TECHNICAL NOTE

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Computer-Based Production of Bite Mark Comparison Overlays*

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ABSTRACT: Bite mark comparison protocols include measurement and analysis of the pattern, size, and shape of teeth against similar characteristics observed in an injury on skin or a mark on an object. The physical comparison of tooth position often depends upon transparent acetate overlays to detect similarities or differences between the teeth and the bite mark. Several methods are used to produce life-sized comparison overlays. The perimeter of the biting edges of the anterior teeth are usually recorded to produce facsimile images called *hollow volume overlays.* Some investigators hand-trace these outlines from dental study casts, or from bite exemplars produced in wax, styrofoam, or similar materials. Some use hand-traced outlines from xerographic images produced with office photocopiers that are calibrated to produce life-sized final images. Others use radiographic images and toneline photography of wax exemplars filled with radio-opaque materials, such as metal filings or barium sulfate. Dependence upon subjective input by the odontologist to trace these images manually is considered problematic. This is because the errors incorporated at any production stage are increased in the final product. The authors have developed a method to generate accurate hollow volume overlays using computer-based techniques. A PowerPC Macintosh computer, flatbed scanner, and Adobe Photoshop (a popular graphical interface application) are used to acquire, select, arrange and export detailed data from class and individual characteristics of a suspect's teeth to acetate film loaded in a high-resolution laser printer. This paper describes this technique to enable the odontologist to produce high-quality, accurate comparison overlays without subjective input.

KEYWORDS: forensic science, forensic odontology, human bite mark, bite mark analysis, comparison overlays, computers, Adobe Photoshop

Bite mark evidence found on skin or objects is of considerable forensic importance. Bite marks on a conscious, unconscious or deceased victim may provide crucial evidence in a criminal investigation (1). Through analysis of this evidence it may be determined that the suspect was at the crime scene and in violent contact with the victim. Bite marks are most frequently observed in homicides, sexual assaults, and domestic violence cases (2). Usually the perpetrator of a violent crime bites the victim. Occasionally, the victim bites the perpetrator in self-defense. Bite mark physical evidence may be highly significant in that it may closely reproduce the characteristics of the biter's teeth. This evidence may be crucial to identify a suspect in a crime, or to exclude an innocent person.

The foundation of bite mark analysis lies in the following premises: (a) each individual's dentition is presumed to be unique, and (b) this presumed uniqueness is accurately recorded in the characteristics of the injury on the skin or object. Consequently, bite mark evidence has become legally accepted and admissible in courts of law (3). Numerous cases have involved bite mark evidence in criminal proceedings (4). Recently, criticism of bite mark evidence as a reliable scientific tool has been expressed due to the subjective nature of the comparative analysis (5,6). Many questions arise about the establishment of guilt beyond a reasonable doubt, and how much weight should be given to this evidence in court proceedings.

Common analysis methods include comparing the pattern, size, and shapes of the suspect's teeth with the unknown bite mark using transparent comparison overlays (7). Several methods which are wide utilized by odontologists exist to produce these overlays (8–11). However, each of these methods involves some degree of subjective input by the odontologist. This may lead to significant errors being incorporated into the overlays which may make it difficult to reach a valid conclusion (12). Additionally, there are often limitations to the use of bite mark evidence. Bite marks on skin may be ill-defined due to bruising or substrate curvature (13). Inaccurate reproductions of the tooth markings may be present due to tissue distortion (14). Healing in the living victim or postmortem changes in the deceased victim may subject the injury to color changes over time (15). Compounded errors may result in substantial difficulties in reaching conclusions with a high degree of confidence.

The authors propose a computer-based technique for the production of life-sized bite mark comparison overlays. This method allows accurate and objective selection of the biting surfaces of a suspect's teeth from dental study casts. Images of the teeth of interest can then be exported to a transparent acetate film. Comparison overlays produced by this method are referred to as *hollow volume overlays* since they record the perimeter of each tooth's biting edge, leaving the inner aspect of the tooth blank. A study by Sweet and Bowers (16) determined that this method was the most accurate when compared to other commonly used methods.

