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# Physical Match: Unique Fracture Patterns in Wooden Popsicle Sticks

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### Abstract

Physical match (or physical fit) evidence was considered reliable in court for years, until the *Daubert* case, which required standardized scientific methodology on all forensic evidence. Physical matching faces the same criticism as other forms of physical evidence (specifically, that it lacks a scientific foundation). Physical matching is based on the idea that when an object is fractured, the shape of each fragment is unique and it is not possible to recreate a fragment that is identical to any other. In this study, fifty wooden popsicle sticks were broken in half, the pieces were mixed, and then reconstructed using physical match analysis. Results of the study show that each broken fragment of the one hundred popsicle stick pieces was unique, which allowed them to be recognized and reconstructed.



### Keywords

physical match evidence, popsicle sticks, daubert standard, forensic methodology

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Physical match (or physical fit) evidence was considered reliable in court for years, until the *Daubert* case, which required standardized scientific methodology on all forensic evidence. Physical matching faces the same criticism as other forms of physical evidence (specifically, that it lacks a scientific foundation). Physical matching is based on the idea that when an object is fractured, the shape of each fragment is unique and it is not possible to recreate a fragment that is identical to any other. In this study, fifty wooden popsicle sticks were broken in half, the pieces were mixed, and then reconstructed using physical match analysis. Results of the study show that each broken fragment of the one hundred popsicle stick pieces was unique, which allowed them to be recognized and reconstructed.

## Introduction

Physical match evidence has long been accepted as evidence in court. Every fragment from broken pieces of paper, glasses, or other materials is unique. Anyone with experience in reconstructing broken objects from daily life could draw this conclusion. This conclusion helps to establish physical match as common knowledge, yet it is far from being a scientific theory supported with evidence. Criticism against the method of physical match analysis for lacking a scientific foundation continues today.

The field of forensic science acknowledges the need to establish a scientific foundation for physical match examination. Researchers have conducted experiments assessing physical match by matching torn edges, reconstructing fragments, and/or examining fractures on several materials. Materials studied include glasses, duct tape, glass polymers, paper, pieces of wood, bones, and teeth. The focus of these studies varies from finding out minimum length required for physical match, simple fragment reconstruction, and error rate of physical match. Despite these varying focuses, all studies on physical match evidence support the theory that fracture condition cannot be reproduced, thus, conclude that each fracture is unique.

Through conducting an experiment by identifying the fracture pattern and matching the fragments to its original state, it is hypothesized that each fracture condition is unique.

## Literature Review

Many within the field of forensic science have attempted to collect data to support the claim that physical matching is a reliable scientific method. Numerous experiments conducted within the past two decades help establish the scientific foundation and reliability of physical matching.


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Tsach, Wiesner, and Shor's experiment (2006) focused on the uniqueness of a tear under measurable and reproducible conditions. Tsach and colleagues used three different materials in the experiment: metal-coated paper, white silicon cast, and red silicon cast. The researchers performed the tearing with a tensile machine (a machine designed for material testing), which provided consistent mechanical force throughout the tearing process at a consistent tearing speed. All 48 sheets were torn in half under the same condition. A total of 96 pieces were compared in a double-blind test so that neither the observing researchers nor the researchers performing the reconstruction knew which two pieces originated from the same sheet. The researchers' hypothesis stated that since each tear was unique, they would be able to match the torn part easily. They also used two different comparison methods. First, they compared the torn parts by examining the original pieces, which are about 8 cm in length. Then, they attempted to match the pieces solely from the photograph of the original pieces, in which the photograph shows only 1 cm of the original pieces. The researchers were unable to match four of the twelve 1-cm comparisons in the photograph analysis condition. Results suggested that there was a minimum length requirement for an observable unique tearing pattern while examining through photographs only; therefore, performing comparisons through photographs alone would be less effective than examining the real fragments.

