TECHNICAL NOTE

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A Method for Mathematically Documenting Bitemarks

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ABSTRACT: A method for describing and documenting bitemarks is presented in which the patterned injury from each arch is broken down into its constituent marks. The centroid of each mark is determined and used as a point to define the mark. Lines are used to connect each point around the arch. The length of each line is recorded and the angle formed between each pair of adjacent lines is also recorded. The ordered set of line lengths and angles is used to describe the bitemark. This format lends itself to computer storage, manipulation, and comparison.

KEYWORDS: forensic science, forensic odontology, bitemarks, computers

At present bitemark analysis is a blend of both art and science. No schema currently exists for classifying, storing and retrieving information about specific bitemarks or for comparing one bitemark with another. Forensic odontologists have been working for some time to classify or explain bitemarks in mathematical terms. This paper is one such effort. The proposed method will allow forensic odontologists to begin to describe the number of dentitions from a defined population of biters that might fit a specific bitemark and provide a known margin of error. The method will also lend itself nicely to the establishment of a repository of mathematical information.

A bitemark represents the forceful application of teeth to a surface capable of being deformed. The deformation may result in injury to skin or physical change in substances such as foodstuffs. Many factors determine how teeth will mark human skin, and forensic dentists have analyzed bitemarks in a number of inanimate substances. Once a bitemark has been correctly photographically documented, its characteristics can be accurately measured and recorded. Generally speaking, bitemarks exhibit more uniqueness as the number of marks attributable to teeth increases.

The typical bitemark on skin reflects the cross-sectional shape of several teeth which forms an arch. The cross-sectional shape of each individual tooth marking is usually rectangular or triangular in outline. In skin, the definition of an individual mark is primarily dependent upon the depth to which that individual tooth penetrates the normal plane of the skin. Due to the nature of soft tissue and its response to injurious force, these rectangular and triangular-shaped tooth marks acquire rounded angles and corners so that all of them usually take on a generally oval appearance.

Although teeth are dimensionally stable, the corresponding cross-sectional plane of the injuring tooth or an exemplar fabricated from it will of course be more linear and have sculpted landmarks. Teeth can exhibit wear, but the wearing of teeth is a gradual process. Teeth are brittle and can fracture when exposed to extremes of force. A fractured tooth will mark differently than an intact tooth. Although a freshly fractured tooth may demonstrate a different marking pattern, it too will continue to wear after the fracture. Sharp points and edges will round off quickly, but in most cases wear remains consistent across any area of interest in a dental arch.

Method

Using these facts, each individual tooth marking in a bitemark or the tooth itself (or its exemplar) can be approximated by a circle whose center is coincident with the centroid (geometric center) of the tooth or tooth marking. The human eye has been shown to be quite adept at locating the centroid (1). Additionally, imaging software may also be used to locate the centroid of a mark. Figure 1 shows a marking with its centroid.

Using this principle, bitemark injury patterns observed in a photograph inflicted by the maxillary or mandibular teeth can be expressed as a collection of points. Each of these points is the centroid of an individual tooth marking. The marks can be placed on a grid. The centroids can be plotted with their associated X and Y coordinates.

Once the centroids have been plotted for each mark, attention is turned to the complete maxillary or mandibular pattern. Starting with an endmost centroid, the centroid points are connected to each other by lines. The length of each connecting line is recorded. Lengths are calculated by taking the square root of the sum of the squares of the differences of the X and Y coordinates of two points.

