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## **Abstract**

In the forensic science field, it is generally accepted that all tears and fractures are unique; however, there is limited scientific evidence to support this. This study tests the claim that all tears are unique, focusing on paper. One-hundred Office Depot® brand 3" x 5" blank, white index cards were torn in half by hand. Six halves were randomly removed; the remaining 94 halves were mixed and then matched by a novice using end-match analysis. The removal of the 6 random halves left 44 matching pairs. Of the remaining halves, all 44 pairs were correctly matched. The results show that each tear was unique and that no two halves were similar enough to be misidentified as a match.

## **Keywords**

physical match, paper, tearing, end-match, Daubert

## Physical Match: Uniqueness of Torn Paper

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### **Abstract**

In the forensic science field, it is generally accepted that all tears and fractures are unique; however, there is limited scientific evidence to support this. This study tests the claim that all tears are unique, focusing on paper. One-hundred Office Depot® brand 3" x 5" blank, white index cards were torn in half by hand. Six halves were randomly removed; the remaining 94 halves were mixed and then matched by a novice using end-match analysis. The removal of the 6 random halves left 44 matching pairs. Of the remaining halves, all 44 pairs were correctly matched. The results show that each tear was unique and that no two halves were similar enough to be misidentified as a match.

## Introduction

Physical match, also referred to as physical fit, is a method forensic scientists use to match two or more broken pieces of an object to determine whether the two pieces were a part of an original whole. Physical match can be used in various cases; some examples include matching broken glass shards from the crime scene with glass shards from the suspect's clothing, matching tape used to bind a victim with the roll of tape, and matching a piece of torn paper with a notepad. Determining whether these items originated from the same source can inform detectives that a suspect made contact or did not make contact with the original source material.

The underlying assumption of physical match analysis is that all tears and fractures are unique. Before the publication of the 2009 National Academy Science (NAS) report on forensic science, physical match experts used this assumption to perform their analyses, but there was limited scientific evidence supporting this assumption. After the publication of the NAS report, there has been more research supporting this assumption, and more validation tests for the methods used to match pieces to their original source. Prior to the release of the NAS report, the Daubert standard was another set of requirements emphasizing more sound scientific methodologies in forensic science.

The Daubert standard states that for the testimony of expert witness to be admissible in court, their conclusions must be scientifically sound and of scientific methodology (*Daubert v. Merrell Dow Pharmaceuticals*, 1993). In order to satisfy the needs of the Daubert standard more empirical evidence and studies need to be conducted.

There is limited research on physical match analysis with paper. There are studies researching physical match analysis on

other materials including tape, bones, and metal-coated paper but none on standard paper. This study focuses on the uniqueness of tears from hand-torn index cards. One-hundred blank, white index cards were torn in half and matched by a novice using physical match analysis. Following the assumption that all tears are unique, the halves were matched to their respective pairs.

## **Literature Review**

### **Reproducible Study**

Tsach, Wiesner, and Shor (2007) tore 24 samples of metal-coated sheets and 12 samples each of both red and white silicone sheets, using a tensile machine. A tensile machine is a device that uses a controlled force and speed to tear paper, plastic, wood, foils and rubber. The tensile machine was set at a constant force and tearing rate of 100 mm/min. Tsach and colleagues (2007) composed a double-blind test and created 12 samples in both 1 cm and whole length. The researchers then had five experts initially match photographs of the torn halves of both the whole length and 1 cm samples. For the whole length samples, all five experts determined matches using just the photographs. For the 1 cm samples, eight samples were matched from the photographs and the remaining four were matched after examining the original material. This study found that torn materials can be matched given the same tearing conditions. Tsach and colleagues (2007) focused on a study with reproducible results while the following studies tested the physical match methods used in crime labs.

