

CLASSIFICATION OF TOOLMARK SURFACES ON ZIPPER TEETH

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This study proposes the classification of the toolmark under the heads of zipper teeth as a subclass characteristic as outlined by the Association of Firearm and Toolmark Examiners (AFTE). Two separate cases in which zipper teeth were found at crime scenes prompted this study. Brass zipper teeth manufactured by YKK were taken from 20 pairs of jeans and studied using a Reichert comparison microscope at 4X power. Photographs were taken and over 750 comparisons made. It was found that the toolmarks on each side on the 20 zippers were unique and independent of all other sides. The observations made in this study indicate that classifying zipper teeth toolmarks as a subclass characteristic is valid.

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## CHAPTER 1

### INTRODUCTION

Toolmark examination has been a long-standing and valuable investigative tool used by criminalists. Toolmark identification is a discipline of forensic science, which has as its primary concern to determine if a toolmark was produced by a particular tool (1). A toolmark can be any gouge, cut, abrasion or impression caused by a tool coming in contact with another surface(2). Examiners in the field study firearms as well as many different types of tools. Some of the more common tools seen in a laboratory are chisels, screwdrivers, knives and hammers. Toolmarks are often recovered from evidence found at crime scenes and are an important part of physical evidence.

Toolmark examination has been used since the turn of the century with written documentation found from Europe and South America (2). Pioneer work in the field is credited to Dr. R. Kockel at the University of Leipzig, who first identified the use of striation matching in the 1800's (3). The practice of using a comparison microscope to study striae was found dating to April 1925 (3). The introduction of new techniques, and the perfecting of old techniques, have helped examiners develop better ways of studying toolmark evidence.

The large number of toolmarks encountered in crime laboratories make classification of toolmarks a necessity. Depending on the type of toolmark, different

investigative methods are used for comparison. Toolmarks can be grouped into 2 main types: *impression* marks and *striated* marks (3,4).

*Impression* marks are made when a tool is placed against a surface with enough force applied to the tool to leave a negative image of the tool on the surface. An example of an impression mark is a firing pin hitting a cartridge case. *Striated* marks are the result of a tool moving across a surface leaving microscopic parallel ridges and valleys on the surface. An example of a striated mark is a screwdriver sliding across a surface. Striated marks are due to defects on the tool's face from wear and use. The significance of a toolmark is related directly to the degree of individuality of the edge that made the mark (4). To further describe each toolmark, more descriptive classifications have been developed.

Both impression and striated marks can have class and or individual characteristics (1). Individual characteristics of a tool are irregularities produced incidental to manufacture and/or caused by use, corrosion or damage (1). Class characteristics are measurable features on a specimen, such as size and shape, that are determined prior to manufacture. These characteristics indicate a restricted group source.

An additional classification that increases the specificity of a toolmark is a subclass characteristic. The requirements of a subclass characteristic as described by the Association of Firearm and Toolmark Examiners (AFTE) journal is a discernable surface feature of an object, which is more restrictive than class characteristics in that they are:

1. produced incidental to manufacture
2. significant in that they relate to a smaller group source
3. can arise from a source which changes over time



New and unusual evidence is constantly encountered at a crime scene that broadens an examiner's responsibility. Investigators are now studying a wide range of materials.

Zipper teeth are items that have been discovered at crime scenes and have been used as evidence in criminal cases. The limited number of studies of zipper teeth and the increasing probability of finding a zipper tooth at a crime scene prompted this study. The toolmark used in this study is found under the head of the tooth and is a very small toolmark.

In a reported case, a loose zipper tooth was found at a rape crime scene (5). The investigator was able to use witness marks and match the tooth back to the original place on the victim's jeans. Witness marks are the scratches made by the pull-tab on the side of the tooth. In another case in 1997, a zipper tooth was found in the suspect's vehicle. The side witness marks were also used in this case to match the loose tooth back to the original place on the jeans of the victim. The evidence was used to positively establish that the victim had been in the suspect's vehicle. In both of the cases listed above, the side witness marks were used as toolmarks. Other toolmarks on a zipper tooth can be used to relocate loose teeth back to their original place on a zipper. A manufacturing mark under the head of the zipper tooth is a reliable and constant toolmark that is unique to a manufacturer and can be used to compare individual teeth. By categorizing the toolmark on the zipper tooth, future cases in which a zipper tooth is found may allow the tooth to be admitted as evidence. In this study I show that the manufactured toolmark under the head of a zipper tooth can be used to relocate a loose zipper tooth.

Zipper teeth are manufactured by an automatic zipper chain machine. This machine forms the teeth or elements by a series of cutting and stamping dies (6). This stamping mechanism creates the toolmark under the head of the individual zipper tooth. The method of machine stamping to mass-produce tools can result in duplicate edges (4). With industrialization, countless objects are mass-produced creating new toolmark surfaces. The manufacturing process also produces various accidental surface characteristics that individualize the toolmark (7). The YKK zipper manufacturer uses a manufacturing technique that distinguishes its zippers from those of other manufacturers.

