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INTERCANINE DISTANCE USED AS A MEASURE TO RULE OUT BITERS IN BITE MARK FORENSICS

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I am submitting herewith a thesis written by Alana Joy Scudiere Ohana entitled "INTERCANINE DISTANCE USED AS A MEASURE TO RULE OUT BITERS IN BITE MARK FORENSICS." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Comparative and Experimental Medicine.

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INTERCANINE DISTANCE
USED AS A MEASURE
TO RULE OUT BITERS
IN BITE MARK FORENSICS

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Master of Science
Degree
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ABSTRACT

The science of identification by bite mark analysis has recently been called into serious question. (Reesu and Brown 2016) Human dentition is truly variable, but often not unique. When animal bites are considered, a proper ID of the perpetrator is nearly impossible. Primary distortion (when the bite is made) and secondary distortion (during decomposition or healing) both further disrupt landmarks that might be used for identification. (Sheasby and MacDonald 2001) Using only ink marks and intercanine distance on live subjects, this study attempts to determine maximum distortion possible for a variety of bite mark locations on skin. (Pretty and Sweet 2010) Lower arm, lower leg, upper back where chosen because of the high instance of bites occurring here. (Dogsbite.org, 2016) Though bite location likelihood does vary with age of the victim, these were relatively consistently common locations across groups. (Karbeyaz & Aranci, 2013) Facial bites were very common, but the face does not present continuous skin and therefore likely not useful for data. It may be an option for future study. Caliper measurements of body fat will also be used, to check for variation of distortion due to malleability of the area in question. It is hoped that this research will produce a numerical value relating the bite mark on the victim to the intercanine distance of the suspect (either human or animal) that will allow a rule-in or rule-out assessment. Also, it is hoped that a hospital protocol can be developed so that bite mark victims are more likely to see justice and the perpetrators accurately identified.

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CHAPTER ONE

INTRODUCTION AND GENERAL INFORMATION

Previous bite mark analysis techniques have all focused on determining a precise outcome: a particular biter matches a particular mark. (Eckholm, 2016) This type of matching is highly subjective, and in most cases, no longer admissible in court. (Bohan, 2010)

This study aims to look the other direction: produce less focused results (rule-in/rule out only) but with a high degree of clarity.

While these results will not pinpoint any individual subject, they may save lives or stave off conviction of innocent defendants by being able inarguably rule out certain suspects in bite mark cases.

CHAPTER TWO
LITERATURE REVIEW

<u>Bite Marks in Court</u>

Bite mark analysis as a science has been used in courtrooms, police proceedings, and more for decades. (ISJR, 2016) To date it has multiple problems and little scientific data backing it. (Rai et al., 2007)

Human bite mark analysis has been used in courtrooms since the late nineteen seventies, most famously in the Ted Bundy case. (Bitemarks.org) (Riaud 2014) Bitemark analysis is preferably performed by a forensic dentist but this is not a guaranteed scenario. The matches arrived at by forensic dentists are usually subjective and do not always agree. (I SJR, 2016) Even matches made from direct impressions in an impression-holding material often proves to provide a relatively subjective matching process, with experts agreeing as low as approximately eighty percent of the time. (Rai, et al., 2007)

In many cases, human bites cannot be distinguished from animal bites by bite marks alone. (Tedeschi-Oliveira, et al., 2011)

In light of recent appeals funded by The Innocence Project, and the amount of subjectivity in the science of bitemark analysis, the US Justice Department is suggesting an overhaul in how forensic science handles these cases going forward. (InnocenceProject.org, 2016) Currently, several states have ruled that forensic bite mark analysis is no longer admissible in court. (Bohan, 2010)

Daubert Standard Regarding Evidence

The "Daubert Standard" was legally set in 1993 from the legal proceedings of Daubert v Dow Pharmaceutical. This standard allows either the defense or prosecution to protest any evidence that does not meet scientific standards. (Page, et al., 2011) Currently, there is a general acceptance of the Daubert Rules regarding evidence. These rules were set with the intention of governing what evidence is allowable as empirical in a court case. (Page, et al., 2011) The five rules established from this landmark case are:

1. Empirical testing: whether the theory or technique is falsifiable, refutable, and/or testable.
2. Whether it has been subjected to peer review and publication.
3. The known or potential error rate.
4. The existence and maintenance of standards and controls concerning its operation.
5. The degree to which the theory and technique is generally accepted by a relevant scientific community.

While empirical testing has been performed on bite mark analysis, it has consistently produced inconsistent results. (Avon, et al, 2010) Peer review turns up a variety of issues with bite mark analysis, often pitting one "expert witness" against another in trial. There is to date no known potential error rate of bite mark analysis. Studies by Rai, et al. suggest that best case scenarios offer 90-95% accuracy. This should not be considered an allowable error rate in a court case, particularly one in which a lifetime sentence or the death penalty is at stake. While there are a handful of cases like this, one famous one is the case of Eddie Lee Howard. (InnocenceProject.org, 2016)

While many experts have suggested standards for bite mark analysis, these standards do not necessarily agree, and none have been adopted universally. (Pretty and Sweet, 2010) The theory of bite mark analysis as a definitive way of matching a biter to a victim has long been under contention. Thus, very few of the Daubert rules apply. (Rai, et al., 2007)

Bite Mark Analysis Studies

As early as 1971, DeVore found that photographs and excised skin had large margins of error when compared to original measurements. Many cases that have been tried and convicted on bitemark analysis are currently under appeal, with a handful already overturned based on the subjectivity of the examiners in the original trials. These overturned convictions include: Keith Allen Harward's rape conviction from 1982, Robert Lee Stinson's rape and murder conviction from 1985, Gerard Richardson's murder conviction from 1995, Willie Jackson's sexual assault conviction from 1986, and Roy Brown's 1992 conviction for murder as well as others. (InnocenceProject.org, 2016)

(InnocenceProject.org, 2016) At least six convictions have currently been successfully overturned, and more remain in appeal and new appeals are being generated. (Pretty and Sweet, 2010)

Though multiple bite mark studies have been tried on humans, they lack fundamentals to find what's necessary. For example, it is undeniably unethical to bite a human and then have them die for the sake of understanding the science behind bite mark decomposition. Scientists have tried to recreate bites, but it's incredibly difficult to recreate a true bite scenario as these are almost always dynamic. (Barbanel, 1974) It's also, once again, unethical to bite a person and cause the kind of damage often seen in bite cases. (Rai, et al., 2007)

This leaves many studies causing light-force bites using steady pressure applied by machine to a human forearm or other location. The bite is caused often by a cast of human or animal teeth (since using an actual biter would not work.) The bite does not break the skin.