Bradley and colleagues (2006) prepared five sets of duct tape for analysis. Three sets contained hand-torn duct tape of three different brands and two contained scissor-cut ends; each set contained five duct tape pieces that were torn in half. The researchers gave these sets to four analysts who then performed tape end matching following the Federal Bureau of Investigation

(FBI) laboratory's standard operating procedure. The result of the comparison showed that the analysts successfully matched 46 of the 50 hand-torn samples and 25 of the 31 scissor-cut samples. The researchers noted that no mismatches occurred, but some results were inconclusive due to the failure to find a match. They found that the scissor-cut method was close to a straight line (a 90° angle with the tape) and therefore provided fewer points of comparison between the two pieces, thus increasing the difficulty in matching.

Bradley and colleagues (2011) conducted a follow-up experiment using vinyl electrical tape. The test sets were conducted by tearing the tape and if the tape was too difficult tear by hand then a nick-and-tear approach or tape dispenser was used instead. There were a total of 106 matching ends in the 30 test sets and physical match methods were performed on each of them. Eight of the matching results were inconclusive and one resulted in a mismatch. The researchers suggested that one possible reason for the mismatch could be due to the soft texture of the tapes. Therefore, tearing of those materials could deform or distort the edge, making it impossible to examine the fracture line. The research team suggested a revision of the FBI protocol in tape comparison to address the issue the team had found in the experiment.

The experiments discussed above only consider flat sheets with two-dimensional examinations. However, physical matching is not limited to flat sheets. Tearing is not the only condition to apply a physical matching method; fractured objects such as glass and plastic can also be physically matched. Tulleners, Thornton, and Baca (2010) conducted a physical matching experiment with glass and plastic materials. The experiment used three different materials: double-strength glass


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windowpanes, clear glass wine bottles, and polymer tail light lens covers. A dropping weight or tensile machine was used to fracture the materials. The researchers measured the mass and velocity of the dropping weight to create a consistent shattering force in order to avoid distinctive fractures from stronger or weaker forces applied. They then compared each fracture to other patterns with the same materials to examine if any of the fractures were duplicated. Each material had 60 samples for a total of 1,770 comparisons required. Because there were three materials to compare, a total of 5,310 comparisons were necessary to match all the pieces. Although the researchers note that some similarities were observed, they found that no two fracture patterns were identical among all the samples. The researchers also found that plastic lenses have several similarities, such as the centers breaking completely out of the lens and their tendency to fracture along the mold lines, which can affect the comparisons.

Conversely, an experiment Christensen and Sylvester (2008) conducted focused on the performance of physical matching analysis between experienced and inexperienced individuals. The researchers provided 57 fragments consisting of human bones, non-human bones, non-human teeth, turtle shells, and mollusk shells. Six of the fragments had no corresponding match. There were 96 individuals participating in this physical matching experiment with various education levels ranging from high school educated to forensic scientists with years of experience. Results showed that even those individuals without osteology experience held a high assembly rate, comparable to that of the experienced group. However, those individuals with experience in physical matching assembled the bone fragments in less than 38 minutes, while the inexperienced individuals took an average of 63 minutes for assembly. Only four of the samples were assembled incorrectly by two of the participants. The researchers suggested that, based on this experiment, the ability to perform physical matching analysis had little relation to an individual's education or professional experience.

Jayaprakash (2013) argues that uniqueness has been the paradigm of forensic science practice for over 100 years. The author argues that, while uniqueness was the basis of physical match, physical match was the basis of individualization. However, the author points out one problem with physical match, or even individualization itself, which is that it lacks the use of relevance points as the fingerprint system uses. In other words, it is not possible to quantify the data gathered from a physical matching analysis; 5,000 unique fractures performed under the same condition may not guarantee that the next 5,000 would be unique as well. The author acknowledges recent studies on the minimum area of a fragment for physical matching, yet he points out that more studies are necessary to form a valid argument. He also discusses the lack of statistical methods pertaining to the scientific basis of physical matching to determine whether the results of matching are reliable. Jayaprakash concludes that uniqueness is not fact, but rather a theory that is supported by facts.