The purpose of this study is to show that the toolmark under the head of a zipper tooth meets conditions of a subclass characteristic. This classification improves the usefulness of zipper tooth evidence in future cases. In order to establish the validity of any type of physical evidence, the courts have created “the Daubert challenge” for the admission of evidence. The Daubert challenge established criteria by which scientific testimony must be evaluated before it may be admitted (12). The four criteria are:

1. Testability of scientific principle
2. Known or potential error rate
3. Peer review and publication
4. General acceptance in a particular scientific community.

These criteria help the courts in deciding the value of novel scientific evidence (1,8). The evidence must pass the criteria in order to be admitted into court as valid and significant to the case; and thus establishing a precedent for future admissibility of this

type of evidence. This study and future studies on zipper teeth should extend the admissibility of zipper tooth toolmarkings according to the Daubert criteria.

## CHAPTER 2

### MATERIALS AND METHODS

The zipper industry along with the American Standard of Testing Materials (ASTM) has developed terminology frequently used in the industry. Standard terminology has also been developed by the forensic community to simplify and regulate the vocabulary used by toolmark examiners. The following terms relate to types of zippers and their components and some commonly used terms defined by the AFTE. Figures follow the definitions.

***Bead-*** an enlarged section on the inner edge of each tape to which interlockable elements are affixed.

***Chain-*** the assemblage formed by interlocking several elements of two stringers.

***Class Characteristics-*** Measurable features of a specimen which indicate a restricted group source. They result in design factors, and are therefore determined prior to manufacture.

***Cord-*** a strand of multiple yarns for use in forming a bead.

***Element-*** a device designed for interlocking, capable of being affixed along the edge of a tape. Also called a *tooth*.

***Head-*** the portion of an element that engages the pocket.

***Individual Characteristics-*** Marks produced by the random imperfections or irregularities of tool surfaces. These random imperfections or irregularities are produced

incidental to manufacture and/or caused by use, corrosion, or damage. They are unique to that tool and distinguish it from all other tools.

***Legs-*** the two portions of a separate element that affix the element to the bead.

***Line-*** a short substitute word for striation describes the visual impression of parallel contour changes as they appear under illumination.

***Pull-*** a part connected to a zipper slider by which the slider is operated.

***Pocket-*** the cavity of an element (on the back) designed to receive the head.

***Slider-*** the part that opens a zipper when it is moved in one direction and closes the zipper when it is moved in the opposite direction.

***Stringer-*** the tape, bead, and element assembly that constitutes one side of a chain.

***Striation-*** contour variations, generally microscopic, on the surface of an object caused by a combination of force and motion where the motion is approximately parallel to the plane being marked.

***Subclass Characteristics-*** discernable surface features of an object which is more restrictive than Class Characteristics in that they are:

- 1) produced incidental to manufacture.
- 2) are significant in that they relate to a smaller group source.
- 3) can arise from a source which changes over time.

***Tape-*** a strip of material along one edge of which the bead and elements are attached.

***Tool-*** an object used to gain mechanical advantage. Also thought of as the harder of two objects which when brought into contact with each other, results in the softer one being marked.

