J Forensic Sci, May 2009, Vol. 54, No. 3
doi: 10.1111/j.1556-4029.2009.01009.x
Available online at: www.blackwell-synergy.com

TECHNICAL NOTE

Allan J. Lasser,[1] D.D.S.; Allan J. Warnick,[2] D.D.S.; and Gary M. Berman,[3] D.D.S.

Three-Dimensional Comparative Analysis of Bitemarks*

ABSTRACT: Historically, the inability to accurately represent bitemarks and other wound patterns has limited their evidentiary value. The development of the ABFO #2 scale by Krauss and Hyzer enabled forensic odontologists to correct for most photographic plane distortions. The technique presented here uses the ABFO #2 scale in conjunction with the evolving technologies of laser scanners and comparative software commonly used by the automobile industry for three-dimensional (3D) analysis. The 3D software comparison was performed in which measurements were analyzed of the normal distance for each point on the teeth relative to the bitemarks. It created a color-mapped display of the bitemark model, with the color indicating the deviation at each point. There was a correlation between the bitemark and the original teeth.

KEYWORDS: forensic science, bitemark analysis, laser scanner, comparative software, forensic odontologist, three dimensional

In the Supreme Court ruling in *Daubert vs. Merrill Dow Pharmaceuticals* (1), the court listed several factors that the trial judge should consider in the evaluation of expert scientific testimony.

These include:

- Whether the technique or theory can be tested.
- Whether the technique or theory has been subjected to peer review and published.
- Whether the technique or theory's error rate is known.
- Whether the technique or theory is generally accepted within the relevant scientific community.

The analysis of bitemark evidence has been criticized in the past for its subjective rather than objective nature. The Daubert ruling set forth standards which resulted in a need for a formally recognized and reproducible evaluation of bitemarks and other wounds (2,3).

Materials and Methods

The impression of the dentition is poured in the following material to make a positive model. This acrylic model consists of 42 cc of poly-methyl methacrylate mixed with 13 mL of methyl methacrylate and cured for 9 h in a water bath at 163°F. To create a bitemark (an impression of the human dentition) the upper and lower acrylic models, are mounted on a #11 SP vice grip. Bitemarks are created on the legs and abdomen of a refrigerated, non-embalmed male cadaver. These bitemarks are documented using the technique outlined in the ABFO guidelines for the collection of bitemark evidence. Photographs of the bitemarks are made in both color, black and white, with and without the AFBO ruler (Fig. 1) (4). Impressions of the bitemarks are taken in a resilient dental impression material (i.e., Examix by GC Co.). All impressions are poured in Die-Keen Dental Die stone (Fig. 2), per manufacturer's instructions, using a Vac-U-Spat machine (not shown) (5). A model of the deepest bitemark, as well as the model that made the wound pattern injury are scanned by a third party as described below. After scanning, commercially available software, Geomagic Version five is used to see to what extent the bite and the original model correlate to each other. This software is used to compare various manufactured parts for accuracy in many industries including the automotive companies. These industries depend on exacting standards in their manufacturing process, thus they have developed the ability to analyze each manufactured component and compare it to the initially fabricated component. Accuracy is expressed by the different colors displayed, red being the most accurate followed by yellow.

FIG. 1—*The bite with an ABFO ruler.*

[1]33521 Six Mile Road, Livonia, MI 48152.
[2]31632 Schoolcraft, Livonia, MI 48154.
[3]9840 Haggerty, Belleville, MI 48111.

*Presented at the 54th Annual Meeting of the American Academy of Forensic Sciences, February 10–16, 2002, in Atlanta, GA.

Received 20 Jan. 2008; and in revised form 1 June 2008; accepted 21 June 2008.

