density and integrity of the biological samples were not altered by the Coca-Cola®, although all of the samples became darker in color (Fig. 10).

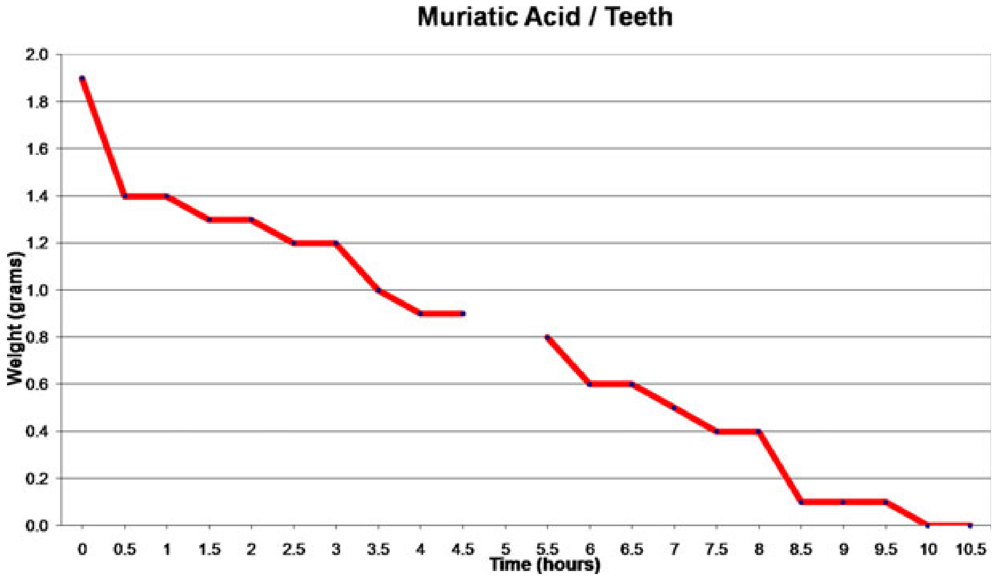


FIG. 4—*Tooth weight (in grams) after submersion in muriatic acid over time.*


FIG. 5—*Complete molar tooth before submersion in hydrochloric acid (a), after 8 h where the root is gone but the crown still remains (b), and absence of all tooth material after 19 h (c).*

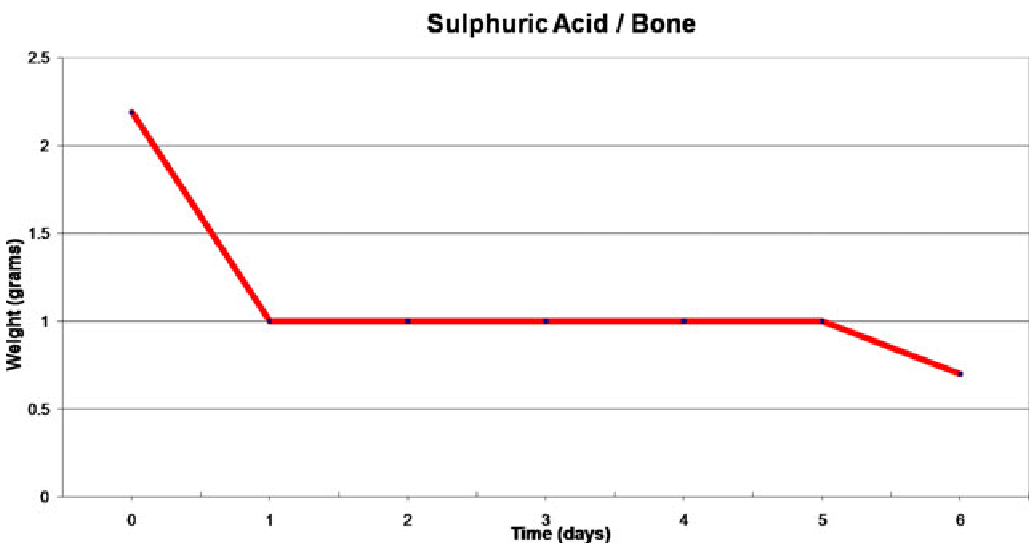


FIG. 6—*Bone weight (in grams) after submersion in sulfuric acid over time.*

## Discussion

The results of this study demonstrate that various types of household corrosive substances are capable of damaging and destroying human tissues and thus could be used to mask or eradicate evidence and features used for identification and trauma analysis. Of the six corrosive agents tested, hydrochloric acid was by far the most destructive and could conceivably be used to consume an entire human body or portions of a human body when used in a large enough quantity to fully submerge the remains. According to

