The Physical Fit Analysis of Duct Tapes and its Relevance to Forensic Anthropology

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ABSTRACT

Physical fit analysis is a common occurrence in the trace evidence discipline of forensic science. It can involve materials such as tapes, glass, plastics, textiles, and other polymers. A physical match can demonstrate that at one time two (or more) objects were one single object. This is important for reassociation and identification. While physical fit analyses play a prominent role, there is still a general lack of standardized procedures that are followed across different departments or laboratories. By developing and following a standard order of procedure for duct tape physical fit analysis and implementing it for various sample sets of different fracture mechanisms and material quality, we can demonstrate the validity and reliability of physical fit determinations. The basic principles of this type of analysis are also applicable in the field of forensic anthropology. This connection was explored through a critical literature review, and it was concluded that physical fit analysis is a crucial aspect of skeletal analysis and can aid in the determination of a biological profile, minimum number of individuals, and allow for more complete trauma analysis and other metric analyses.

INTRODUCTION

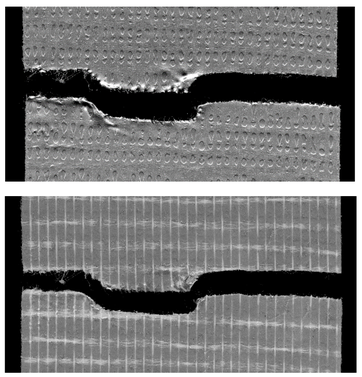
- Forensic science in the broadest sense is the application of science to law and encompasses a variety of subfields, many of which focus on the analysis of physical evidence
- Physical evidence can be examined for identification or comparison purposes; comparison analysis is to ascertain whether the materials or objects originated from the same source
- The principle of divisible matter allows for physical fit analysis or reconstruction efforts
  - "Matter divides into smaller component parts when sufficient force is applied. The component parts will acquire the characteristics created by the process of division itself and retain the physico-chemical properties of the larger piece." (Inman and Rudin 2002)
  - Physical match = "the realignment of two or more objects to prove that they at one time formed a single object"
- Physical fit analysis in trace evidence can involve tapes, glass, fabric, plastics, and other polymers
- In forensic anthropology, physical fit analysis is referred to as reconstruction or refits and involves fragmented bone or teeth
- Recent efforts in forensic science to generate SOPs for physical fit analysis & SWGANTH efforts to create SOPs and other guidelines for skeletal trauma analysis

The aim of this project was to establish and explore the connections between physical fit analysis as it exists in trace evidence and as it exists in forensic anthropology.

MATERIALS AND METHODS

- Physical fit comparisons in duct tape, glass, and plastics were conducted to provide training and experience with physical fit analysis on different materials
- Tape samples of different qualities (high, medium, and low) were used in comparison set and consisted of hand-torn and scissor cut separation methods
- Analyzed the same set in Fall 2019 and Fall 2020 using the same SOP
  - Compared results to examine intra-examiner variability
- To investigate how physical fit analyses were applicable to the field of forensic anthropology, a literature review was conducted
  - Case studies, original research, and review articles were considered
  - Searched for articles that related to "reconstruction," "refits," and skeletal trauma or fractures in general

From left to right: Glass vehicular front headlamp, glass vehicular front headlamp, plastic vehicular taillight. All are exemplar physical matches.



Top: Backing side of duct tape. Bottom: Adhesive side of duct tape. Physical match between two ends of duct tape. Corresponding deformations visible on both edges. Source: Prusinowski et Al 2020.

RESULTS FROM DUCT TAPE PHYSICAL FIT ANALYSIS

- By following the guidelines for examination and analysis, examiners, even with little previous experience with duct tape edge comparisons reported similar edge similarity scores
- Edge similarity scores allowed for a more quantitative analysis – information beyond a simple determination of "match," "non-match," or "inconclusive"
- Fall 2019 and Fall 2020 analyses
  - Same set of duct tape pairs analyzed using our SOP
  - Determine if there was any intra-examiner variation
    - All determinations of match, non-match, and inconclusive were consistent
    - No significant differences in edge similarity scores
- Demonstrated that intra-examiner variation can be decreased through the consistent use of the same SOP

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A complete bibliography is available and is attached at the conclusion of this presentation.