FIG. 2—*The model of teeth prior to digitizing.*

Scanning Methodology

There are two ways to scan an object. You can use either a mobile arm that is manually positioned or one that is totally machine controlled. Industry suggests that a manually positioned mobile arm inherently has a greater error rate of + or −0.004 inches over a machine controlled one, yet no proof is offered. To minimize potential variances a 40 by 40 inch bridge machine was used to scan the models. The bridge machine in this case was a converted Pratt & Whitney Bridge Mill. It is a square machine tool that weighs 2 tons and has a bridge that straddles the middle of the machine over the machine tool table. The table has the ability to move in the horizontal plane in any direction. In the vertical plane, the sensor head is suspended from the bridge and has the ability to move vertically, up or down. In this experiment the sensor head was a Kreon KLS51.

The sensor head projects a laser plane on the surface of the object to be measured. The section is then sampled by a CCD camera, which supplies 600 points over a 25 mm width. This surface is then digitized with laser lines by moving the sensor over the object. This creates a set of sections that characterizes the surface. Each point is referenced in the laser space. Knowing the position of the sensor, through its software interface and installation on a CNC (Computer Numeric Control) machine, (will) calculate the point coordinates.

Measuring accuracy is achieved by the registration of the laser plane with the machine space. A small sphere, *c.* 10 mm in diameter, is installed on the machine bed to align the sensor. Four available identifiers, −x, +x, −y, and +y, are used to establish positioning. These identifiers relate the sensors' orientation to the machine bed and its indexed position at 0, 90, 180, or 270°. Moving the sensor over the sphere at all four identifiers through the CNC's control, captures its position with the laser's software. The positions displayed by the CNC's control are checked against the displayed position of the software. Once the CNC mill and sensor are calibrated, an object can be digitized. (Bob Anderson of Standard Systems International Inc., Personal communication) (Figs. 3 and 4).

The Inspection Process

Once the images (Figs. 5 and 6) are digitized, the comparative software by Geomagic is utilized. Geomagic takes your nominal CAD geometry and compares it to your measured data and tells if your part meets specifications. In our case it will tell us which points of reference match and the degree of match by the color of each individual area.

- The teeth and the bitemarks were scanned with a three-dimensional (3D) scanner. Point sampling tools reduce the size of the data set (for performance) and both data sets were triangulated (polygonized).
- Initially, the two objects were in completely different positions and orientations in 3D space. Three common points were selected on each model and matched to perform a rough alignment.
- With the models roughly aligned, a best fit alignment was performed to finely position the teeth relative to the bitemarks, minimizing the error between the two.
- After alignment is complete, a 3D comparison was performed, to measure the normal distance for each point on the teeth relative to the bitemarks. This created a color-mapped display on the bitemark model, with the color indicating the deviation at each point.