### **Validation Studies**

In the previously study (Tsach et al., 2007), materials were placed in reproducible conditions, but at crime scenes, criminals do not have access to a tinsel machine. These following studies' methods included hand tearing and they were all validation studies. Bradley and colleagues (2006) performed a

validation study on the FBI's methods for end-matching of duct tape. Bradley and colleagues (2006) used three different rolls of duct tape and two different grades (two utility and one industrial grade). The tapes used were representative of the tapes encountered in forensic examinations. The researchers designed five tests varying the roll of tape and mode of separation from the roll. Ten tape strips were either hand-torn or cut with scissors, placed on plastic sheets, and labeled randomly. These 10 strips were then placed in envelopes and called sets, 3 were removed at random, leaving 3 to 6 potential matches. The sets were then sent to experts for matching. Of the hand-torn sets, 92% of the end matches were matched correctly. The remaining end matches were determined to be inconclusive because there was not enough detail to declare a match. There were no mismatches (false positives) for the hand-torn sets. Of the scissor-cut sets, 81% of the end matches were identified. Bradley and colleagues (2006) noted that analysts needed to be cautious when performing end-match analysis on cut tape.

McCabe, Tulleners, Braun, Currie, and Gorecho (2013) build upon the Bradley study but McCabe and colleagues (2013) used different color and grades of tape, and four different modes of separation. The tapes were separated with hands, an Elemendorf tear tester instrument (uses constant force and speed to tear paper), scissors, and a boxcutter knife. Each method of tearing created 1600 pairs total. The tape strips were analyzed by graduate student researchers who were trained to perform tape end-match analysis. McCabe and colleagues (2013) found that the student researchers' accuracy ranged from 98.15% to 100% for hand-torn tape strips and 98.15% to 99.83% for cut tape. Their false-positive rates ranged from 0.00% to 0.67% and false-negative from 0.00% to 2.67% for torn tape. The researchers

stated the following limitations are as follows: the number and type of analysts used, the sample size was not large enough to accurately estimate a small error rate, and the random selection of tape was not representative of the availability of tapes in stores (McCabe et. al., 2013).

Bradley, Guantt, Mehlretter, Lowe, and Wright (2011) performed a validation study on end-matching analysis of vinyl electrical tape. Seven rolls of black, three-quarters inch wide vinyl electrical tapes were used for the study. The tapes were either hand-torn or nicked with a knife and then torn. They were then separated by two different preparers. The researchers created 10 tests varying the roll of tape, mode of separation, and the test preparer. The 10 tests were made into 3 sets which contained either 6 or 7 strips and only 1 to 6 matches. The sets were given to the analysts who were told to determine whether end-matches existed. There were 106 total possible end matches: 98 of the 106 were matched, 8 were found inconclusive, and one was a false positive. The misidentification (false-positive result) error rate was found to be 0.049% (Bradley et. al., 2011).

### **Three-Dimensional Physical Match Evidence**

Physical match research is not just limited to flat objects: there has also been research using bones. Christensen and Sylvester (2008) focused on matching fragments from human bones, nonhuman bones, nonhuman teeth, turtle shells, and mollusk shells. One-hundred fragments were made by deliberately fracturing larger specimen. Only 57 of the fragments were used in the study and were randomly labeled. The matching exercise contained 40 possible matches and six unmatchable fragments. The participants of this study had varying levels of experience and education on osteology and physical matching. They were given fragments and told to find matches; one group was informed about

confirmed matches and a second group was not. The study found that, with no statistical significance, people with more experience performed slightly better on average than those with less or no experience (Christensen & Sylvester, 2008). The correct match rate was 0.925, with an incorrect match rate of 0.001. Christensen and Sylvester (2008) concluded that physical matches are intuitively evident.

### **Importance of Uniqueness**

Jayaprakash (2013) provided cases in support of unique physical patterns from both fingerprint and non-fingerprint evidence. He stated that individualization and uniqueness have been the fundamental tenants of forensic science for over 100 years. He also stated that it is impossible to provide proof that every broken edge in the world is unique; however, the inability to provide statistical proof should not dismiss the individualizations of physical matching as unreliable since physical match evidence is binary, conclusive, and not probabilistic. Jayaprakash (2013) concluded that more research and theoretical support is needed for features to determine individualization.