Materials and Methods

Computer hardware used in this technique includes a PowerPC Macintosh 8500/120 MHz CPU with 96 mB RAM (Apple Computer Inc., Cupertino, CA), PowerShop PCI graphics accelerator

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card (Adaptive Solutions Inc., Beaverton, OR), 17-in. color monitor (Apple Computer Inc., Cupertino, CA), H-P ScanJet 4c flatbed scanner (Hewlett-Packard Co., Palo Alto, CA), and Apple LaserWriter 4/600PS high-resolution printer (Apple Computer Inc., Cupertino, CA). Acquisition of digital images of dental study casts, selection of the biting edges and production of overlays are completed with Adobe Photoshop v 3.0.5 image-editing software (Adobe Systems Inc., Mountain View, CA). Personal computers running Photoshop with Windows-95 (Microsoft Corp., Redmond, WA) provide a similar graphical interface as that described below for Macintosh computer platforms.

Study casts are fabricated from accurate upper and lower dental impressions of the suspect. These casts are placed on the scanner with the biting edges contacting the glass platen. An ABFO No. 2 scale (Lightning Powder Co. Inc., Salem, OR) is placed at the left side of the casts to establish left-right laterality and ensure life-sized reproduction.

The biting edges of the teeth are not always at the same height or in the same plane. Therefore, not all of the teeth of interest (usually anterior teeth) contact the glass platen of the scanner. The study casts should be positioned so the maximum number of teeth possible touch the scanner interface. Tests to evaluate the accuracy of resulting digital reproductions of teeth which do not contact the scanner interface determined that a tooth may be $\leq$5.5 mm from the glass and introduce no significant error (data not shown).

The image is acquired using the TWAIN interface of the Photoshop application. This opens the scanning application and allows the image to be imported directly to Photoshop. Tool palate parameters are adjusted to the following values: Brightness 125 and Contrast 118. Image Type is set to sharp black-and-white photo. A grayscale digital image of the biting edges of the dental casts and the ABFO No. 2 scale is produced (see Fig. 1). This can be saved to the hard drive in one of several file formats (PICT, JPEG, TIFF, etc.) depending upon final output or transmission requirements.

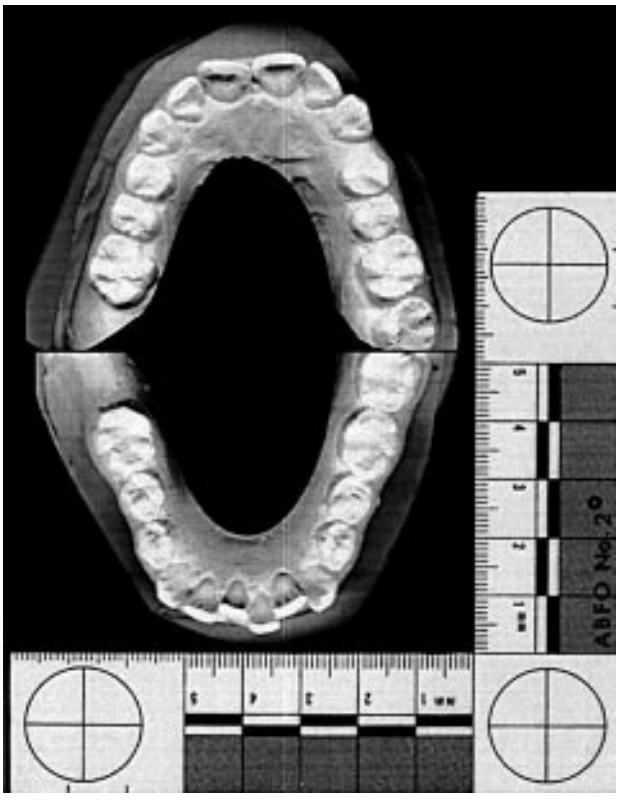

FIG. 1—*Grayscale digital image dental study casts and the ABFO No. 2 reference scale which provides a left laterality marker.*

Within Photoshop, an additional layer is produced over the background image. From the ''Windows'' menu, find ''Palettes'' and select ''Show Layers'' (see Fig. 2). Save the new layer as Overlay. Either layer can be made active or inactive, or objects can be moved between them by clicking the selection with the cursor.