## Materials and Methods

In this experiment, 50 Popsicle sticks made up of the same material with similar lengths, shape, and thicknesses were used. An individual was asked to write random numbers, letters or symbols on both ends of all Popsicle sticks. All the marked pairs were recorded by that individual for validation after the experiment. All the Popsicle sticks were broken in half by hand and mixed. Then, all the Popsicle sticks were reconstructed by


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performing physical matching analysis. Two additional Popsicle's sticks were used as a control; they were assembled right after being broken in half. This ensures no deformation of the fragment line during breaking, which would cause the two pairs to be unmatchable.

## Results and Discussion

Reconstruction of all the Popsicle sticks took 133 minutes. The physical matching experiment resulted in no mismatches or inconclusive fragments, indicating that each fragment condition was different, which allowed the author to distinguish one fragment pair from another.

Since breaking of the 50 Popsicle sticks was performed by hand, the force applied to each break varied. One could argue that the difference in fracture lines were due to the inconsistent force applied on the Popsicle sticks. This could result in fragments of ranging lengths, thus reducing the number of possible matches by estimating the combined length of two fragments. Therefore, for future experiments, consistent force provided by a machine could avoid uneven force applied on each Popsicle sticks. During this experiment, the author was aware that each fragment must have a matching counterpart; therefore, random fragments without a matching counterpart should be added to the sample for future experiments.

Figure 1 shows several Popsicle sticks with unique fracture patterns, which the researcher analyzed and physically matched the samples with their other half.

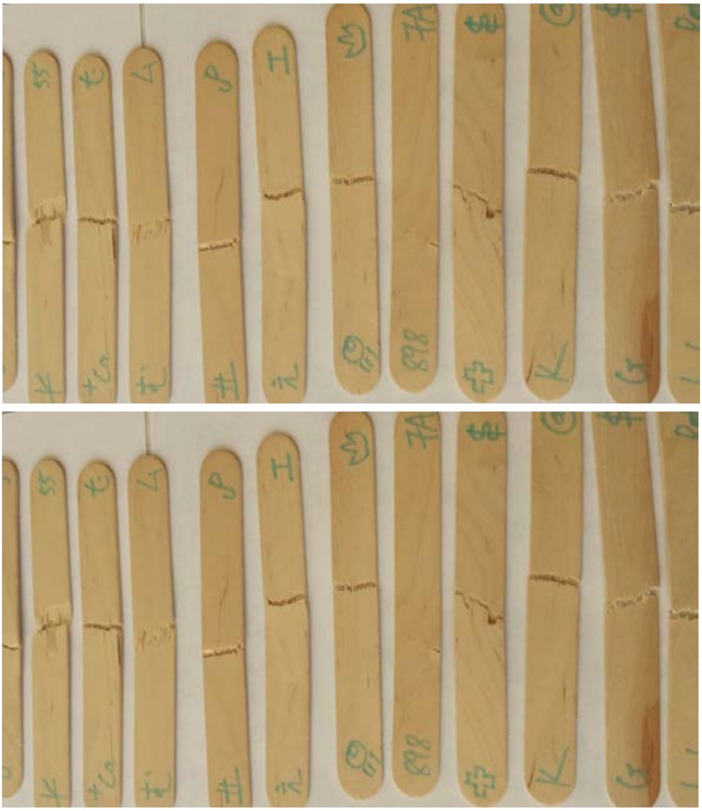

*Figure 1*. Popsicle sticks with unique fracture patterns reconstituted using physical matching

## Conclusion

The physical matching experiment resulted in successful matching of all broken Popsicle pieces, indicating that each fracture was different and, thus, allowed the author to distinguish one fragment pair from another. Although this experiment cannot prove uniqueness of all physical match evidence, it supports the claims that each and every fragment is unique even if the fractured samples are of the same material. Studies


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continue to strengthen the claim that each fracture is irreproducible and unique, supporting physical matching analysis as reliable evidence.

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