### **Materials and Methods**

In order to test the uniqueness of tears and fractures, this study used 100 Office Depot® brand 3" x 5" blank, white index cards.. The cards were labeled on the top left and right corners using a numerical and alphabetical key. Each label was randomly assigned and a key was developed. The key was random to ensure that the person performing the matches would focus on the tears and not on the letter on the cards. The cards were then torn in half by hand. The key was used to validate the results from the analyst. The halves were mixed and then placed into a gallon size freezer bag. Six halves were randomly removed leaving 94 halves and a

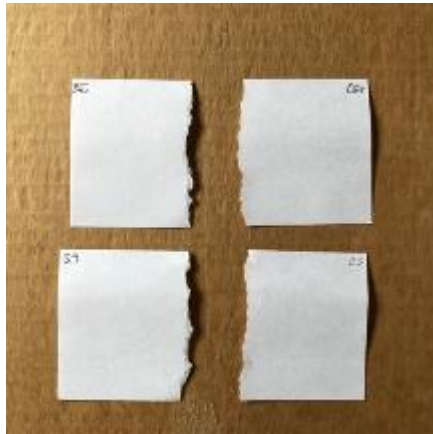


potential for 44-47 matching pairs. The halves were then matched using end-match analysis.

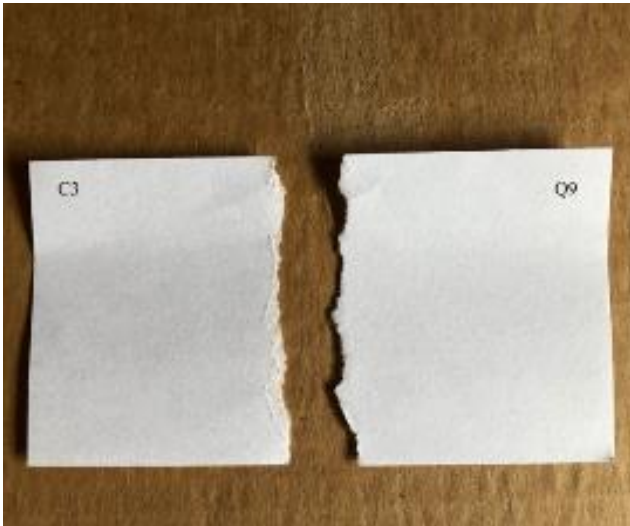
### Data

Using the end-match analysis method, 44 potential matches were identified. All 44 pairs were correctly matched, having a 0 % error rate. The error rate was calculated by dividing the number of incorrect matches by the total potential matches and then multiplying by 100.

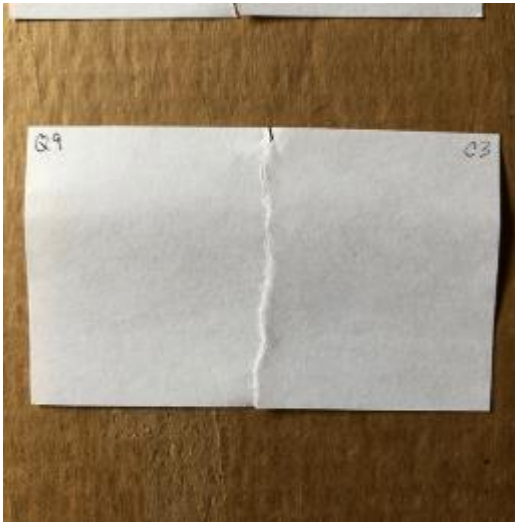
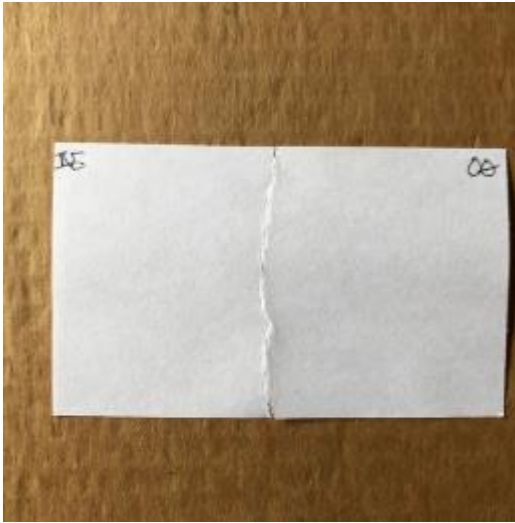
Most of the halves were distinguishable, as shown in Figure 5, but there were some that appeared similar in size and had similar features. Upon closer inspection there were enough features to correctly match each pair. This is shown in Figure 4. The data supports the claim that all tears are unique.



