The Forensic Evaluation of Fracture Marks:
A Validation and Experimental Study.

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[Signatures]

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Background:

The forensic evaluation of fracture marks involves the examination of the unique features that are present on two pieces of material once they have been separated. The individualizing characteristics on the fracture surfaces have been evaluated in materials involved in criminal cases to prove that the two parts were once a whole, aiding in the connection between crime and suspect. Although the examination of fracture marks has been widely practiced in crime labs, the research available on the topic is limited, reducing its admissibility in court. The research in this paper involves the validation of techniques previously used on some materials and the application of those techniques on a wider range of materials to determine if the fracture features exhibit enough evidence to prove that the two halves were once a whole.
Literature Review:

Fracture surfaces can be seen in any material or object that has been separated by breaking or tearing. A fracture match or physical match (as defined by Miller quoting from the Association of Firearm and Toolmark Examiners Journal, or the AFTE) is the examination of such fractures in materials “either through physical, optical or photographic means which permits one to conclude whether the objects were one entity or were held or bonded together in a unique arrangement.” [1] In “Metal Fractures: Matching and Non-Matching Patterns,” which is also published in the AFTE Journal, Jerry Miller describes the way the fracture is observed and how a match is made using the characteristics that are observed. [2] The examination that occurs most often is of the pattern that the break or tear causes along the surface of the material; this checks for the “jigsaw puzzle fit” of the two objects (see photo 1). This “perfect fit” fracture happens only in certain types of materials and is dependent on the way the material is separated. The second part of examination involves the area surrounding the break on the surface. Any “chips” or “chunks” that are missing from the surface of the material should be accounted for on both pieces of material in question. The missing sections along the cracks are usually toolmarks, which are marks that are left from the object that was used to separate the material. The final portion of the examination of the fracture mark is inside, along the fracture itself. The patterns of matching halves will exhibit a symmetric topography along the interior of the cracks; in one half where there is an elevated feature, there should be a corresponding depressed feature on the other half. The examiner should also look for matching striations, discoloring, or grooves that can often be seen in this portion of the fracture.

Forensic examiners have used the characteristics in fracture marks to prove that two objects were once joined to create physical evidence for criminal cases. For example, the Texas Department of Public Safety Crime Lab was given a section of a nylon jacket that was torn from a suspect’s jacket while fleeing the scene of a burglary. The examiners positively identified the section of cloth as once belonging to the jacket in question by the “jigsaw puzzle” fit the fracture marks created (see photo 2). Though the jacket had other
positive correlating factors such as color and fabric, the fit of the two sections removed any doubt that the suspect “just happened” to own a similar jacket. The TDPS Crime Lab additionally encountered two separate hit and run cases where they were able to use the “fit” that fracture marks exhibited in paint and plastic that had come off the vehicles during the crimes (see photos 3-7). In another crime lab, an antenna that was torn from an attacker’s car by the victim during a sexual assault was paired back to the suspect vehicle by an “excellent agreement of the striated excursion marks” that were present in both of the sections that were in question. [3] Again, the “pattern fit” that was seen in a tail pipe retrieved after it broke from a pick up truck that bottomed out while leaving the scene of a double homicide is what led police back to the suspect. [4]

So why is this promising evidence losing its admissibility into our court system? In a letter to Dr. Horst Katterwe, a material technologist for the Forensic Science Institute in Wiesbaden, Germany, from the 2003-2004 AFTE president, Ann Davis, states that this is occurring because of a “serious lack of scientific research on this subject and lack of validation of the various techniques for associating two or more separated objects.” [5] In her letter to Horst, Davis went on to say that “very little has been presented at past forensic science seminars and no scholarly research on this subject has been published in this country.” Due to a series of court rulings, such as Frye and Daubert, forensic analysis must, and should be able to, prove their findings are based on valid reasoning. A common agreement of the facts must exist that allows the results of the evidence to be reliable. Reliability is the number one trait a piece of evidence must have in order to be heard during a criminal trial.

The most effective research that has been published on the topic thus far was conducted by the previously mentioned Dr. Horst Katterwe. His paper, “Science of Fracture Matching and Validations Studies,” was presented at the AFTE 2004 Anniversary Training Seminar. The results of his experiments show that positively identifying two parts as once being a whole is possible because fracture surfaces do not occur in any predictable fashion. Even under “controlled, repetitive conditions and with the same material- the fracture surfaces show different details and features.” [6] What this
means is that no matter what material was used or how the material was separated, no
two fractures or cracks could be reproduced.