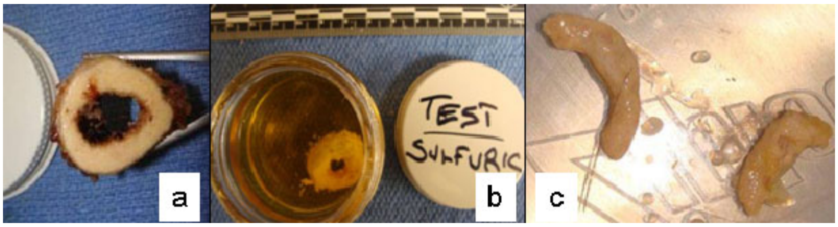


FIG. 7—*Bone segment before submersion in sulfuric acid (a), after 24 h (b), and after 5 days (c).*

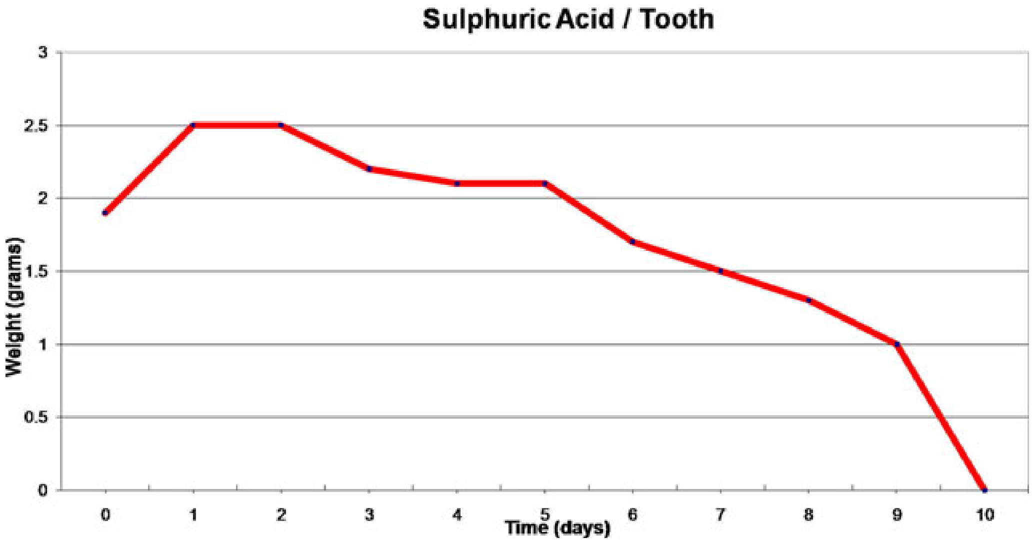


FIG. 8—*Tooth weight (in grams) after submersion in sulfuric acid over time.*

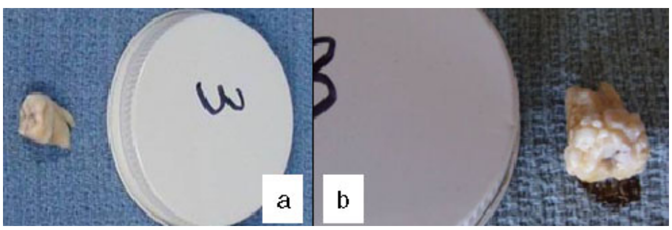


FIG. 9—*Complete molar tooth before submersion in sulfuric acid (a), and after 1 day when enamel bubbles have formed (b).*

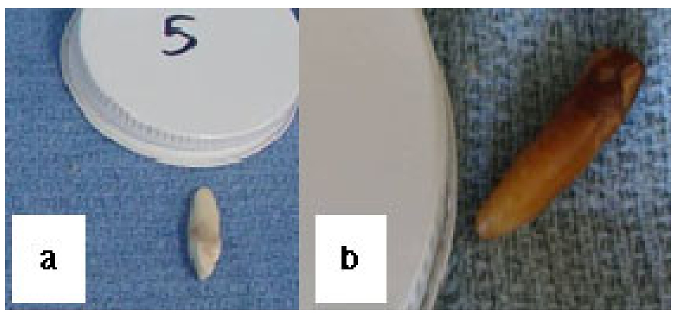


FIG. 10—*Complete incisor tooth before submersion in Coca-Cola® (a), and at 26 days when the tooth crown and root have been stained a dark brown color (b).*

Mazza et al. (10), the amount of acid needed to completely dissolve a body is approximately 80–100 L. As hydrochloric acid and sulfuric acid are readily available to consumers and less expensive than other acids, Mazza et al. (10) speculate that they would be the preferred acids to use should someone want to dispose of a body. Both Cope and Dupras (11) and Dupras et al. (12) also concluded that hydrochloric acid was the most destructive acid tested in their studies.