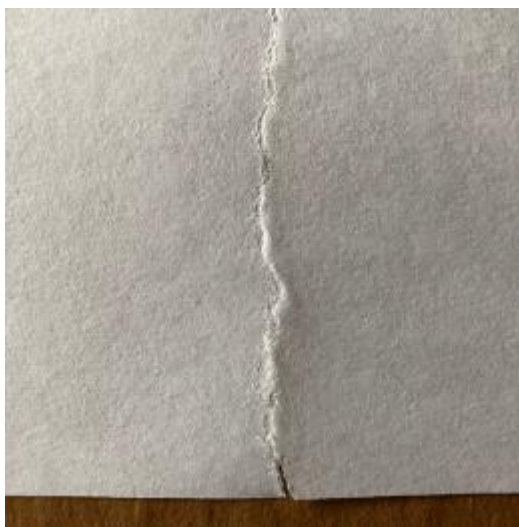
*Figure 1.* Pairs I5-O0 and Q9-C3 had similar tearing patterns.



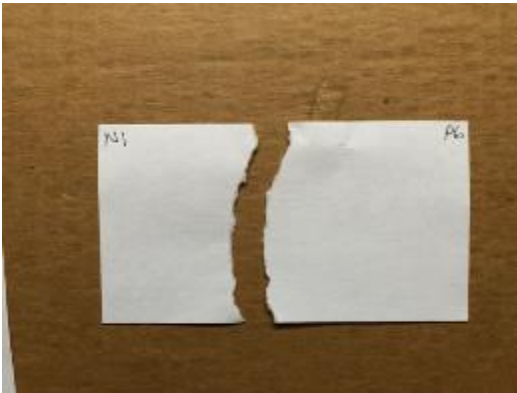
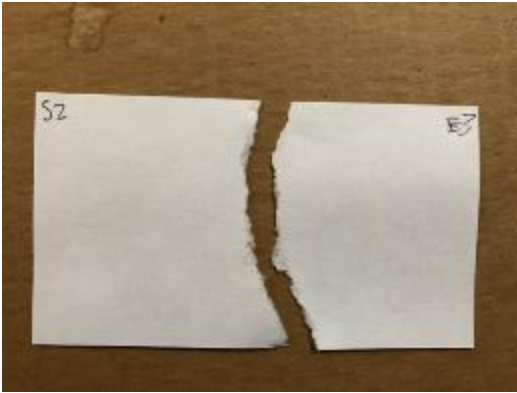
*Figure 2. The backs of pairs I5-00 and Q9-C3.*



*Figure 3. Pairs I5-O0 and Q9-C3 reconstructed.*



*Figure 4. Close-ups of pairs I5-OØ (left) and Q9-C3 (right).*





*Figure 5.* Distinct shapes and features on 4 pairs.

### **Discussion**

Since all halves were correctly matched, the data signifies that there were enough differences in the tears to correctly match each half, supporting the claim that all tears are unique. This claim is generally accepted among physical match experts. Prior to this experiment, a minimal amount of research was conducted to test this generally accepted claim. A novice performed the matching and received a 0% error rate. This signifies that if a novice can match torn paper, so can an expert.

### **Limitations**

One limitation of this study was the way the index cards were labeled. Labeling the cards on the left and right gave the matching analyst additional information on which halves belonged on the left and which halves belonged on the right. This added information took away from the analyst's focus on the tears. For future studies, the cards should be labeled on the top left corner and the bottom right corner but upside down; this will eliminate the added information of knowing which side the half belonged to.

## Conclusion

The claim that all tears and fractures are unique is used by physical match experts. There is limited research on the uniqueness of tears from paper. Many of the studies referenced in this paper found that tears in tape are unique when torn by hand, but they did not analyze paper tears. This experiment supported the claim that all tears in paper are unique. While this research supports the claim, more research is needed to satisfy the Daubert standard.

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*Marilyn Aguilar graduated with her bachelor's degree in Forensic Science with an emphasis in Chemistry from San Jose State University in 2018. She is currently seeking jobs in crime labs and plans on pursuing a master's degree in forensic science or chemistry in the future. In her free time, she enjoys bothering her cat, Socks.*