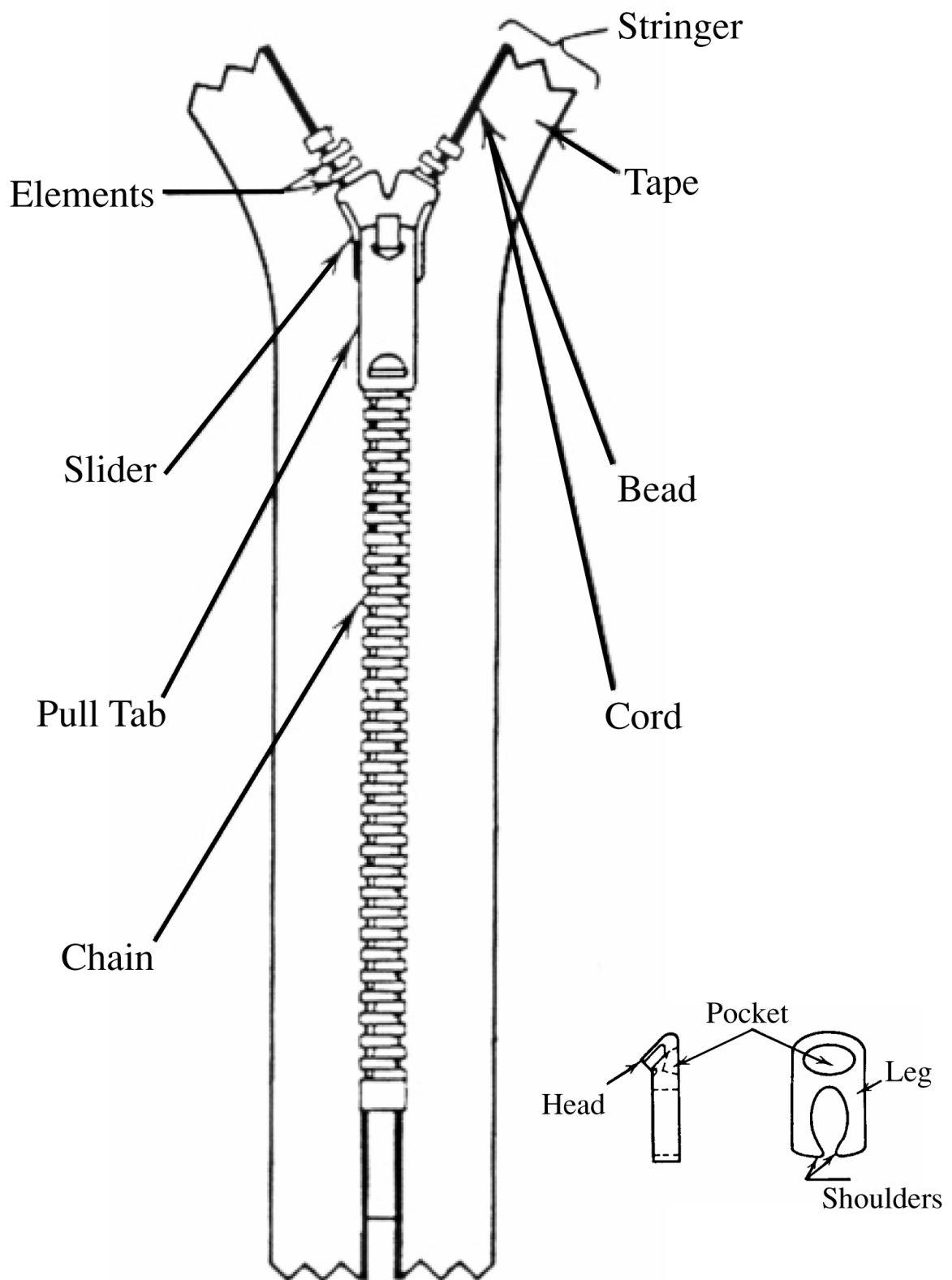


FIG -1 Zipper and labeled parts.

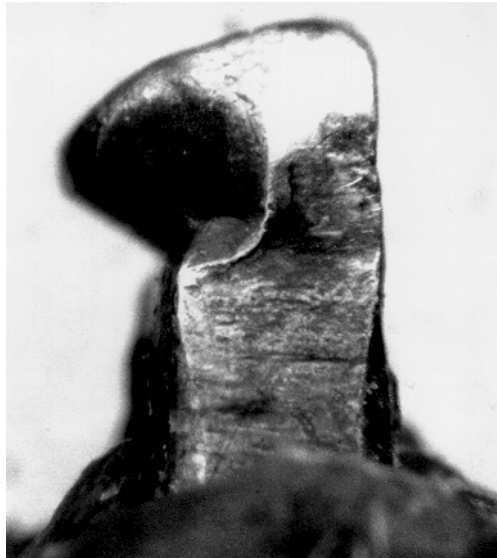


Figure 2 Side view of zipper tooth.

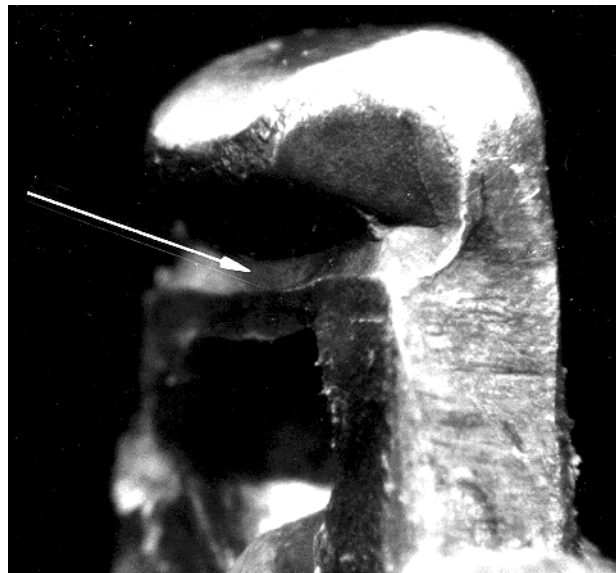


Figure 3 Zipper tooth. Arrow is pointing to toolmark area.