PHYSICAL FIT RELEVANCE TO FORENSIC ANTHROPOLOGY

- Skeletal reconstruction
  - Reassembling skeletal remains can allow for metric analyses, establishing MNI, biological profiles
  - Fragmented or highly damaged remains are commonly encountered in forensic contexts
  - "In confirming a match, the anatomical and physical properties of the match should be given greater consideration than other factors such as color…"
    - Different from trace evidence, as physical color and general appearance plays a large part in physical fit comparisons
    - Cannot be a discriminating factor in forensic anthropology due to factors in the taphonomic process
- Trauma analysis
  - Mechanism (type) of trauma can be recognized by fracture characteristics
  - Need reconstructed skeletal elements in order to see overall pattern of trauma
  - Provides context for trauma interpretation

Cranial reconstruction of the mandible and naso-maxillary complex. Incomplete physical matching between fractured edges of the orbito-zygomatic zone is indicated by the red arrows. Source: Jayaprakash et Al. 2017.

Reconstruction of a tibia (left) and cranium (right). Incomplete physical matching between cranial bones is visible. Elements are held together by adhesive strips which are easily removable as to ensure reconstruction is reversible. Source: Christensen et Al. 2014

CASE STUDY: Burned Human Remains in a Double Homicide in Nicosia, Cyprus

- August 3, 2006, investigators initially responded to a fatal stabbing incident in Nicosia, Cyprus
- The investigators quickly located the suspected perpetrator and discovered that his wife was also missing
  - Physical evidence at the initial stabbing scene had indicated a double homicide was likely – suspect suspect was linked to his wife's disappearance BUT the wife's body was not found at the initial scene
  - During questioning, the suspect confessed to both murders
- Indicated that the wife's body had been taken to a secondary location and that her remains were burned in a metal barrel using accelerant
- After learning the location, investigators search that area and **recovered burn "bone-like" material** from one of the barrels.
  - Samples were submitted for genetic testing, but these tests yielded no DNA.
- **A state forensic anthropologist was asked to join the case to determine if the remains were human, if any cut marks were discernible, and if the biological profile was consistent with that of the missing woman**
- The anthropologist initially analyzed the **290 bone fragments and 4 tooth fragments** collected by the investigators had recovered
  - Determined that they were human and that reassociation and reconstruction, through **physical matching** was possible
- After conducting physical fit analysis, the **minimum number of individuals (MNI), a basic biological profile, a more complete view of burn patterns,** and **trauma analysis with context** were determined
  - Reconstruction revealed several skeletal elements were completely absent; anthropologist returned to the secondary location with a team to systematically search the area
  - Recovered and **additional 677 bone fragments;** combined with the initially examined fragments and reanalyzed as a single group
- Continued physical fit comparisons led to the discovery of more elements and supported the initial interpretations of trauma, thermal damage, and the biological profile
- No positive identification due to lack of individualizing traits or genetic information, BUT as the biological profile of the remains were consistent with that of the missing woman, the suspect was still tried and charged with the manslaughter of his wife
- Without reconstructing the bone fragments with physical fit comparisons, this outcome would not have been possible. **The physical fit analysis of skeletal remains can provide a significant amount of information and context for further interpretations.**

Occipital bone fragments after reconstruction during initial stage of analysis. Source: Chrysostomou 2015.

Distortion fracture consistent with muscle contraction due to thermally related pugilistic stance at insertion site. Two separate bone fragments that are a physical match. Source: Chrysostomou 2015.

Thermally related fractures and abnormal semicircular fracture visible near the distal end of the humerus. Three separate bone fragments that are a physical match. Source: Chrysostomou 2015.

CONCLUSIONS, DISCUSSION, and FUTURE WORK

- Formation of the Scientific Working Group for Forensic Anthropology (SWGANTH) in 2008 characterizes the current push for the formulation and codification of standard practices
- NIST OSAC subcommittee dedicated to forensic anthropology
  - Tasked with the development of SOPs for the field
  - "Standard for Analyzing and Reporting Skeletal Trauma in Forensic Anthropology" is currently in development
- Since physical fit analysis, through reconstruction and "refits," is a major aspect of forensic anthropological interpretations, it is crucial that we work towards generating a SOP that can be used consistently between different examiners and agencies
- Forensic anthropology would benefit significantly from research dedicated to validation and more quantitative methods for conducting physical fit comparisons on skeletal fragments