The lines connecting the centroid pairs are now studied and are inspected sequentially. Again, starting at the endmost line, the angle between each pair of lines is recorded. The slopes of lengths are used to calculate the angle between the lines. The slope is defined as the difference in the Y values of the end points of a line divided by the difference of the X values. Angles are calculated by finding the angle whose tangent is the dividend of the difference of the slopes of the two lines divided by one plus their product. Angles are converted to degrees by multiplying by 180 divided by pi. Computer software is available to determine these values and,

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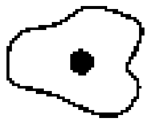

FIG. 1—*The centroid of an irregular shape.*

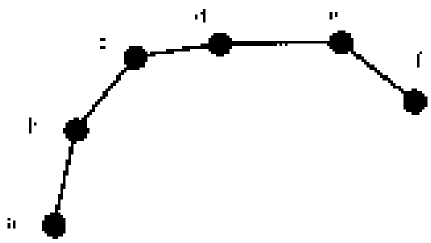

FIG. 2—*The six points (centroids) that define the ordered set of five lengths and four angles representing a bitemark.*

since only the absolute value of the difference is required, alignment to any particular baseline is not critical. As shown in Fig. 2, a maxillary or mandibular injury pattern composed of six tooth markings can be identified by five lengths and four angles.

The teeth of the suspect dentition represented by a stone dental model can similarly be expressed as points either by scanning or photocopying the models, or by producing test bites in wax or other suitable substrates. The same calculations will produce a similarly ordered set of line lengths and angles from the teeth.

Discussion

To aid in comparisons, the first point studied in the bitemark should be the most counterclockwise point and subsequent points studied in a clockwise manner. Similarly, the bite exemplars are also studied from the most counterclockwise point and the subsequent points taken in the clockwise direction.

Should models of the teeth or scans produced directly from the models be used for the comparison, they must be viewed as the mirror images of the bitemarks they produce. In this method of analysis, the most clockwise point should be used first, with subsequent points studied in a counterclockwise manner.

The lengths and angles yield certain information about the bite being studied. Large lengths may indicate large teeth, or at times they may represent greater than normal interdental spacing, indicating perhaps missing teeth or teeth sufficiently removed from the horizontal plane of the bitemark to preclude marking. Short lengths indicate small teeth or overlapping of the teeth.

Angles between pairs of posterior teeth and between pairs of incisors would be expected to approach 180 deg (a straight line) in a well-aligned dentition. The most acute angles in a well-aligned dentition would be expected to be associated with teeth paired with their adjacent canines. A well-aligned dentition would be expected to exhibit symmetry of cross-arch pairs of lengths and angles. In a normal dentition the angles taken from the starting centroid would be expected to indicate progressive curvature in the same direction. Abrupt changes in the measurement of adjacent angles indicate a malaligned tooth or tooth segment.

In a bitemark or in the dental arch being compared, angles generated by the above method will all have a positive sign if the vertex of the angle faces away from the midline. At times the vertex of one or more angles may point toward the midline, in which case the angle is given a negative sign. Negative angles denote abrupt changes in the general curvature of a bitemark and are distinctive features. Teeth associated with negative angles are displaced from their expected positions in a normal dentition.

In each arch the bitemark or bite exemplar can be defined by an ordered set of numbers representing $n - 1$ (n minus one) lengths and by $n - 2$ (n minus two) angles as seen clockwise. Similarly, the marking teeth can also be represented by an ordered set of lengths and angles. Under perfect conditions the suspect dentition and the bitemark would have the same ordered set of lengths and angles. The authors propose that in any dentitions offered for comparison purposes, that the true biter would display close concordance in ordered sets of lengths and angles for the involved teeth.

Computers can be used to display bitemark graphics, calculate centroids, store information associated with each bitemark and dentition in a database, perform the necessary calculations to determine each length and angle, and rank the likely matches between bitemarks and suspected dentitions. The use of the computer for such tasks will put to rest any claims of bias or subjective error being introduced into the process. At the present time the authors are proposing this method only for clearly defined, ''cookie cutter'' types of bitemarks. The possible difficulties that might be encountered in applying this method to highly angled, or raking types of bites, have not been studied.

This simple, straightforward procedure can be easily demonstrated and understood by all parties in a bitemark case. A repository of unknown bites can be established. The models of suspected biters and models of other individuals can be entered to increase the reliability of the database.

Reference

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