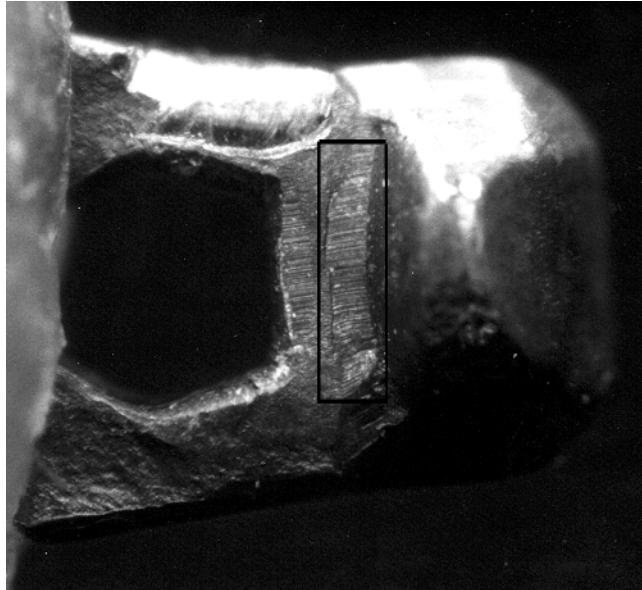


Figure 4 Zipper tooth with toolmark area in box.



YKK was chosen as the manufacturer to be used in this study. YKK is the country's largest manufacturer and supplier of fasteners and YKK also distributes to the majority of jean companies (13). The large number of jeans worn by the population increases the probability of finding jeans linked to a crime scene. Although using one manufacturer limits the study, it rules out possible variables that may arise from mixing manufacturers. Zippers were obtained from the Ideal Fastener Company for comparison of manufacturing techniques. Future studies should be performed on different manufacturers to further classify the toolmarks on the zipper teeth.

The objective of the study is to show that the toolmarks under the head of random zipper teeth from the manufacturer YKK can be classified as a subclass characteristic. The first objective that must be accomplished is determining the individuality of the toolmark. This is accomplished by first matching the toolmark of a tooth on one side of the zipper to another tooth on the same side. To see if the toolmarks are different for other zippers as well, the toolmarks on the first zipper tooth should be compared to toolmarks on other zippers. This shows that the toolmarks are independent of other toolmarks and creating their own class of characteristics. The toolmarks of one manufacturer should be compared to those of another manufacturer to show the difference in manufacturing techniques. Ideal zipper teeth were compared to YKK to show the differences.

The primary equipment used to compare two toolmark surfaces is a comparison microscope. A comparison microscope is a low powered microscope that allows two objects to be compared and viewed together at the same time. A split view allows toolmarks to be aligned and compared for similarities or differences. Depending on the

type of toolmark being studied, an examiner can look for a variety of characteristics. Impression marks and striated marks are two types of toolmarks studied in different ways. The type of toolmarks compared in this study is striated toolmarks made by manufacturing techniques.

Twenty pairs of jeans that were randomly selected with brass YKK zippers were donated by Goodwill Industries. Zippers were all size 45, which is stamped on the back of each pulltab. The type of jeans was recorded, each zipper was removed from the jeans, marked and labeled.

Before the analysis was performed on the sample set of 20 zippers, one zipper was selected for detailed experimentation. To first determine a match or non-match, two consecutive elements from the top of one stringer were removed. To remove the sample elements, first the bead was cut and the cord was removed. All excess fibers between the legs were removed. Each element was mounted on a small piece of paraffin and placed under the comparison microscope. The elements were positioned with the heads to the right and the legs to the left. The toolmarks under the heads of the elements were aligned and focused on 4X power. See Figure -5

The toolmark striations under the heads of the elements have similar patterns. Both of the toolmarks have lines in the same areas that have similar contour and shape, and also match in width. The two toolmarks on the teeth were considered to be a match. Next, an element, located five teeth lower down the stringer from the first element, was removed. The new tooth was compared to the first element. Again, the toolmarks under

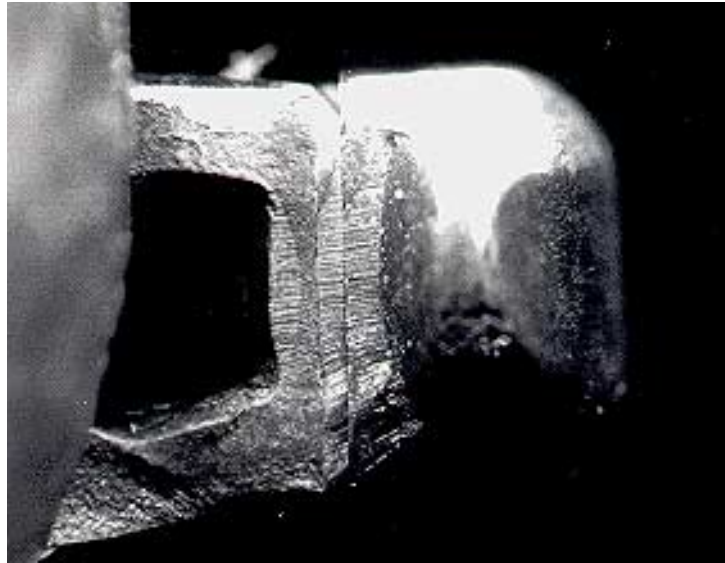


Figure 5 Matching toolmarks from test zipper. Teeth taken from same stringer on one side of zipper.