The research presented in this paper is based on Dr. Katterwe’s experimental data
that “the fracture processes contain inherently individualizing potential.”[7] The
experiments conducted for this paper confirm that previously applied fracture identifying
techniques do in fact mark the positive correlating features present in the marks and
cracks that allow for an observer to determine that the two parts of a material were once a
whole. The research also applies the fracture match techniques to five types of material:
tape, wood, paper, glass, and rubber, to define what type material and mode of separation
will allow for a proper identification of a physical match.
Literature Review Photos:

- **Photo 1**: Example of jigsaw puzzle fit seen in a broken pencil

![Photo 1: Example of jigsaw puzzle fit seen in a broken pencil](image1)

- **Photos 2 and 3**: Jigsaw puzzle fit of a piece of a nylon jacket torn from a suspect’s jacket while fleeing the scene of a burglary. The case number has been cut from the photos and shown here with the permission of the Texas Department of Public Safety Crime Lab.

![Photos 2 and 3: Jigsaw puzzle fit of a piece of a nylon jacket torn from a suspect’s jacket while fleeing the scene of a burglary](image2)
Literature Review Photos:

- **Photos 3 and 4**: Texas Department of Public Safety Crime Lab. A section of paint chipped from a vehicle during a hit and run accident.

- **Photo 5**: Texas Department of Public Safety Crime Lab. Jigsaw puzzle fit of a broken side mirror involved in a separate hit and run accident.
Tape

Materials and Methods:

The presence of distinct fracture marks will often depend on the actual “make-up” of the tape. For this reason, four different types of tape were used for this experiment: electrical tape, masking tape, duct tape, and plastic tape. All four types of tape were purchased at different locations, but are of the same Scotch brand. Two modes of separation were used to divide the sections of tape: a tension tear and a shearing tear. A tension tear involves pulling a section of tape horizontally until it is divided and in a shearing tear the tape is torn vertically into halves. A total of forty trials was conducted: five trials for each method of separation, ten all together for each type of tape.

Conclusion:

A conclusion of a match in the tape fracture surfaces in this experiment are based solely on the jigsaw puzzle fit of the two halves. The result of a matching pattern in the fracture surface is dependent on both the type of tape and the manner of separation. The electrical tape exhibited the strongest physical match when the shearing method of separation was used (see photos 1-2). Due to the elasticity of the electrical tape, when the tension method of separation was used the fracture features become distorted and are not as obvious, therefore a second form of identification should be used (see photos 3-4). The colored plastic tape has a similar make up as the electrical tape, but is not as elastic. The masking tape has no elasticity and has paper like characteristics. In trials for the plastic tape and the masking tape, regardless of the way the tape was parted, there is sufficient evidence to conclude that halves where once a whole (see photos 5-12). The duct tape, an inelastic, very durable tape, also displays a perfect fit of the fracture surfaces regardless of the technique used to split the tape (see photos 13-16).
Therefore, the more elastic properties the tape possesses, the more likely the fracture surface will be distorted. Caution should be taken when evaluating the physical fit of the fracture marks in elastic tapes. An examiner should note that there are many grades of duct tape and this experiment only evaluates one, but research has been conducted supporting that a positive fracture match can be made across qualities and grades of duct tape. [9] Listed below are photos of several trials for each type of tape showing the matching and non-matching patterns present in both modes of separation.

**Electrical Tape Photos:**
- Photos 1 and 2: Shearing method
Electrical Tape Photos:

- Photos 3 and 4: Tension method
Colored Plastic Tape Photos:

- Photos 5 and 6: Shearing method
Colored Plastic tape Photos:

- Photos 7 and 8: Tension method
Masking Tape Photos:

- Photos 9 and 10: Shearing method
Masking Tape Photos:

- Photos 11 and 12: Tension method
Duct Tape Photos:

- Photos 13 and 14: Shearing method
Duct Tape Photos:

- Photos 15 and 16: Tension method
Wood:

Materials and Methods:

There are three manners in which an examiner can identify two sections of wood as once belonging together: 1) a puzzle match along the contour of the break, 2) a match in the annular growth rings, or 3) a match in the xylem and phloem tissue. [10] For this experiment, two blocks of wood varying in width and length were evaluated. The sections of wood were purchased at two different locations to ensure they were of different quality. The wood was separated by simply holding each end and applying a downward force until it snapped. The broken pieces were then evaluated and photographed.