In addition to these factors, a variety of other issues confound bite mark analysis. Actual bites often do not provide consistent pressure. Once the skin gives way, or bone is hit, pressure necessary to create damage changes. In addition, biters have tongues and lips. The tongue of the biter almost always touches the skin of the victim during the bite, pressing against the skin. The mouth and lips can close around the bite and create suction. These factors contribute to the loss of actual bite mark data when tests are reduced to machine induced, consistent pressure, non-dynamic situations. (Barbanel and Evans, 1974)

Other studies have looked at consistency among bite mark analysts themselves. (Avon, et al. 2010) Using transparent overlays of the provided actual human dentition and only modeling materials, one study assessed the accuracy of the examiners. Modeling materials used were clay and cheese. Bite marks were created from known dentitions into non-distorting blocks and forensic dentists were asked to match the bite to the impression. (Rai, et al., 2007)

The cheese was used to model a real-world case where cheese with a bite impression was found at a crime scene. The clay was used as a non-distorting material. However, the analysts were successful in matching these known samples only 81% of the time for the cheese and 95% of the time in the clay. These numbers are likely not acceptable in a criminal case, and likelihood of finding bitten, non-distortable materials at a crime scene that one can positively identify as the dentition of the assailant seems incredibly slim. (Rai, et al., 2007)

Clarity issues

Another problem with bite mark analysis is not only the lack of agreement in whether a mark matches a particular dentition, but lack of agreement in the quality of the mark. (Avon et al., 2010)

Any forensic dentist will agree that a high-quality bite mark will yield more specific, reliable results. He or she will also generally agree on what constitutes quality of bite marks: clear impressions of the individual teeth, a clear outline of the arch, preferably both the upper and lower arch available, and an impression that has very low distortion. (Hinchliffe, 2011)

However, all the terms here are entirely subjective. In court cases, experts often disagree whether a mark is or is not clear, whether one tooth is represented well enough, or even if the biter has a unique enough dentition to declare a match. This is just part of the subjectivity problem. (Page, et al., 2011)

A group of researchers has proposed a rating system to determine the quality of the bite mark. (Pretty and Sweet, 2010) This confidence scale of clarity would limit expert testimony to cases in which the mark scored high enough on a series of analyses to actually be declared viable for expert analysis. The scale would be a 1-6 scale based on clarity, lack of distortion, coloring of the mark and more. The researchers recommend that only marks with a 5 or 6 rating be used for forensic matching. (Pretty and Sweet, 2010)

Unfortunately, while the scale rating would be decided by multiple experts and a few actual measurements, it would still be subjective. Using a collective of examiners would help even out disagreements about quality and would help prevent individuals from presenting disputed information as fact. However, it remains a subjective measure. This method retains two problems. First, finding a forensic dentist is not always an easy feat. Finding a collective to rate a skin impression or even a photograph may not be easy. Second, even highly ranked, clear impressions are often argued as to whether they are or are not a match. So while the quality of the mark itself could conceivably be taken out of play, the actual match is still in the hands of a single, subjective expert. (Page, et al, 2011)

Bite mark locations

While no definitive data exists on the number of bites occurring at any particular bodily location, many articles do express common bite scenarios. (Hinchliffe, 2011) One study out of Turkey posted data for a limited geographic region, showing that common bite areas are lower extremities (below the knees and beyond the elbow), as well as chest and back. Their data also indicated that one-quarter of bites they evaluated ranked as "serious" (meaning they required some level of medical professional care. (Karbeyaz and Ayranci, 2013)

This data was strictly for dog bites on humans; thus, is limited. Bite analysis for human on human and animal on human is strictly anecdotal. (Hinchliffe, 2011)

Animal Bites

Animal bites pose another issue when dealing with bite victims and bite marks. The American Veterinary Medical Association quotes data that has just over one third of US households owning a dog and just under one-third owning a cat. (AVMA.org, 2016) This is approximately 43 million households owning about 70 million dogs and approximately 36 million households owning about 74 million cats. (AVMA.org, 2016)

Though the Centers for Disease Control and Prevention has not released recent data, data from the period of 1982 to 2014 show over 5000 serious attacks and almost 600 deaths from dog bites alone. (CDC.gov, 2016) In this nearly 32-year period this is roughly 155 instances of bodily harm and almost 20 deaths per year, just from dog bites. This accounts for cases where there is certainty that the bites caused death. When one adds in cases where dog bites played a part in death, the numbers go up. (DogsBite.org, 2016)

When the CDC widens their scope, numbers go up even more. They report 88 deaths from dog bites in the three-year period from 2006-2008. They estimate approximately 4.5 million dog bites per year. (CDC.gov, 2015) In many cases, when dogs bite—or are accused of biting—they are euthanized. Cases exist in which owners claim bites cannot be proven to be a particular dog and refuse to euthanize a dog that might be a danger. In other cases, a pet can be euthanized because of the belief that the animal was the cause of the bite when, in fact, it cannot be proven. (Dogsbite.org, 2016)

Of these bites, over 368,000 victims go to the hospital for treatment. These are non-fatality instances. Because pit bulls account for just over half the bites, and Rottweilers around one-sixth of the bites, these dogs are highly suspect in attacks. (AVMA.org, 2016)

Cats pose another domestic bite problem. The Centers for Disease Control and Prevention estimates 400,000 cat bites per year, generating 66,000 visits to emergency rooms. Wild animals are responsible for bites as well. (AVMA.org, 2016) The national park system reports approximately one fatality known to be caused by bears per year—in Yellowstone Park alone. Though the entire park system reports that the likelihood of getting attacked by a bear (often involving a bite) is low—1 in 2.2 million visits—the number of park visitors is very high. At 292.8 million visits in 2014, this gives an estimated 133 bear attacks per year. (NPS.gov, 2016)

Animal bites pose an additional problem, as those animals who bite humans are not always, but very often destroyed as a result of the bite. In some cases, the possible biters are a very closed group. And in some cases, the attack is witnessed and the animals put down as part of defense of the victim. In the recent case of a man attacked in a lion enclosure at the zoo, both animals were put down as part of a rescue attempt and no other lions could have been involved. (Press, 2016) Many witnesses also noted both the lions attacking.