Figure 6 Nonmatching toolmarks from test zipper. Teeth taken from top of both stringers of the zipper.

the head were aligned and the patterns of the toolmarks had similar shape and contour. The two teeth were determined to be a match. This process was repeated for the length of the stringer, skipping five elements at a time. All elements matched within the side.

The second side of the zipper was also studied in the same manner. Following the same procedure, the toolmarks on the second side of the zipper were also found to have matching toolmarks within the side.

Through this preliminary observation, for the study on the 20 zippers, it was determined that at least two elements from each side of the zipper should be matched. One element from the top of the stringer would be matched to one element near the bottom of the stringer. If the two toolmarks matched, it could be assumed that the toolmarks in between the two elements also matched. If the two toolmarks did not match, teeth closer together should be compared, and it should be noted where the matching toolmarks stopped. Because it was determined the toolmarks matched within each side, one photograph of the upper element per side would be taken for comparison.

To make a comparison between the different sides of the zipper, the zipper tooth from the top of the first side was compared to the top zipper tooth from the second side under the microscope. The toolmarks were aligned and compared. See Figure-6. The toolmarks under the heads of different sides do not match. The lines are different and the contours do not match. Because all the teeth on one side match one another, a conclusion was made that the two sides of the zipper have different manufacturing toolmarks.

For the sample set of twenty jeans, two elements were removed per stringer for a total of 80 elements. The labeling method was devised with the experiment (A), the

zipper number (1-20), and the element number (1-4). Four elements per zipper were removed. The areas from which the elements were removed were kept constant:

Sample #1 removed from side 1- 15<sup>th</sup> element from top

Sample #2 removed from side 1- 55<sup>th</sup> element from top

Sample #3 removed from side 2- 20<sup>th</sup> element from top

Sample #4 removed from side 2- 55<sup>th</sup> element from top

See Figure- 7

This procedure was followed for all jeans except children's, due to the shorter length of the zipper A3 and A15).

A modified removal system was used:

Sample #1 removed from side 1- 10<sup>th</sup> element from top

Sample #2 removed from side 1- 40<sup>th</sup> element from top

Sample #3 removed from side 2- 15<sup>th</sup> element from top

Sample #4 removed from side 2- 40<sup>th</sup> element from top

See Figure-8.