Conclusions:

For both sections of wood there is substantial evidence to conclude that the pieces were once a whole. In the first block of wood there is a perfect jigsaw fit in the two halves (see photo 1), in conjunction with the match in the annular growth rings of the wood. In the first trial, because the block of wood is of substantial width, it shows that the two halves exhibit a symmetrical topography along the interior of the actual fracture; for every depressed feature on the top half, there is a matching raised feature on the bottom half (see photo 2). For the second trial, a physical match of the fracture edges joins the two pieces together (see photo 3). The vascular tissues, the dark splotches and lines that are present throughout the wood, pair up perfectly with its counterpart on either side (see photo 4). The wood block used in the second trial has a much smaller width than the first wood section. For this reason, the symmetrical topography cannot be seen. Wood is a ridged material and because of this characteristic, when it is broken, it leaves behind distinct features on its edges giving it the ability to fit back together like a puzzle. The vascular tissues, the xylem and phloem, also give the wood individualizing
properties. These tissues make up the annular growth rings and the dark, parallel lines that can be seen in any section of wood. Therefore, a match in the tissues or the fracture edges gives a positive identification that two separate pieces of wood had once been joined together.

**Wood Piece One Photos:**

- **Photo 1:** A jigsaw puzzle fit along the contour of the break and a match in the annular growth rings.

![Photo 1: A jigsaw puzzle fit along the contour of the break and a match in the annular growth rings.](image1.jpg)

- **Photo 2:** The raised features on the top portion match the depressed features on bottom portion.

![Photo 2: The raised features on the top portion match the depressed features on bottom portion.](image2.jpg)
Wood Piece Two Photos:

- **Photo 3:** Jigsaw puzzle fit along the contour of the break

![Image of jigsaw puzzle fit along the contour of the break]

- **Photo 4:** A match in the vascular tissues of the wood

![Image of vascular tissues match]
**Paper**

**Materials and Methods:**

When conducting this research, the materials were chosen based on the likelihood that they could be encountered at a crime scene. With this in mind, matches and ticket stubs were chosen for the paper section of the experiment. Three different matchbooks were collected from separate locations. Two of the matchbooks contain matches that are black. The third matchbook has matches that are brown, resembling the color of cardboard. Three separate tickets were collected from different events: a concert, a sports game, and a museum. The matches were separated from the books in two different manners: a shearing tear and a tension tear. Recall from the tape experiment that a shearing tear occurs when the material is torn vertically and a tension tear is the result when the material is pulled horizontally. Three matches were torn from each book using the shearing method and two additional matches were torn from each book using the tension method. The tickets were simply torn along the perforated edges, where they would have normally been separated if they had been used. The items were then placed under a stereoscope microscope and photographed.

**Conclusions:**

The three matchbook trials did not provide enough proof for a positive match regardless of the way the matches were torn from the books. The black top layer of the matches from the first two matchbooks dose slightly create a puzzle fit when they were separated using a shearing tear (see photos 2 and 4). There are no positive correlating factors in the third trial using the brown matches (see photos 5-6). This is because the lack of a colored top coating enables the fracture edge from taking on a more definite shape. Although some points on the colored matches pair up in the shearing methods, the fibrous make up of the matches prevents a perfect physical match. Another approach should be used to determine if a particular match came from a certain matchbook.
When evaluating the ticket stubs, the first of the three tickets showed a positive factor that they once belonged together (see photos 7 and 8). The top layer of this ticket was thicker, making it more rigid; when the ticket was torn the thick top layer created a fracture surface that allowed the halves to piece back together. The other two tickets, however, did not contain a heavier top coating and the fracture marks did not generate any evidence that the halves were once together (see photos 9 and 10). The tears along the perforated edges of the ticket stub become too “hairy” when they are separated, making a fracture mark nonexistent. Examiners should use characteristics other than the fracture surface when evaluating paper that has been torn along a perforated edge. An example would be to use the connection of the black line that can be seen on the two halves of one of the tickets (see photo 9).

**Matchbook One Photos:**

- **Photo 1:** Tension tear in black colored match
Matchbook One Photos:

- Photos 2 and 3: Shearing tear in black colored match, front and back photos
Matchbook Two Photos:

- **Photo 4:** Tension tear in second black colored match

![Image of a match with a tension tear]

- **Photo 5:** Shearing tear in second black colored match

![Image of a match with a shearing tear]
Matchbook Three Photos:

- **Photo 6**: Tension tear in brown match

![Photo 6: Tension tear in brown match](image)

- **Photo 7**: Shearing tear in brown match

![Photo 7: Shearing tear in brown match](image)
Ticket Stub Photos:

- Photos 8 and 9: Jigsaw puzzle fit seen in the first ticket
Ticket Stub Photos:

- Photos 10 and 11: Non-matching patterns of the second two tickets
Glass

Materials and Methods:

According to the Scientific Working Group for Material Analysis (SWGMA), fracture features in glass can tell an examiner a wide arrange of information about the glass. [11] Additionally, the fracture marks can reveal the direction of travel and the velocity of the object that broke the glass. SWGMA notes that a “physical match of two sections of glass establishes that they came from the same source to the exclusion of all others.” [12] For this experiment, two sections of glass of the same size and same thickness were analyzed. The glass was broken by laying the section on the floor and hitting it with a hammer directly in the center of the glass. The glass was broken in one swing of the hammer, no repetitions were made. The glass was then put back together using the jigsaw puzzle fit the pieces made. After examining the fragments of broken glass under a stereoscope microscope, they were then photographed.