However, many animals are identified as biters by a solo witness. As children are often victims of bites in unwitnessed situations, an identification is sometimes the only one available. In many cases, no information at all is given regarding the certainty of correct identification of the biting animal. (Wake et al., 2009) (O'Sullivan et al., 2008) In another specific instance, a bear used its mouth to pick up a male child at a campsite. (Burkeman, 2006) The family fended off the bear and the boy survived, but the daughter, who ran away at the time of the attack, was later found dead with a bear standing over her. Rangers went in search of the bear.

Bite marks in this case cannot be matched by visual identification of the perpetrator, nor did anyone witness the bear actually attacking the decedent. Forensic dentists are then asked to be certain that the destroyed bear is (at least likely) the one that killed the child. Currently, this analysis is entirely subjective. There is no known data supporting any matches in this or similar cases.

DNA

While DNA tests would be the conclusive for bite mark analysis, a wide variety of problems exist in DNA analysis with bites. When DNA is gathered in a bite case, it needs to be matched to a donor sample or against a sample already stored in a database. This is a DNA matching problem that has the same problems as bite mark analysis: only known possibilities can be compared.

Collection of DNA samples provide an additional problem in bite cases. When biting, as previously mentioned, the tongue usually touches the skin, leaving behind saliva, a quality source of genetic material. In matching bites, DNA collection is not often possible as many things get in the way of collection. For example, if the bite bleeds, the blood from the wound can destroy the biter's DNA sample. Also, the first response to such a wound is to wash it, rather than to swab for DNA. This will also destroy any DNA evidence.

First, the recommended and best-known treatment for a bite is to first thoroughly wash the area. Human mouths contain more pathogens leading to infection than do dogs or many other animals—thus people are wary of leaving the saliva intact in the case of a bite. For example, in 2016 the CDC reports 4.5 million dog bites per year in the United States, but only 368,000 make it to the Emergency Department. In many cases, at home treatment is the only treatment—which often includes a thorough washing of the area—and thus removal of any DNA. The same would hold true for a human bite that does not result in an immediate doctor visit. So many bite cases will not present an opportunity to collect salivary DNA even if the person visits a physician. Only immediate medical attention would likely yield a good sample.

Second, bad bites—the ones most likely to lead to an immediate trip to a medical facility that could take a DNA sample—will almost definitely involve bleeding directly in the bite area by the victim. This blood will mix or wash away any possible DNA from the biter. Any attempts to staunch the blood flow can ruin DNA collection.

Lastly, the physician's first priority is care of the wound—not collection of evidence. Thus, many things can happen at or around the site of the wound that will remove or alter any perpetrator DNA, making it unsuitable for collection. Thus, if DNA samples can be obtained, they should be used, but a majority of bite cases likely will be excluded from this possibility and need another option.

<u>Bite Mark Matching</u>

DeVore (1971) showed high variability in bite marks. Barbanel (1974) shoved a variety of mechanical aspects of biting that altered the created marks. Each of these involved best case scenario—immobile skin.

Bite distortion is possibly the major problem in bite mark analysis. Victim skin is a mobile surface. The biter is in motion and the act of getting bitten is often not performed while stationary. This can occur in an incapacitated or already deceased victim, but often is not the case. (Lewis and Marroquin, 2015)

Skin distortion in a bite is so complex that various levels of distortion require identification. Primary distortion occurs during the biting process, which includes movement of the biter, movement of the skin of the bitten and any underlying tissues. (Hinchliffe, 2011)

Secondary distortion occurs after the bite happens and is classified into three categories. Category 1) Alteration that occurs with time. This is usually due to wound healing on a live victim or wound decomposition at the site of the wound on a deceased victim. In either situation, the marks of the bite can change with time. Category 2) Alteration caused by posture, such as alignment at the time of the fight/bite is rarely the normal stance of the victim. Thus, changing posture to move, escape, travel to the ER, or in any way will often change the shape of the wound. Category 3) Alteration due to photographic distortion. In many cases, the bitten area is on a curved piece of skin/tissue, and the picture cannot be accurately visualize the bite in its original form. (Sheasby and MacDonald, 2001)

CHAPTER THREE
MATERIALS AND METHODS

Eleven dentitions of carnivorous or omnivorous mammals were measured for intercanine distance. The dental mold created from these dental arches are inked, as seen in figure A-1, and placed in key locations on skin surfaces and measured for variability.

Eleven maxilla with intact canines were used. Maxilla were either claimed from autopsy procedure or procured from a dental mold from a live subject.

Two maxilla had incomplete molars; one had missing (burned) incisors; one was a child with emerging molars (but a complete arch); one 1 was a mandible. Nine complete sets of human dentition were used. All maxilla (and one mandible) were molded in alginate using an alginate powder (Identic Dust-Free Alginate in pink) and water mix that set into a flexible mold of the dental arch, as seen in figure A-2. This mold was then filled with wet dental stone (Denstone Model Stone) and allowed to set, as seen in figure A-3. This created an identical cast of the dentition, as seen in figure A-4.

The intercanine distance was measured two ways:

1) With digital calipers from tip of canine to tip of canine, in millimeters (mm)
2) By inking the canines and producing a mark on paper, then measuring this distance with the calipers. If the mark was wide, the center of the mark was always used as the point for measurement.

Nineteen human subjects were tested. Subject ages ranged from eighteen to seventy. Three subjects were non-Caucasian. Six subjects were male, the remaining thirteen were female.

Continuous skin was used on the forearm, e.g. radius and ulna, the lower leg below the patella but above the protrusion of the lateral malleolus or the back, in the area between the spine and the deltoid, below C7 and above T9. Continuous skin is defined here as skin with no lesions over ½ inch and no natural folds and no joints.