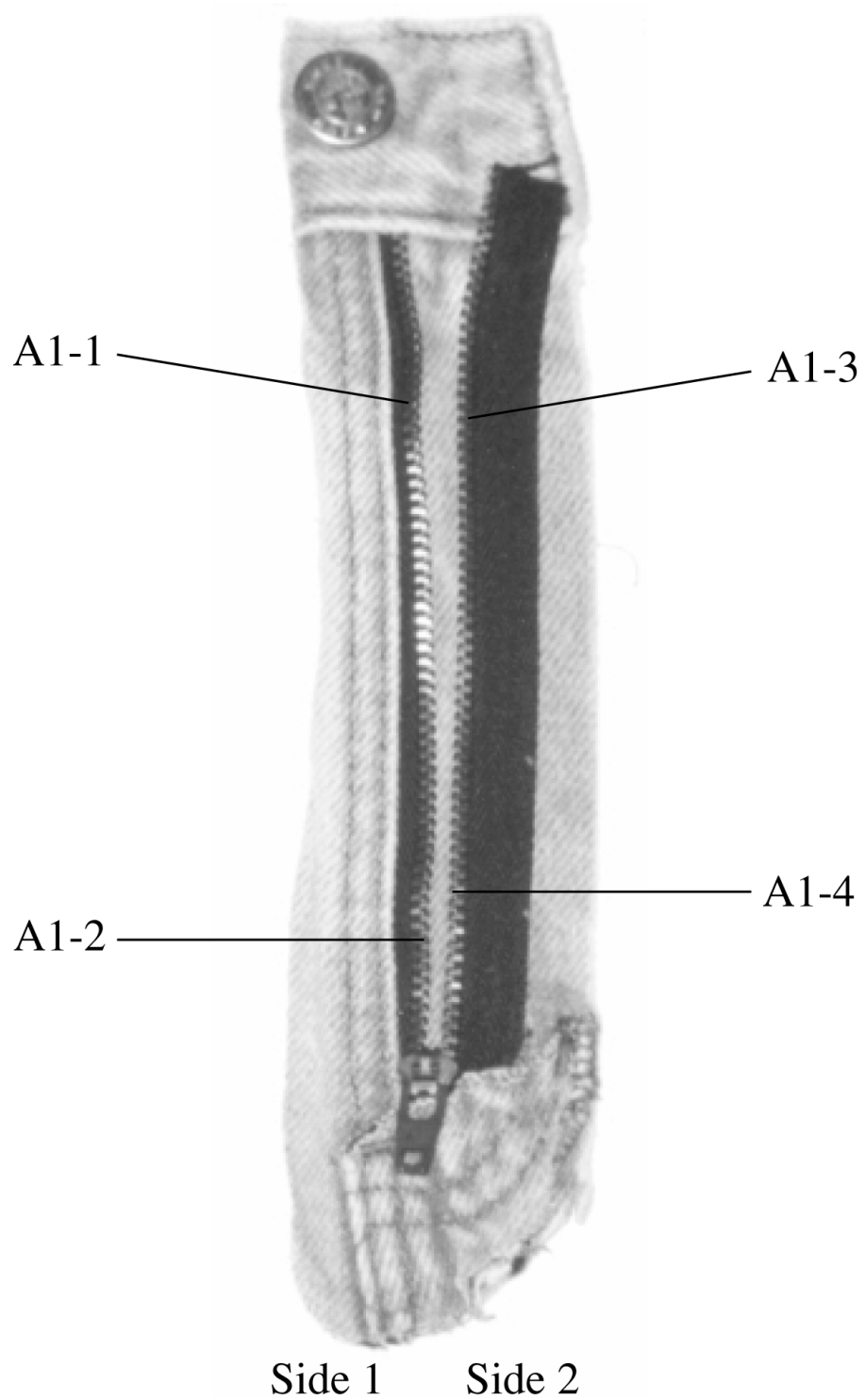


Figure 7 Adult zipper with removal areas noted.

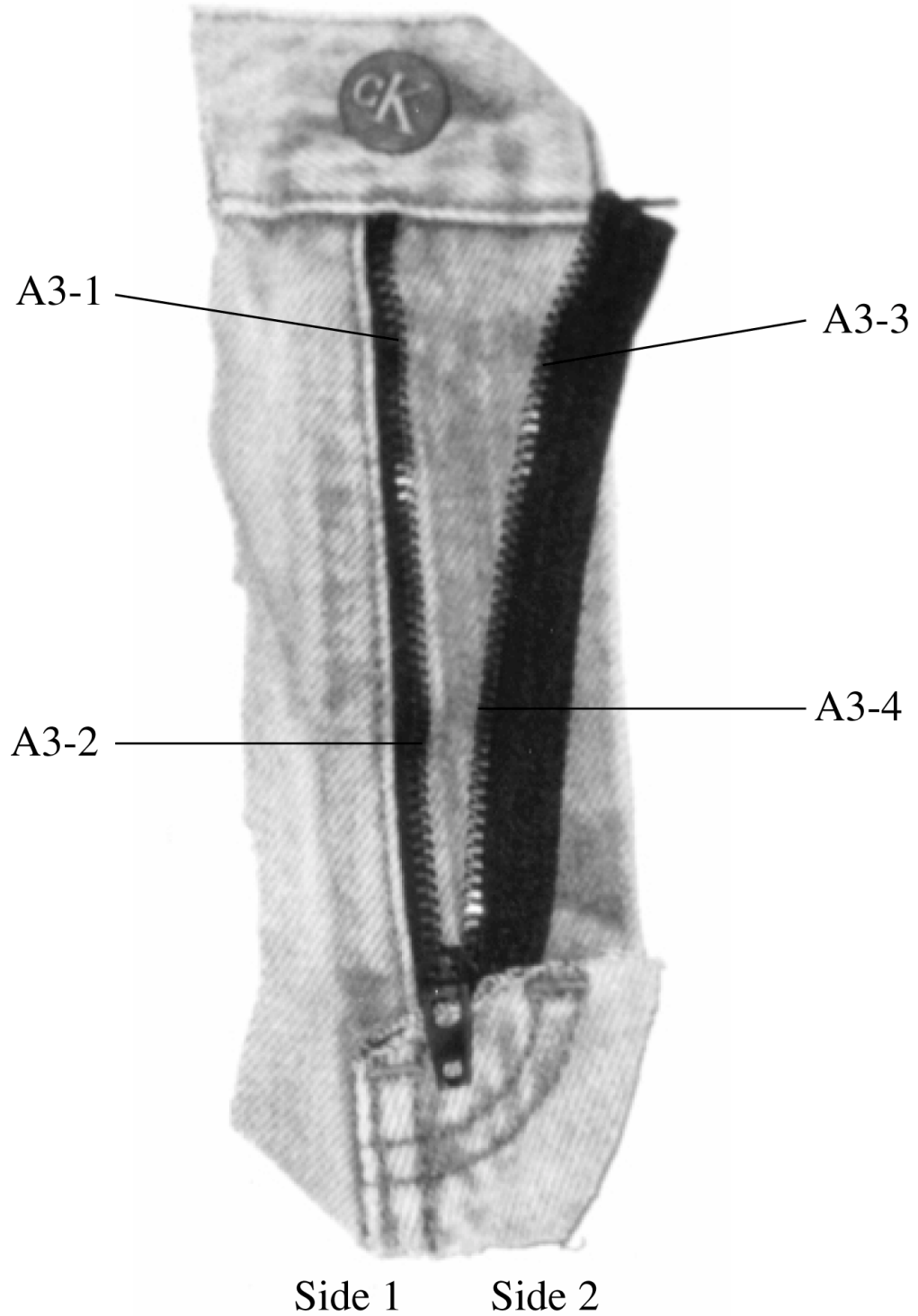


Figure 8 Children's zipper with removal areas noted.