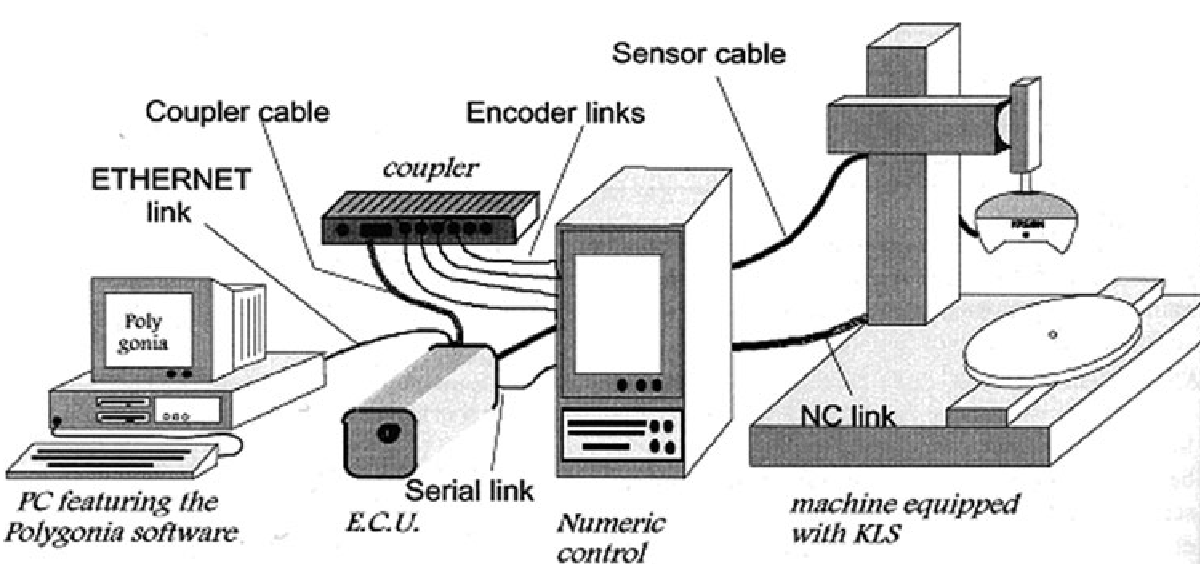

FIG. 3—*Drawing of equipment set up.*

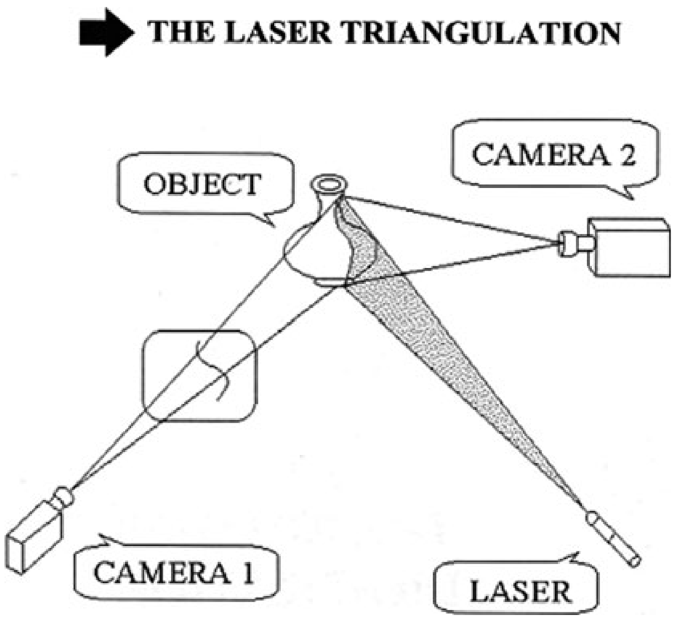

FIG. 4—*Laser set up.*

FIG. 5—*The digitized maxillary model.*

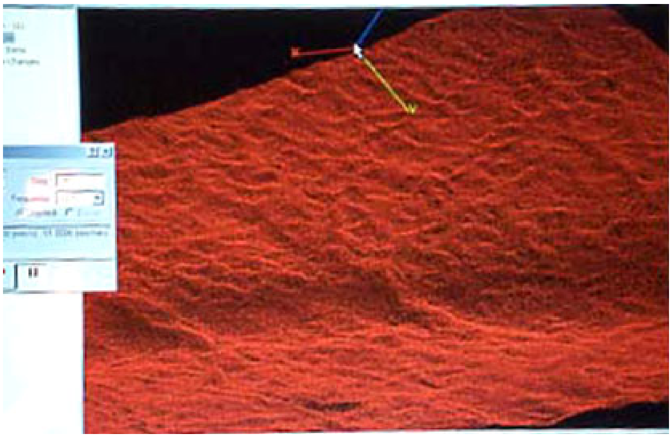

FIG. 6—*The initial digitized bite.*

- The color spectrum (or scale) was edited to set the displayed maximum and minimum deviation values to best show the fit and deviation between the models. In this example, a range of +/− 1 mm was selected. Any deviation result from the bitemark model and the teeth were shown simultaneously to aid visualization (Figs. 7 and 8). Yellow indicates the best correlation. Images were saved as JPEG (.jpg) files for the final report. (David Bell of Geomagic Software, Personal communication).