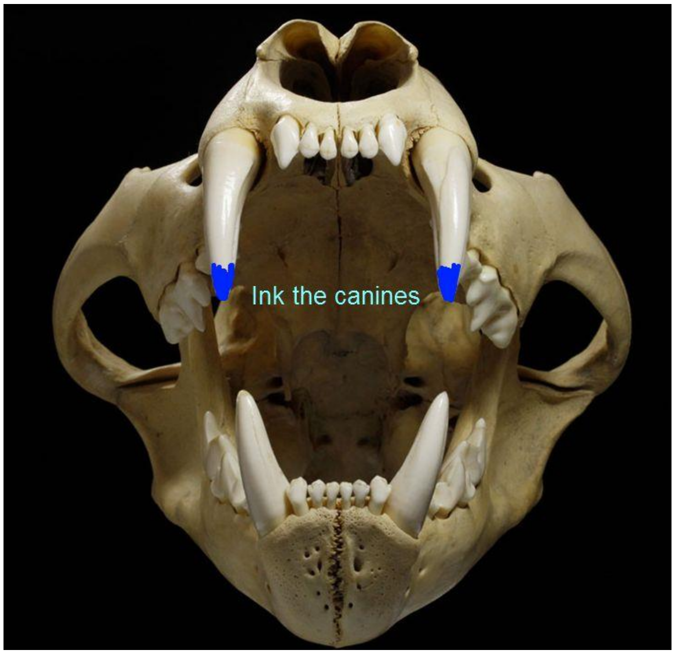

figure A-1 – Inking the canines

figure A-2 – Alginate mold of excised dentition

figure A-3 – Dental stone in the alginate molds

figure A-4 – Dental stone mold, post set

Locations of bite marks are first measured with body fat calipers to determine the leanness of the ‘bitten’ area. Canines of the cast dentitions are then inked and placed on the humans in a variety of locations, with the humans in anatomically correct position, leaving ink marks where the canines encountered the skin.

Inked canine marks on the skin were then measured three times. The measurements were made using a stainless steel digital caliper. The caliper measures with an error of 0.001millimeter to 0.01millimeter. All measurements were taken with the same caliper by the same investigator for consistency. Subjects are then subjected to a series of movements to determine the maximal and minimal widths of the bite marks with skin movement.

CHAPTER FOUR
RESULTS AND DISCUSSION

All marks measured on all skin surfaces appear somewhat malleable in the intercanine distance. The distance between the canine marks when compared to the actual distance on the dental mold used to create the marks was almost uniformly different from the actual measured distance between the tips of the canines. See raw data in Table 1 in the appendix. However, while the actual percent change varied with position of the bite and anatomical position of the subject, many of the intercanine distances measured on "bitten" subjects remained very similar to the actual intercanine distance of the dental mold.

The average intercanine distance of the nine dental molds was 31.125millimeterwith a standard deviation of 4.029mm. Because many of the dental molds were from anonymous donors, demographics of the molds cannot be completely determined. Two additional dental molds were also used from a feral pig and a domestic dog. The dog was considered to be of the pit bull variety, but exact breed is not known. These were not included in the measures of central tendency because they were not human.

In most cases, the first measurement taken regarding each "bite" was the measure of the marks as they appeared with little to no movement of the subject. Some subjects lost this measurement due to moving before the first measurement could be taken. Even these "unmoved" marks yielded up to a ten percent change in distance when compared to the dental mold. Three additional measurements from each "bite" were designed to create maximal distortion, producing much larger percent changes. In the case of the subjects who moved first, four data points were taken, giving all subjects a total of four data points for each "bite." Several subjects declined to have measurements taken on the upper back, yielding a total number of measurements there significantly lower than in the other two areas. The total number of measurements on the back was 203. Arm and leg respectively yielded 247 and 245 measurements each. (Raw data is in Table 1 in the Appendix.)

In the limited pilot study, caliper measurements of bite areas were taken. Both extremities showed a lower average body fat measurement than did the back area. Average arm reading was 3.5 millimeters with a standard deviation of 1.29 millimeters. For the lower leg the average was 0.4 millimeters with a standard deviation of 0.1 millimeter. For the lower leg one result was missing because of inability to get a pinch of skin for the measurement. For the back, the average body fat measured was 0.425 millimeters with a standard deviation of 0.09574 millimeters. However, the caliper measurement of the bite areas was dropped for the main study because it would not be useful in a forensic scenario.

Data from the bites to the lower leg yielded the lowest average percent change, indicating that this area will best preserve a bite mark in human flesh, as seen in figure B-1. The average change in intercanine distance from dental mold to measured mark was 3.80%. This was calculated by taking the difference between the measure on the dental mold and the mark on the skin, divided by the dental mold measure.

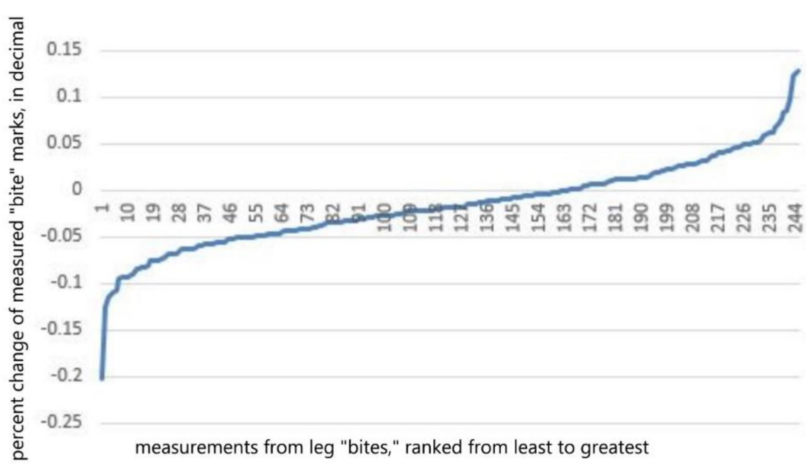

figure B-1 – Distortions from the lower leg

The area of next lowest malleability was the forearm which yielded a 4.62% change average, as seen in figure B-2. Again, this result was calculated by absolute value and was close to that for the lower leg.