The first two samples, A1-1 and A1-2, were placed under the Reichert comparison microscope in the same manner as the test elements. The microscope was focused on 4X power with a magnification of approximately 39. The toolmarks were aligned and the general appearance of the toolmark and any defects or observations recorded. Once a match was determined, a photograph of element A1-1 was taken. (Polaroid PolaPan 4X5 Instant Sheet Film, Black and White, ISO 400)

The next two samples of the same zipper, A1-3 and A1-4, were examined in the same manner. The toolmarks aligned and observations were recorded. A picture was taken of element A1-3. This procedure was followed for the rest of the zippers in the experiment, for a total of 40 same side comparisons and 40 photographs. To compare each side of each zipper with every other side, the photographs were all compared to each other. Photograph A1-1 was compared to A1-3, next to A2-1, next to A2-3, next to A3-1 and so on, until compared to all 39 photographs. Then A1-3 was compared to A2-1, next to A2-3, until it was matched to all 38 photographs. This allowed all sides to be compared to every other side for a total of 780 comparisons. When two toolmarks looked similar, the two teeth were taken to the microscope and compared.

To show the differences in manufacturing techniques, YKK zipper teeth were compared to another manufacturer, Ideal Fastener Company, (IFC). An IFC tooth was removed from the stringer the same way as the YKK tooth and a photo was taken. See Figure-9. The photo shows that the IFC tooth does not have a manufacture mark under the head where YKK does. See Figure- 10. The missing toolmark on the IFC tooth shows the difference in manufacturing techniques.





Figure 9 IFC zipper tooth. Area in box shows there is no manufactured toolmark.



Figure 10 YKK zipper tooth. Area in box shows manufactured toolmark.

## CHAPTER 3

### RESULTS

The toolmarks under the heads of YKK zipper teeth were found to be unique for each side of the 20 zippers for a total of 40 different toolmarks. The first two toolmarks compared in each set were on teeth from the same stringer. In every zipper the first two toolmarks matched, showing the toolmark was constant for the side of the zipper. When two teeth from the other stringer were compared with each other, they also matched. This again showed the toolmark is constant for the side of the zipper.

The top tooth from one stringer was then compared to the top tooth from the other stringer. These toolmarks did not match. This showed that the zipper had two different toolmarks, one on each stringer. All of the zippers in the sample set of 20 showed the same results when they were compared across the zipper.

The final comparison was between the toolmarks on the teeth from all 20 zippers. Pictures of the top element on each stringer were taken for comparison. The 40 pictures were compared against each other. The toolmarks were all different on all 40 pictures. The results of this comparison showed that the toolmarks were independent of all other sides and were unique for each side of the zipper.

An IFC zipper tooth toolmark and a YKK zipper tooth toolmark were also compared to each other. The IFC zipper tooth did not show the same toolmark as the YKK zipper tooth. This showed the difference in manufacturing techniques, thus

restricting the YKK to a smaller group source and satisfying one of the criteria of a subclass characteristic.

According the AFTE, in order to classify the toolmark on each side of a YKK zipper as a subclass characteristic, three criteria must be met. The AFTE journal describes a subclass characteristic as a discernable surface feature of an object, which is more restrictive than class characteristics in that they are:

- 1) Produced incidental to manufacture.
- 2) Are significant in that they relate to a smaller group source.
- 3) Can arise from a source which changes over time.

First, the toolmarks directly under the head of the element was produced incidental to manufacture. The toolmarks were made by the manufacture, by a machine used to cut the individual elements. This manufacturing technique of stamping rather than pouring the teeth into molds produces a unique toolmark under the head of the zipper tooth. Cutting is accomplished by using a die, which cuts the tooth to specific dimensions from a formed wire fed through the automatic zipper chain machine. Toolmarks made by the cutting process have a greater chance of having individual characteristics, and also typically exhibit striated types of toolmarks (9). It is necessary to understand the manufacturing process used to make the striations to avoid possible misidentification.

The second criterion of a subclass characteristic is that the toolmark is significant that it relates to a smaller group source. There are two ways YKK zipper teeth can be related to a smaller group source. First, a small group of elements were obtained

from the IFC and were compared under the microscope in the same manner as the YKK elements. The IFC elements when viewed under the comparison microscope did not show the same toolmarks as the YKK elements. The IFC element toolmarks were in a different area on the element. This allows the elements manufactured by YKK to be related to a smaller group source. The difference between companies is due to a variety of factors such as copper content of the elements that require a harder or softer wire depending on the machinery. The manufacturing process of the two companies is different in that the same object, a zipper element, can be traced back to a manufacturer by the toolmarks under the head. The second way the elements can be related to a smaller group source is because the manufacturing of the zipper teeth is a stamping technique, the die used to make the teeth becomes dull and worn and must be sharpened. The usual length of a die is approximately 50 hours (6). The die is then taken and sharpened, thus creating a new set of toolmarks on future zipper teeth

The third criterion that must be met is that the characteristic toolmark can rise from a source which changes over time. As stated above, the die used to make the zipper teeth usually lasts 50 hours. The toolmarks made during the 50 hours can vary due to the wearing of the die. The tools accurately repeat themselves with each successive element will nearly be identical until the point that the tooling is worn and must be changed (6). The hardness of the wire and the quality of the tool determine the length of time that the die is used, which is typically between two to four days. When the tool is replaced, the new tool gives the elements their own unique set of characteristics, thus creating a new independent group source.