Conclusion

We have taken the rigorous parameters required by the automotive industry and applied them to the needs demanded by our profession and the courts. These parameters require that subjective results be replaced by a more intense and easily reproducible method where objectivity is paramount. The results indicate a correlation between the bitemark and the teeth. Further research will

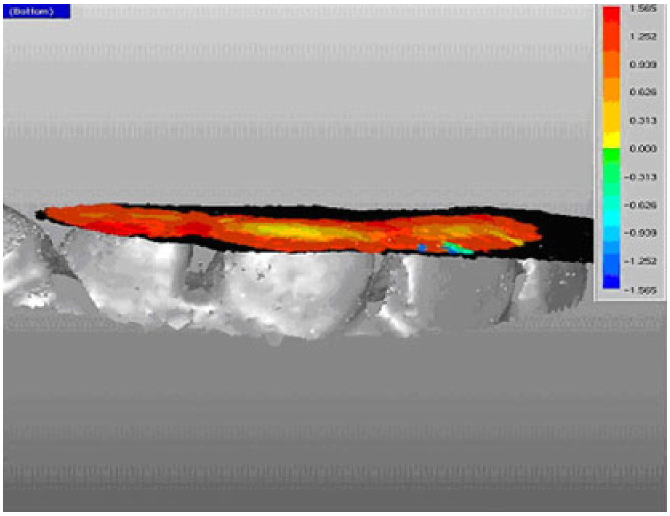

FIG. 7—*Labial view of the comparison.*

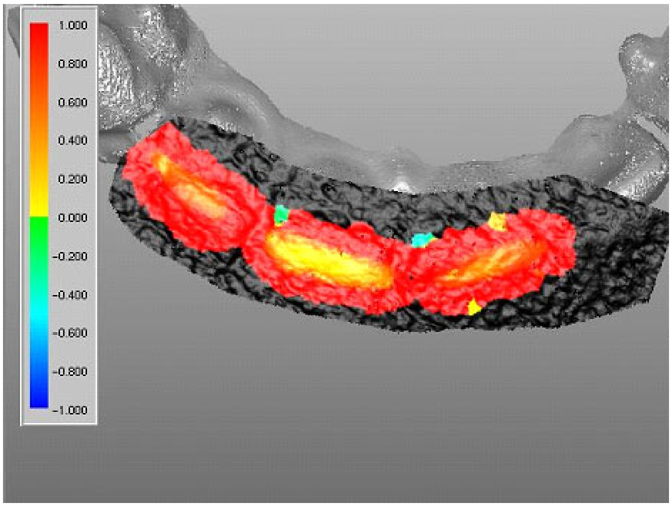

FIG. 8—*Incisal view of the comparison.*

be required using this method. Research by others involving 3D comparative analysis will be needed to prove reproducibility (6).

Acknowledgments

We would like to thank Bob Anderson of Standard Systems for doing the scan, David Pearson and Spike Milligan for their help in capturing and processing the data. Additionally, we would like to thank Kevin Crute for his always helpful comments and suggestions, Rear Admiral Lee Landes for his initial guidance, and Peter D. Frade, Ph.D., Departmental Chair and Associate Professor, School of Mortuary Science at Wayne State University, Detroit, Michigan, for access to the body used in this study.

References

1. http://straylight.law.cornell.edu/supct/html/92-102.ZS.html
2. Naru AS, Dykes E. The use of a digital imaging technique to aid bite mark analysis. Sci.Justice 1996;36(1):47–50.
3. Bowers CM, Johanssen RJ. Photographic evidence protocol: the use of digital imaging methods to rectify angular distortion and create life size reproductions of bite mark evidence. J Forensic Sci 2002;47(1):178–85.
4. Hyzer WG, Krauss TC. The bite mark standard reference scale—ABFO No. 2. J Forensic Sci 1988;33(2):498–506.
5. Sperber ND. Further discussion on discussions of ‘‘bite mark impressions: a review of techniques and materials.’’ J Forensic Sci 1990; 35(4):777–8.
6. Thall MJ, Braun M, Markwalder TH, Brueshweller W, Zollinger U, Malik NJ, et al. Bite mark documentation and analysis: the forensic 3D/CAD supported photogrammetry approach. Forensic Sci Int 2003; 135(2):115–21.

Additional information and reprint requests:
Allan J. Lasser, D.D.S.
33521 Six Mile Road
Livonia
MI 48152
E-mail: ajlass43@sbcglobal.net