Data from the upper back showed the highest variability in intercanine distances, as seen in figure B-3. The average percent change was 10.29% using absolute values.

The greatest percent change in the distance of the intercanine marks on the skin from each group was recorded. The greatest percent change in any bite mark to the forearm was a -27.56% difference from the measured intercanine distance on the dental mold. The negative change represents the movement of the bite marks closer together on the skin surface, while a positive percent change denotes a greater than start value distance. The greatest positive distance change was 16.01%.

The greatest percent change of any bitemark in the lower leg was -20.19% difference from the intercanine distance measured on the dental mold. While the greatest positive percent change in this area was 12.93%.

And the greatest percent change in the back was a -52.58% difference from the intercanine distance measured on the dental mold. The greatest positive percent change in the back was 36.29%.

In each location, the greatest percent change in each location was negative, while the greatest positive percent change in each location was at least 8% lower than the greatest negative percent change. Of 247 data points collected on the forearm, only five showed a change greater than 15% difference from the dental mold. Four of these were negative; only one was positive. Of the 245 measurements collected on the lower leg, only one showed a change greater than 15% difference; it was negative. Eight showed a change greater than 10% difference, with five of these measures in the negative direction and three in the positive.

On the back, sixteen measurements showed a greater than 30% difference out of 203 measurements total. Ten of these were in the negative direction and six were positive. Seventy-four measurements exceeded 10% change, with every subject showing at least one measurement that exceeded the 10% mark.

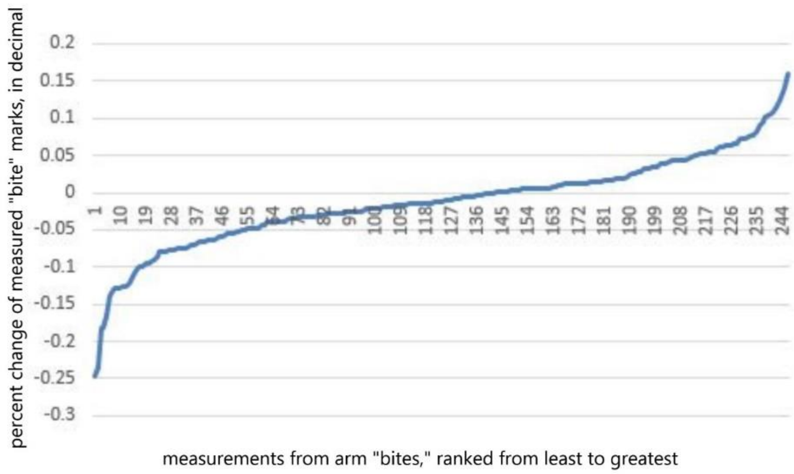

figure B-2 - Distortions from the forearm

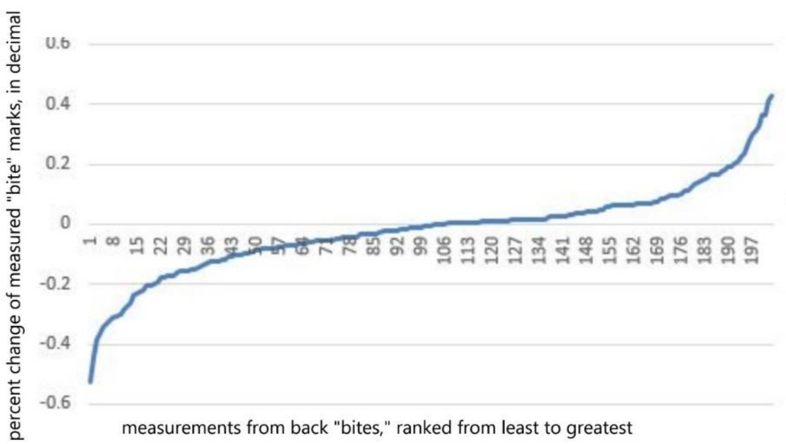

figure B-3 – Distortions from the back

Distortions from each test location are shown below. Axes show percent change in bite mark from least to greatest by value. Thus the "Least" is the most negative percent change—or greatest movement of the bite marks toward each other. "Greatest" represents the highest positive percent change—or greatest movement of the bite marks away from each other.

Normalizing the data, in order to run a student's t-test involves grouping the data and graphing the points as number of measures that fall within a specific range. See figures B-4, B-5, and B-6. These graphs show twenty-five equal ranges, though data was tested at twenty, thirty, thirty-five, and forty equal range breakdowns or "bins." Twenty-five was chosen because it visually displays the best best-fit curve. All t-tests showed a p value of 0.01 or less, regardless of "bin" size.

Curves, though relatively normal, shows central tendency just negative of zero because all maximal measurements in the negative were greater than any positive maximal measurement by a minimum of 8% difference.