The biting edges of the teeth of interest are objectively selected using the Magic Wand Tool (see Fig. 3). The program selects portions of an image based on similarities of adjacent pixel values. The wand tool is positioned over the tooth's biting edge and the mouse button is depressed. Photoshop selects an area with a color value similar to the pixel that is under the cursor (default tolerance value = 18). The biting edges of consecutive teeth are selected by depressing the Shift key while moving the cursor from tooth to tooth.

Using the Copy and Paste commands from the Edit menu, remove the selected images from the background layer and place them in the Overlay layer. The selection remains active in the new layer. Using the Stroke command from the Edit menu, a 2-pixel-wide line can be added to the perimeter of the selected teeth. A hollow volume is produced using the Fill command from the Edit menu to produce a clear center within the perimeter line. The image of the ABFO No. 2 scale is Selected, Copied and Pasted into the Overlay layer to show laterality and verify dimensional accuracy (see Fig. 4).

Labels are added using the Text tool to illustrate such things as: (*a*) left-right laterality, (*b*) individual tooth numbers, (*c*) case numbers, or (*d*) suspect name. This image is printed on transparency film (3M Visual Systems Division, Austin, TX) using a high-resolution printer such as the Apple LaserWriter 4/600PS (Apple Computer Inc., Cupertino, CA) (see Fig. 5).

Results

The final product of the technique described is presented in Fig. 5. The hollow volume images of the teeth are accurately reproduced and left-right laterality is indicated. The comparison overlay is printed at 100% and the reference scale can be used to verify this. The perimeter of the individual biting edges has been outlined with a 2-pixel wide black line. The overlay can be utilized for a pattern association comparison of the suspect's dentition to life-sized photographic evidence of the bite mark.

Discussion

The most common methods to produce bite mark comparison overlays involve subjective input by the examiner, usually in the form of hand-tracing the biting edges of the teeth of interest (16). The technique described here eliminates this controversial premise in favor of a much more objective, accurate overlay production method.

The application of computer technology to this aspect of forensic physical comparison is seen as an advantage for various reasons. Significantly, registering the shapes and sizes of a suspect's dentition from digital images of dental study casts is more accurate than other techniques. In addition, the technique is rapid and highly reproducible. Disadvantages of this method include the relatively high cost of fast and powerful computer hardware and the need for the examiner to possess at least a moderate level of computer literacy. However, the Macintosh platform is user-friendly and the technique is simple and straightforward.