Conclusions:

Both sections of glass that were broken exhibited the same results of a matching pattern in the fracture features. In both sections of glass the fracture cracks form what is known as concentric cracks. Concentric cracks are cracks that make an approximate circle pattern around the point of impact [13] (see photos 1 and 2). This information tells an examiner where the point of impact was on the glass. The broken sections of glass have jigsaw puzzle matches along the fracture edges creating a perfect physical match between the broken pieces (see photos 3 and 4). Along the interior of the actual break, the wallner lines are visible. Wallner lines are rib shaped marks with a wave like pattern; they are also called ridges or rib marks, after the pattern they make (see photos 5-7). [14] When placing the interior fracture of two pieces of broken glass side by side under a microscope, the ridges are in perfect symmetry in the two sections. This makes the interior fracture surfaces of the glass pieces mirror reflections of each other (see photos 5 and 6). An examiner can use these characteristics of fracture marks found in glass to properly determine if two broken sections of glass was once one continuous piece.
Photos 3-7 of the interior fracture surface of the broken glass were made possible by Material Analysis Incorporated in Dallas, Texas.

**Glass Photos:**

- Photos 1 and 2: Concentric cracks forming a circular pattern around the point of impact
Glass Photos:

- **Photos 3 and 4:** Jigsaw puzzle fit of the broken pieces of glass
Glass Photos:

- Photos 5 and 6: Mirror image of the wallner lines in the two section of glass
Glass Photos:

- Photo 7: Interior of the fracture mark: the ridges of the fracture are seen near the bottom of the fracture.
Rubber

Materials and Methods:

The forensic evaluation of fracture marks in rubber had been conducted in several criminal cases. The Texas Department of Public Safety was able to correctly identify a semi-truck involved in a hit-and-run accident when a section of rubber found at the scene was connected to the tire in question (see photos 1 and 2). At a different crime lab, investigators were able to locate a suspect when they traced rubber shoe sole fragments found in a glass fragment from a window that had been kicked in back to the perpetrator’s shoes.[2] Rubber is mentioned in this experiment because it is an interesting material and is sometimes encountered at a crime scene. Two rubber bands were used for this evaluation. They are both of the same brand and size. The rubber bands were then separated by the tension tear method, pulling the rubber band horizontally until it broke. The fracture edges on the broken rubber band were evaluated using a stereoscope microscope and photographs were taken.

Conclusions:

When examining the fracture edges on rubber, both trials for this experiment yielded a result of a match between the two sections. Each rubber band presented a jigsaw puzzle along the contour of the break (see photos 3-5). Because of the physical makeup of rubber, when it is separated, the inside of the fracture exhibits a mirror image of the two halves. For every raised feature on one half, there is a corresponding depressed feature on the other half (see photos 6-8). This knowledge can be used to determine if a section of rubber originated from a larger whole.
Rubber Photos:

- Photo 1 and 2: Physical match of a section of shredded tire: the case number has been removed from the photo and is shown here with the permission of the Texas Department of Public Safety Crime Lab.
Rubber Photos:

- Photos 3 and 4: Physical match of the fracture edges
Rubber Photos:

- **Photo 5**: Jigsaw puzzle fit of second rubber band

![Image of a rubber band cut in half with a smooth fit]

- **Photo 6**: Symmetric topography on the two halves of the broken rubber band

![Image of a rubber band cut in half with a smooth topography]
Rubber Photos:

- **Photos 7 and 8**: The mirror images of the two halves seen in both trials of the rubber bands
Discussion

The forensic evaluation of fracture marks has been conducted in crime labs for some time now, but the evidence that is collected from the marks is losing its admissibility into the trial process. The lack of research on the subject is the cause of the rising problem. The research conducted and presented in this paper confirms that properly identifying two parts as once being a whole based on the characteristics that fracture marks present is feasible. The conclusion of a match or a non-match should take into consideration the type of material that is in question and the manner in which it was separated. A positive identification of a material’s origin due to fracture surfaces provides solid evidence in a criminal case. The jigsaw puzzle fit and the symmetric topography that fractures yield remove any doubt that a section of a material found at a crime scene just happened to be of the same type of material found on a suspect. Fracture features can tell an evaluator exactly the source of origin of the material, rather than relying solely on the match of the actual makeup of the material.
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Sherry Bethune.
Endnotes


2. Ibid., 133-134.


6. Ibid., 8.

7. Ibid., 8.


Endnotes


12. Ibid.

13. Ibid.

14. Ibid.
Bibliography