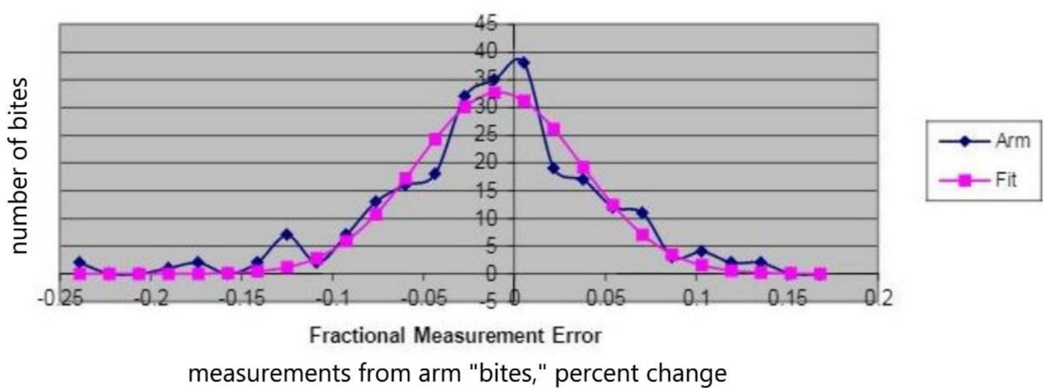

figure B-4 – Normalized data from arm with best fit curve

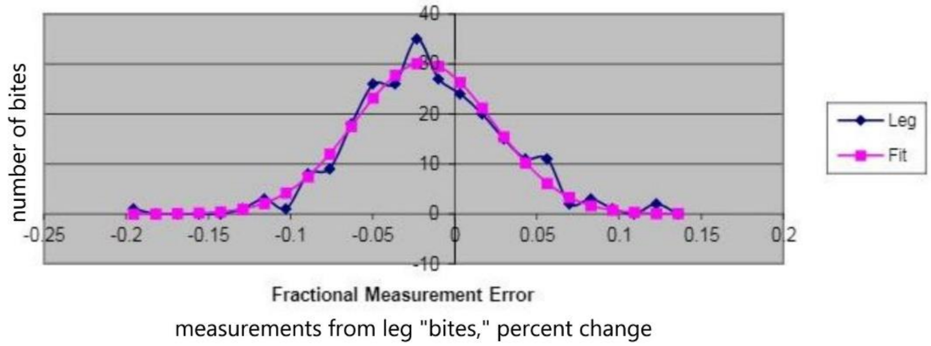

figure B-5 – Normalized data from leg with best fit curve

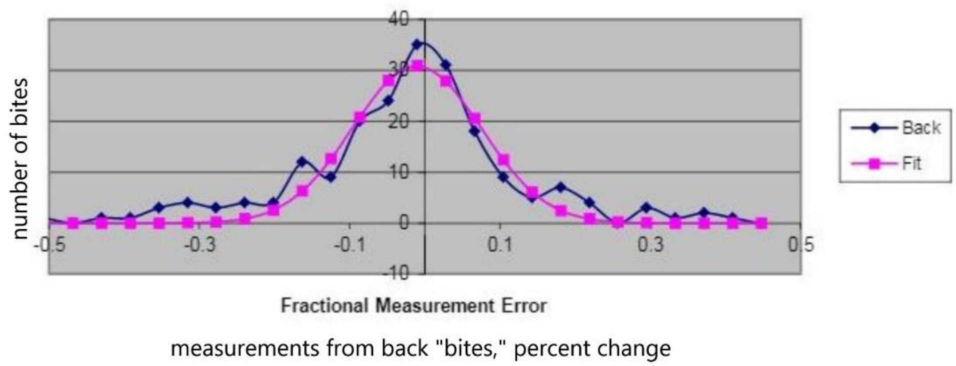

figure B-6 – Normalized data from back with best fit curve

Comparing the intercanine distances of the dental molds showed differences as well. The smallest intercanine distance here measured 23.47mm. This produced a greater than 30% difference against seven of the eight remaining molds. The greatest intercanine distance was 36.14 and showed a percent change of greater than 30% to the two smallest molds.

Using the median measurement of 32.59 also gave a greater than 30% difference to the smallest mold, a greater than 20% difference to the next smallest mold, and a greater than 10% difference to the largest mold. A midpoint of the range was also used since the molds skewed to the larger size. This number yielded a measure of 29.87millimeterdistance and was more than 20% different from both the largest and smallest molds and a greater than 10% difference to the next smallest and two next largest molds.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

The values most useful in ruling out a biter would come from skin surfaces showing the least percent change in either direction from the actual measurement of the dental mold. In this study, the forearm and the lower leg are very close in greatest percent change with the lower leg being the best location by a small margin. The upper back proved the least useful for skin surface for bite mark analysis.

The marks made by this study, though still clearly distortable, were not as variable as expected. This data is consistent with earlier studies that have found that bite marks can be highly distorted. (Devore, 1971) (Barbanel, 1974) (Sheasby and McDonald, 2001) (Pretty and Sweet, 2010) (Lewis and Marroquin, 2015) However, those studies were looking to show variability in the entire dental arch, which does occur. This study identified body positions with low, or the lowest possible, distortion in only one dimension. While the entire arch does alter dramatically with skin movement, it appears to distort in specific and predictable ways. In order for the intercanine distance to distort, the skin directly between the canine marks must either compress or expand to change the measurement.

This data is limited and while extrapolations can be made, it should be applied only to the locations studied. Forearm, lower leg, and upper back were chosen because they do not cover joints or other locations with known high distortion rates. Even with these limitations, not all these locations proved useful in producing a greatest possible percent change in measure. Bites made to the upper back appear relatively unreliable as a measure and should be reliable as a rule out only in extreme cases. This would likely only rule out only a small number of possible perpetrators. Bites to the forearm have not exceeded a 28% change from the measured intercanine distance. Bites to the lower leg have not exceeded a percent change of greater than 21%.

This could be used to rule out biters with a smaller or larger intercanine distance than the possible range given the measurement and distortion rate. This rule out could be applied such that biters with an intercanine distance larger or smaller than X could be ruled out, or that the intercanine distances of the possible pool of biters can be obtained.

The variability of the adult human dental models used in this study shed light on the variation of human intercanine distance, too. The standard deviation of approximately 4 millimeters, along with the percent differences between the actual intercanine distances, shows that, while not all adults will be able to be ruled out, almost 40% of these molds differed by more than the greatest variability found on certain sections of the skin, namely the forearm and lower leg. As these locations were chosen because of their high likelihood of bites, they can prove useful in future cases.

This rule out becomes more useful if either the biter or the bite mark is either very large or very small. More average size dentitions will be harder to rule out in any scenario using this method.

The upper back area showed the greatest variability in measurable intercanine mark distance of the three locations studied here. However, the largest and smallest of our small sample human population here still had an actual intercanine distance that would be distinguishable given this test. So while not all biters could be ruled out here, some still could. In the case of animal biters, intercanine distance varies even more than in human populations. Animal biters may be more successfully ruled out even in cases of bites to the upper back. Though the greatest variation in intercanine distance of bite marks on the back was slightly greater than 50%, this would still be useful in distinguishing some dogs from each other, or bears, or a variety of other animals.

In the future, physicians in offices and emergency departments have the option, when lives are not at stake, to find and photograph the most useful bite mark information as close as possible to the time of the attack. This will minimize dependence on data collected later, after healing has occurred and after the wound has altered or even just possibly altered. A forensic scale (Lewis and Marroquin, 2015) can be used to photograph the bite and provide measurement. The physician can also measure and record the intercanine distance of the marks using calipers. This will provide data that can now be used to compare against possible known biters or even provide information about the range of intercanine distances in possible known biters.