Due to proprietary reasons of YKK, manufacturing information and production numbers were not available. For statistical analysis, the sample zippers obtained from the IFC are used. The IFC produces 2,000 yards of zippers a day from one machine. The dies are used for approximately 50 hours or 4 eight-hour workdays until they are worn and must be sharpened (6). Of the 8,000 yards produced per toolmark, the result is 48,000 zippers assuming a 6-inch useable zipper. Without the clothing manufacturing distribution information, or the exact wear down time of the die, according to the probability theory, the probability of matching a zipper tooth with another zipper would be 1 in 260,000. The number of zipper manufacturers, their distribution, the jean companies being supplied, and the amount of jeans bought by the public, are factors in figuring the probability of matching loose teeth. Not all information is available concerning the production of zippers.

The results of this study indicate that the toolmarks under the head of zipper teeth manufactured by YKK can be classified as a subclass characteristic. This classification of the toolmark should help in the discrimination of zipper teeth as valid evidence. The large number of jeans worn by the population and the high number of YKK zippers used in jeans, should allow the validity of such evidence in court. Since this is the first study of it's kind, future studies on zipper teeth are needed to extend the data base.

## CHAPTER 4

### DISCUSSION

As a limited study in the area of toolmarks, this study attempts to categorize an unusual piece of evidence, a zipper tooth. By categorizing the toolmark as a subclass characteristic, future cases in which a zipper tooth is found should allow the toolmark to be admitted in court as valid evidence. Twenty randomly selected zippers were used in the study, all from the same manufacturer, YKK. Toolmarks under the head of the teeth were compared within the same side of the zipper, and also across the zipper. The results showed that the toolmark was the same for one side of the zipper, but when compared to the other side they were different. When each side was compared to every other side of the 20 YKK zippers, the toolmarks were all independent of each other. The criteria to classify the toolmarks as unique sub-class characteristics according to the AFTE were also met.

This study focused on the toolmark under the head of the tooth as the matching toolmark. The low number of studies performed on zippers and the appearance of zipper teeth as evidence in forensic labs has indicated a need for more research. Other areas of the tooth can be used to establish individuality of a zipper tooth. Different components such as the side witness markings, may also indicate a restricted group which would enable a loose tooth to be relocated in its original place on a zipper. Future studies on the

side witness markings may show the handedness of the user. Specific wear patterns of the individual can be observed from zipper teeth by studying certain areas of stress placed on the zipper. This may also produce information specific to one person which could be used to trace a pair of jeans back that particular person.

Inevitably, some problems with declaring a match arise, since some matches are less convincing than others (5). Questions may also arise if statistical line counts were needed in the study. The use of statistical line counting to produce factual data has been used by examiners to establish criteria for matching (16). Although line counting has been performed on many toolmark surfaces, the need for line counting to determine a match was not necessary. Even with statistical studies and models, the experience and skill of the examiner is the basis of matching conclusions (1). The basis of objective criteria supports the rule that when comparing the toolmark in questioned with known toolmarks, it is only when agreement is found that exceeds the best known nonmatch agreement that an identification can be made (1). Training and the processing of different types of evidence help examiners to become more secure in addressing questionable matches.

As more information is discovered about zipper teeth, and the more studies completed on different aspects of the zipper, the more the forensic community will come to accept the use of zipper teeth as evidence. Future studies would also validate the toolmarks and the actual zipper itself as evidence by fulfilling the Daubert criteria.

## APPENDIX

### ESTABLISHING CLASSIFICATION OF TOOLMARKS ON ZIPPER TEETH

#### CLASS CHARACTERISTIC:

Measurable feature of a specimen, which indicate a restricted group source.

Result from design factors and is therefore determined prior to manufacture.

*Example of zipper tooth class characteristic:*

1. Size of tooth.
2. Shape of tooth; determined by manufacturer.

#### SUBCLASS CHARACTERISTIC:

Discernable surface features of an object, which are more restrictive than class characteristics in that they are:

1. Produced incidental to manufacture

*Example of zipper tooth:*

Machine stamping method used to cut each tooth.

2. Are significant in that they relate to a smaller group source (a subset of the class in which they belong).

*Example of zipper tooth:*

A. Ideal zippers did not have the same toolmarks.

B. After tool is sharpened, a new toolmark is created.

3. Can arise from a source that changes over time.

*Example of zipper tooth*

As cutting mechanism wears, the toolmark pattern wears and changes..



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