The authors have used this computer-based overlay technique

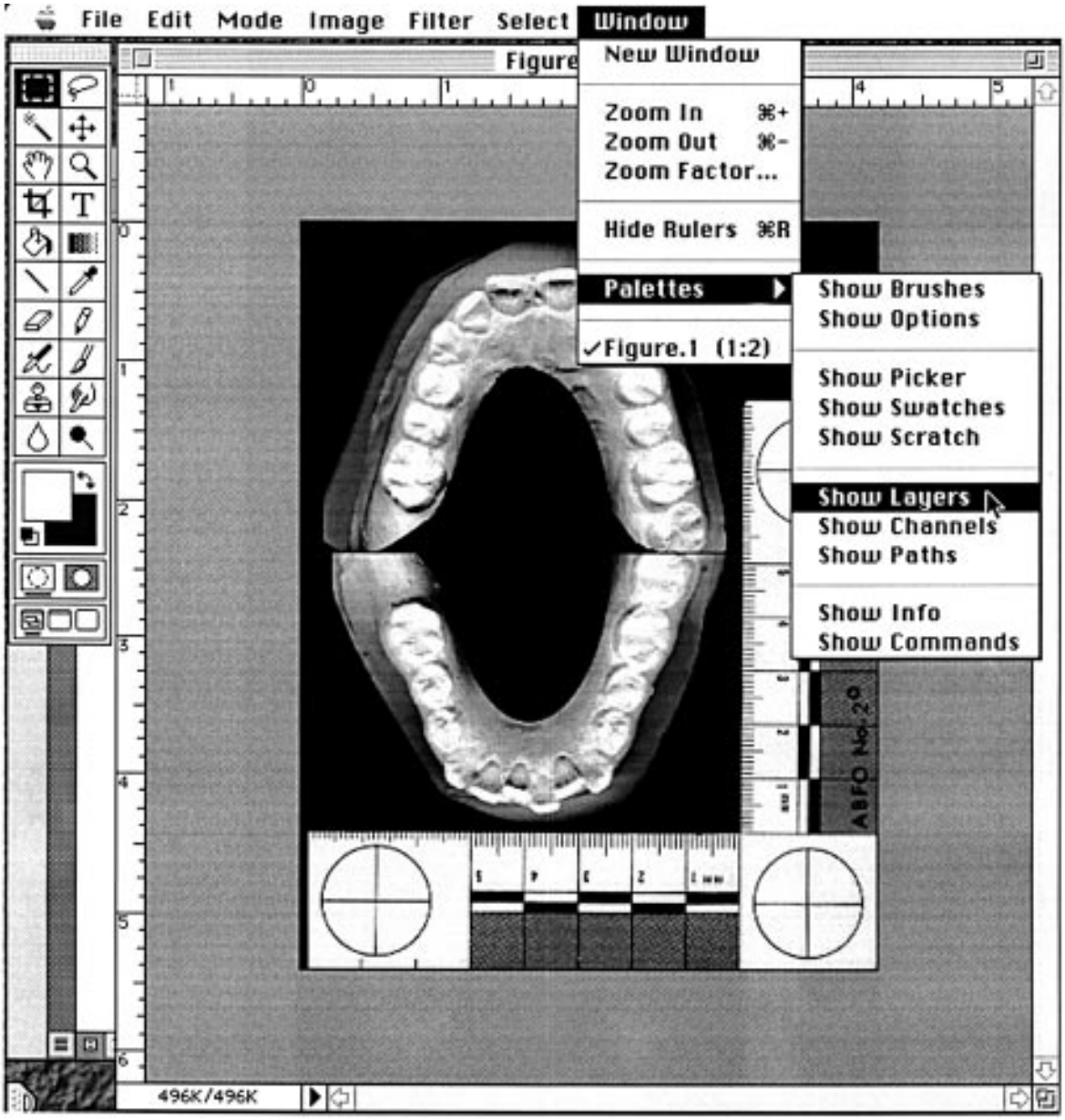

FIG. 2—*An additional layer is produced over the original digital image of the dental study casts.*