Emergency department personnel and medical workers can use this information to capture more bite marks for evidence in future cases, as the only distinguishable marks need to be the canine marks. Previously, the entire dentition was hoped to be captured in a bite mark on flesh. Because of the minimal information necessary in this procedure, more marks will be able to be considered useful. Also, medical personnel and technicians can choose bite marks in locations better used to determine rule-out analysis.

This method does not solve some of the issues of expert comparison in court, namely that very average human dentitions are still the hardest to distinguish. However, even in ideal situations, bite mark comparisons were not without possible fault. This method compares those marks by data rather than an individual analysis, and should help take ‘warring experts’ out of the courtroom.

There are definite limitations to the application of this work. These measures only apply to the locations on the body that were tested and should not be extrapolated to other anatomical locations. Future studies should focus on finding distortion values for other locations on the body. Many bites occur on the face and were not addressed in this study.

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APPENDIX

Table 1 – Raw Data from all bite marks (listed as percent change.)

ARM	LEG	BACK
0	0.050023596	0.097215668
-0.166861371	0.038225578	0.203397829
0.002141745	0.061821614	0.097215668
-0.134735202	0.002831524	-0.056158565
-0.048725814	0.038225578	-0.003322259
0.061703634	0.02642756	0.026880097
0.018876829	0.014629542	-0.033524615
0.014157622	0.014629542	0.057082452
-0.026479751	-0.002982531	0.004854369
-0.084890966	0.031103536	0.166019417
0.051401869	0.050703025	-0.000647249
-0.065420561	0.020877716	0.193203883
0.011959522	0.060051911	-0.00720405
0.011959522	0.097333648	0.016744548
0.011959522	0.018758849	0.028426791
-0.080036799	0.047310052	0.026869159
-0.024922118	-0.034549689	-0.10019084
-0.036020249	-0.081909938	-0.525763359
-0.140186916	-0.084627329	0.062340967
-0.017523364	-0.012850467	-0.195610687
0.002213614	-0.011682243	-0.016865992
-0.033480908	-0.042056075	-0.067770623
0.033204206	-0.02258567	-0.019932536
-0.057830659	-0.028338509	0.064704079
0.026009961	-0.04386646	-0.069610549
-0.065578307	0.010093168	-0.020545845
0.061704483	-0.05939441	-0.033731984
-0.014111787	-0.029259084	-0.105489114
-0.052552099	-0.031736668	0.007470946
-0.040169133	-0.031736668	-0.301328168

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
0.00936273	-0.031854648	-0.033757609
-0.0628209	0.032229965	-0.44355285
-0.001278228	-0.093495935	0.413356698
-0.18236046	-0.06271777	-0.38415109
0.0634853	0.013646922	0.324376947
0.044311888	-0.018705918	0.429127726
-0.275621118	-0.093222938	-0.003236246
0.004658385	-0.09475621	0.092556634
-0.180900621	-0.017479301	0.018122977
-0.118012422	-0.00275989	0.069255663
-0.005523167	-0.045691506	-0.022975078
0.00122737	-0.021159154	0.061915888
0.024240565	-0.109475621	-0.104166667
-0.072721694	-0.091175608	-0.078465732
-0.003320421	-0.0627382	0.008928571
-0.003320421	-0.074464966	0.061723602
-0.040121749	-0.060979185	-0.088121118
-0.063918096	-0.034345293	0.024068323
-0.013208351	-0.056731064	-0.021465808
-0.016616958	-0.033731984	0.139527752
0.016190882	-0.043851579	-0.107022386
0.016616958	-0.028776978	-0.228764183
0.004854369	0.036247925	-0.013239875
0.102265372	0.000830105	0.068341121
-0.017475728	0.062811289	0.015186916
0.080906149	-0.074766355	-0.202297508
-0.025505717	-0.014992212	0.002912621
0.015537965	-0.062694704	-0.097411003
0.015537965	-0.047313084	-0.174110032
0.025798886	-0.052480916	-0.053074434

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
0.003657386	-0.042302799	-0.224274406
0.010972157	-0.041984733	0.235121665
-0.077277017	-0.05478694	-0.063617707
0.054111632	-0.048146099	-0.04624823
0.065189604	-0.046485888	0.168003775
-0.004686834	-0.004703929	-0.32255781
0.039198977	0.029262087	-0.030202926
0.012080942	-0.007315522	0.042624962
0.052250076	0.02894402	0.134621282
-0.02718212	-0.014949109	-0.080036799
-0.015403201	-0.009320434	0.042624962
0.001704303	-0.021472393	0.031931464
-0.014060503	-0.019230769	0.362928349
0.018747337	-0.007432751	0.362928349
-0.034938219	0.006133088	0.168224299
-0.004832377	-0.124501687	-0.030990592
-0.050135911	-0.054891138	-0.087437742
-0.00936273	0.022692426	-0.052850028
-0.025369979	0.011504048	-0.052850028
-0.074758135	0.067319983	0.061919505
-0.075051305	-0.004260758	0.005239343
-0.075051305	-0.021303792	-0.043819957
-0.128114922	0.012461059	-0.062395809
-0.077890218	0.012461059	-0.052131248
-0.065930696	-0.026479751	0.011652867
-0.006133088	-0.026479751	-0.155167127
-0.127261576	0.023796348	-0.061944189
-0.013807917	0.051466519	-0.041082555
-0.059834305	0.051466519	0.06152648
0.05093587	0.023796348	-0.197040498