In this study, hydrochloric acid completely consumed all biological tissue samples, except nails and hair, which had been reduced to stubble-like pieces, in 24 h or less. The teeth were consumed in 19 h and during the course of their exposure to the hydrochloric acid in this experiment lost their integrity. Research by Cope and Dupras (11) also demonstrated that hydrochloric acid was extremely destructive to teeth and caused complete destruction of the crown portion of the tooth in 24 h. In addition, the authors noted that crowns became spongy and gelatinous prior to complete dissolution. Furthermore, a study by Mazza et al. (10) documented that hydrochloric acid completely dissolved an incisor in 14 h. In the present study, complete dissolution of teeth was not achieved until 19 h; however, molar teeth, which are larger than incisor teeth, were used. Unfortunately, no other published studies quantifying the effects of hydrochloric acid on bone, hair, nails, and flesh were found during a literature review for comparisons to this research.

Sulfuric acid, while not as fast as hydrochloric acid, was also observed to completely dissolve bone and teeth. Bone lost its integrity, became gelatinous in 1 day, developed bubble-like formations on the surfaces immediately exposed to the acid, and was completely dissolved in 6–7 days. Teeth became viscous with bubble-like formations on their surfaces and were completely consumed in 10 days (see also fig. 3 in [10]). An increase in mass of the tooth was observed during the first 2 h of submersion in sulfuric acid. This increase was also noted by Cope and Dupras (11) and was most likely due to the absorption of acid into the enamel. Nails, hair, and flesh were also completely consumed by the sulfuric acid. During the course of the experiment, all tissues were observed to turn a darker color—a finding consistent with Cope and Dupras (11) and Plunkett (5). Both Cope and Dupras (11) and Mazza et al. (10) concluded that sulfuric acid was not able to fully consume the teeth they tested, but observations on the tooth were terminated at 24 and 90 h, respectively. In this study, when the tooth was allowed to remain in the sulfuric acid solution for 10 days, complete dissolution was achieved. Sulfuric acid was the most destructive acid to flesh; all flesh/fat/fascia, as well as hair, was completely consumed in <5 h.

The lye, bleach, and organic septic cleaner (Rid-X®) were tested because they were easily obtainable at a consumer hardware store and appeared to be toxic and corrosive to a person walking the aisles and unfamiliar with chemistry. The Coca-Cola® was tested mainly to dispel the urban myth that a body could be dissolved in it, and also because it does contain phosphoric acid (in an unknown concentration).

Surprisingly, the organic septic cleaner (Rid-X®), which contains bacteria and enzymes that are supposed to break down biological materials in septic tanks, did not affect any of the tissues tested. One would expect that an agent marketed to break down biological waste in septic systems with natural bacteria and enzymes would have some effect on at least the hair and flesh, but there were no observable changes in any of the tissues tested. The lye (sodium hydroxide) also did not significantly affect the tissues as was expected. Hair was rapidly dissolved in 3 min, nails turned yellow in color, and fat was dissolved, but the lye did not structurally alter the portions of the flesh without fat, nails, bone, or teeth. Cope and Dupras (11) found that sodium hydroxide was the least effective agent they tested in degrading teeth. The authors observed significant changes on the surface of the enamel, such as widening cracks as well as a polished and later flaky texture to the enamel. Results of this study do not conform to their findings for the teeth, likely due to the different concentrations or brand names of sodium hydroxide tested. While the urban myth that Coca-Cola® can dissolve a body is untrue, the fact remains that the cola stained the incisor a dark brown color in a fairly short time span. The authors encourage cola drinkers to curb consumption to prevent permanent discoloration of the dentition!

## Conclusions

While some of the corrosive agents were effective on individual specimens, the hydrochloric acid was the most effective across all of the tested material and was likely the agent used in the cases described in the Introduction. Hydrochloric acid is inexpensive (the authors paid $1.49 for one gallon) and very easy to obtain (it is sold in multiple container packs at almost any hardware, home improvement, or pool supply store), making it a convenient, inexpensive, and highly effective substance that has a devastating effect on all types of human tissue. Sulfuric acid, touted as an effective agent in the nonscientific literature, is available only through specialized suppliers; thus, the public would not have ready access to it at a hardware store, but would be able to obtain it with a little more effort. The remaining agents tested were either only effective on a particular type of tissue (bleach on hair) or did not demonstrate an appreciable effect on the tissues tested.

The quantitative and qualitative data generated by this study are extremely useful when a forensic case shows some evidence of chemical modification. Future experiments will include more extensive testing using complete body segments and perhaps an entire human body, testing other human tissues such as blood, semen, and skin with the agents used in this study, and testing whether any elements of human DNA, cells, or other markers are detectable in the material remaining after dissolution. Furthermore, other agents such as nitric acid and the combination of nitric acid and hydrochloric acid (*aqua regia*) could be tested for their effect on human tissue.

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