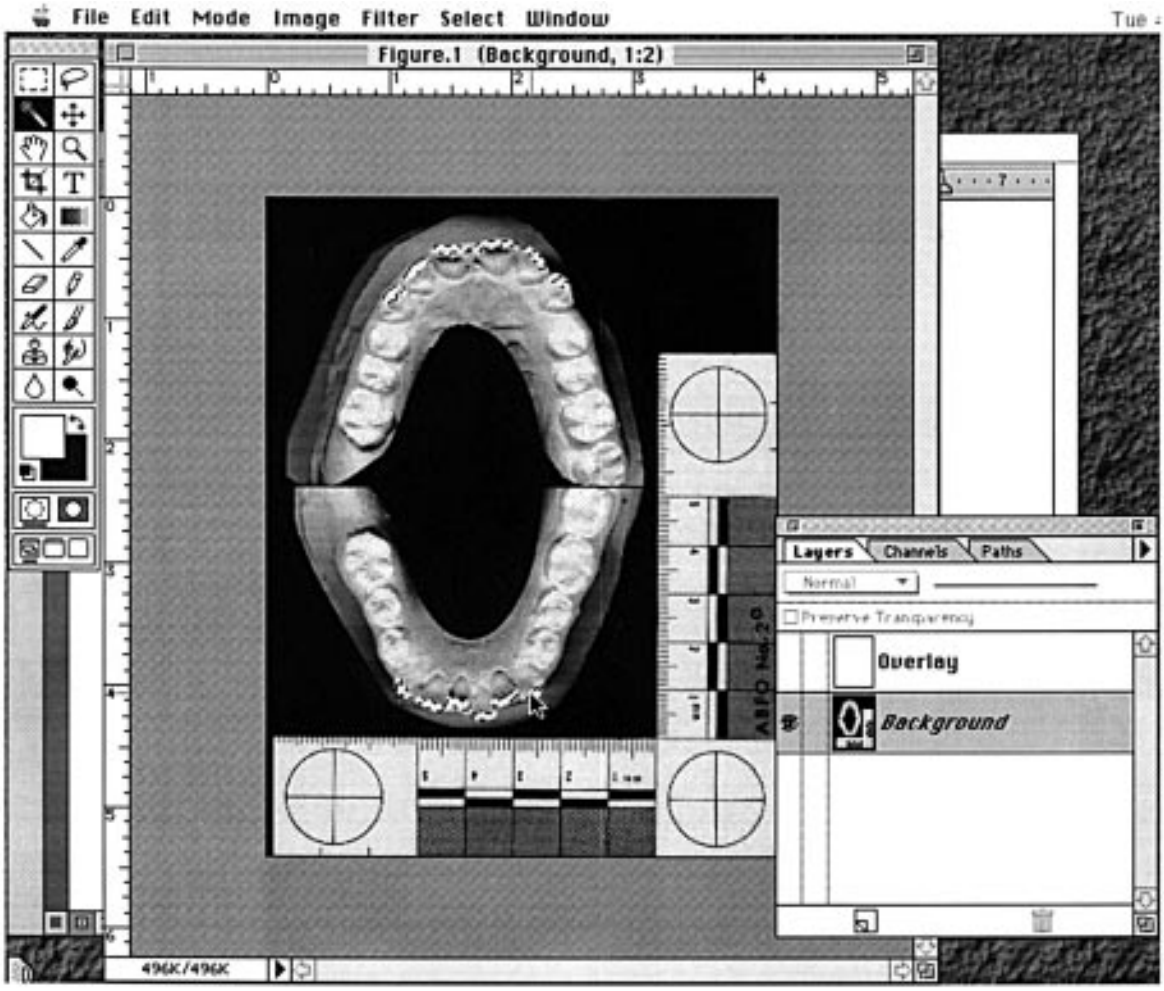

FIG. 3—*The biting edges of the teeth of interest are selected using the Magic Wand Tool. Note that the ''active'' layer is the background. The biting edges can be transferred to the Overlay layer.*