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
-0.032541777	-0.00623053	0.147900763
-0.032541777	0.011487539	0.02480916
-0.032541777	-0.00623053	0.010496183
-0.061858692	-0.030995617	-0.238231552
0.011959522	-0.071383845	0.071801166
0.042624962	-0.049467752	-0.282295183
-0.018705918	-0.054790232	0.297023627
0.073290402	0.000353941	0.30929733
0.077103489	-0.002123643	-0.122017517
0.003811199	-0.041764983	-0.013893084
0.14277338	-0.021708353	0.024161885
0.124010554	-0.026537217	0.064633041
-0.026880097	-0.063106796	-0.024143302
-0.016309272	-0.042071197	-0.173870717
-0.038659015	0.004854369	-0.335280374
-0.048625793	-0.081553398	-0.119742991
-0.019024241	-0.042718447	0.008154636
0.002147898	-0.067313916	0.037450921
-0.046946916	-0.108090615	-0.10268801
0.02730899	-0.041925466	0.09845968
0.049252905	-0.010869565	0.001839926
-0.050913116	-0.010093168	-0.076970255
-0.125345877	-0.010481366	-0.052131248
0.034311013	-0.047417699	0.006439742
0.006439742	-0.047115675	0.006361323
0.074210365	-0.047115675	-0.09764631
-0.02023919	-0.01781939	-0.083651399
0.008279669	-0.002862595	0.121501272
-0.079935275	-0.049936387	-0.012879485
0.103559871	0.011768448	0.034651947

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
-0.039482201	-0.018765903	-0.150260656
-0.100647249	-0.008587786	-0.06899724
-0.048961774	-0.02480916	0.014114759
0.01297782	-0.030852417	-0.058913777
-0.032326569	0.001590331	0.017490028
0.044737963	-0.050015342	0.073949064
0.06561568	0.026695305	0.044492176
0.094588837	0.028229518	0.208652961
0.007243289	-0.073028536	-0.127032832
-0.028787164	-0.04802799	0.194845044
-0.247168476	-0.048982188	-0.041781959
-0.035630014	-0.035305344	0.055893747
-0.014629542	-0.034987277	0.013835086
0.004672897	0.050276949	0.007470946
-0.089563863	0.007243289	-0.045801527
-0.02355919	-0.056242011	0.176844784
-0.000778816	0.051981253	-0.363867684
-0.079165388	-0.027116768	0.113231552
-0.109235962	0.046485888	0.002831524
-0.020865296	0.047039292	0.179801793
-0.099723842	-0.05644715	0.156205757
0.053959627	-0.057461155	-0.162340727
0.073369565	0.002345353	-0.04599816
-0.032996894	0.02081501	-0.141367679
0.013198758	0.029023747	-0.202698559
-0.022196262	-0.068192544	-0.135234591
0.006619938	-0.115148655	-0.025774778
-0.053738318	-0.021118452	0.047867444
-0.027842679	-0.065479	-0.068119055
0.032927504	-0.018122977	-0.343970543

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
0.015495296	0.018446602	0.043571648
-0.02573326	-0.007119741	0.066891685
-0.042888766	-0.009061489	0.014728444
-0.028625954	-0.025138475	-0.310831543
-0.019083969	0.054963784	0.034430686
-0.055661578	-0.019173413	0.276653579
0.042620865	-0.002982531	-0.170945334
0.006364139	-0.015139752	0.083056478
0.027116768	0.030667702	-0.013192612
0.042335362	0.042701863	0.086484902
-0.008577753	-0.021222741	-0.154793316
-0.014195107	-0.03271028	-0.272060979
0.044095439	-0.084696262	0.005663049
0.160072486	-0.005257009	0.070552147
-0.043491392	-0.026479751	-0.175200566
0.005825243	0.129283489	0.008966494
-0.098705502	0.070872274	0.005810736
-0.129126214	-0.026479751	-0.064194798
-0.015533981	-0.018705918	-0.147482014
-0.052018634	-0.049371358	0.016878805
-0.095496894	0.011959522	0.008758683
-0.074534161	-0.018705918	0.002416188
-0.092391304	0.015210356	0.100573845
0.042624962	0.000970874	-0.15705225
0.011959522	-0.011650485	0.009131157
0.011959522	-0.025242718	-0.003597122
0.042624962	0	-0.09352518
-0.034128662	0.012810559	-0.033757609
0.089700997	0.009704969	-0.047073791
0.059498641	-0.080357143	-0.116412214

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
0.109332528	-0.012356199	0.068066158
0.005899009	0.024712399	-0.150763359
0.00648891	-0.034512143	0.015035287
0.034214252	0.045164039	0.046640074
-0.029613025	-0.062445031	-0.177661859
0	-0.068601583	-0.122737036
-0.054270882	-0.068601583	-0.01729698
-0.121755545	-0.043389035	0.142187042
0.017697027	-0.051555177	-0.221342715
0.006443694	0.012356199	-0.125769569
-0.011046333	-0.003408607	0.016939252
0.077631175	-0.022155944	-0.30626947
0.021478981	-0.038511327	0.10961838
-0.011132316	-0.031391586	0.034033079
-0.058206107	0.007443366	0.222964377
0.032124682	0.004854369	-0.075381679
-0.094465649	0.014018692	0.014949109
0.106092885	0.125	0.007119741
0.053685556	0.041471963	-0.07961165
0.115040477	0.084890966	-0.081877023
0.038772902	-0.048959249	-0.014239482
-0.038819876	-0.032248607	
-0.008540373	-0.074464966	
-0.128493789	-0.018469657	
-0.076086957	-0.075483277	
-0.01321378	-0.201902424	
-0.01321378	-0.11261123	
-0.017932987	-0.09358699	
-0.017815007	-0.034304207	
0.002329193	-0.027184466	

Table 1 – Raw Data from all bite marks (listed as percent change.) (cont)

ARM	LEG	BACK
-0.006599379	-0.057605178	
-0.002717391	0.041100324	
0.015916149	-0.008591593	
0.015101178	-0.05922062	
0.03986711	0.019331083	
0.0628209	0.00828475	
0.064028994	-0.038933459	
-0.038187702	-0.03916942	
0.019093851	-0.004129306	
-0.063106796	0.084001888	
0.004530744	-0.021303792	
-0.02575897	0.007243289	
0.019319227	0.041329357	
0.046918123	0.12398807	
-0.021465808	0.042957963	
0.002416188	0.031297944	
0.135306554	0.058606935	
0.071881607	0.076710647	
-0.021745696	-0.013198758	
-0.027135441	-0.020186335	
-0.236565421	0.026372278	
-0.033385093	-0.088623122	
0.052795031	0.006439742	
-0.069487578		
-0.014751553		
STD DEV: 0.06240759	**STD DEV: 0.045748451**	**STD DEV: 0.145100288**

VITA

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