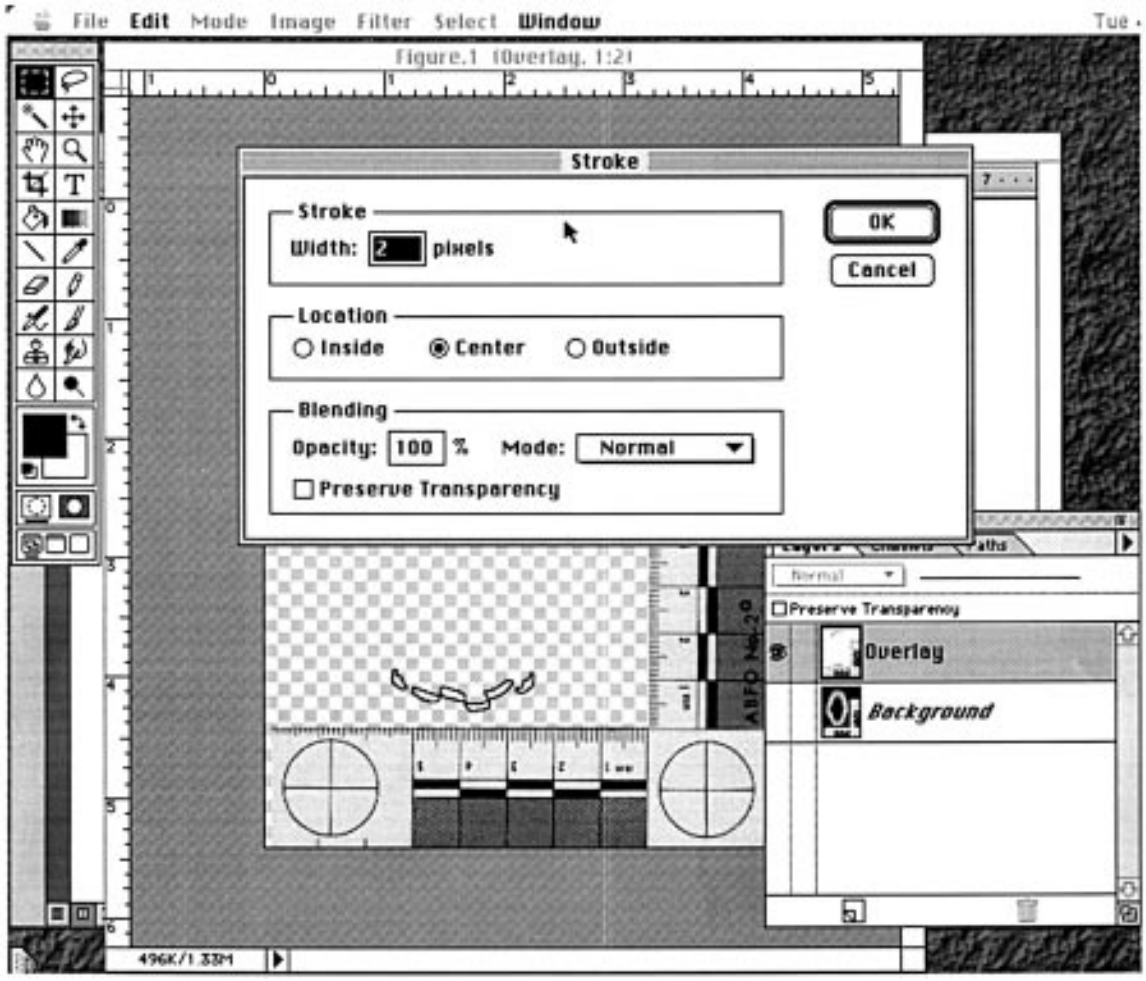

FIG. 4—*The biting edges are copied from the Background layer and pasted into the Overlay layer. While selected, the images are ''filled'' with* Clear *to produce a hollow volume, and ''stroked'' with a* 2-pixel-wide line *circumscribing the biting edge.*

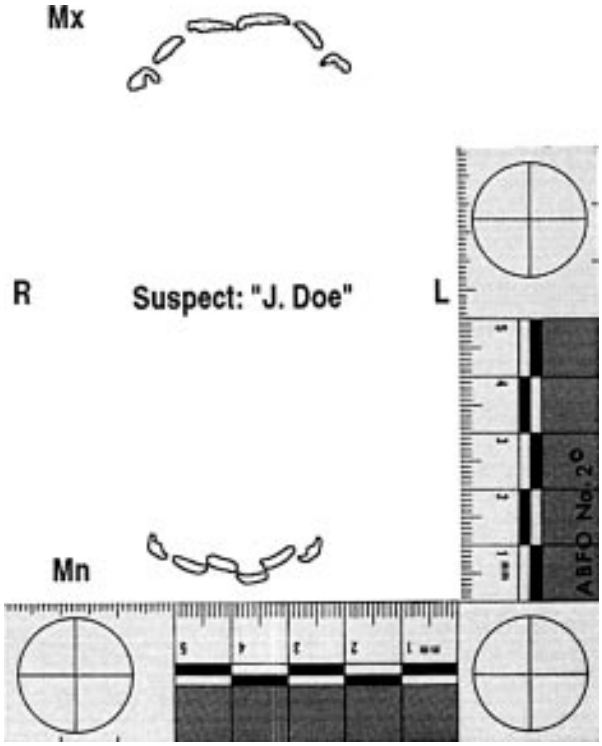

FIG. 5—*Using the Text tool, the suspect's name may be added along with labels for upper teeth (Mx), lower teeth (Mn), and left-right laterality. This image is printed on acetate film in a laser printer. The size of the final output (100%) can be verified using the image of the ABFO No. 2 scale.*

in several recent cases involving human bite marks and other patterned injuries on skin. It appears to be well accepted by the courts due mainly to its demonstrated accuracy—the overlay can be placed over the digital image of the suspect's study casts to illustrate the exact duplication of significant dental characteristics.

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