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## Yet Another Method for Marking Incisal Edges of Teeth for Bitemark Analysis

**ABSTRACT:** Over the years many methods have been proposed and presented for marking or “highlighting” the incisal edges of anterior teeth on a dental stone model—one of the critical steps in production of transparent overlays for bitemark analysis. A method is presented here that is an extension and refinement of the “paint the edges” method shown at least as early as 1966 by Gustafson. This method uses “invisible ink” and ultraviolet illumination to produce a very high contrast image of the incisal edges of the teeth on the model. The advantages of this new method are that it is nondestructive, it does not leave visible marks on the models, operator subjectivity in selecting the portions of anterior teeth to be highlighted is reduced, and the author submits that this technique lends itself to easy construction of overlays using computer image-processing software such as Adobe Photoshop® and ImageJ.

**KEYWORDS:** forensic science, forensic dentistry, odontology, human bite mark, transparent overlay

Gösta Gustafson, in his classic book *Forensic Odontology*, showed, in Figure 56b, the “paint the edges” method of marking incisal edges of teeth of a stone model to highlight them for clarity when performing bitemark analysis (1). Whether he “invented” this method is unclear, and he did not refer specifically to making transparent overlays for bitemark analysis using this procedure. Rather, Gustafson apparently compared a photograph of the highlighted incisal edges of the anterior teeth from the model to a photograph of a “Silicon” impression of the bitemark. (He describes “Silicon” as the brand name for silopren, or organic polysiloxan (*sic*), pastes that were manufactured by Bayer in Germany.) Painting the incisal edges of the teeth on the model is an intuitive method that may well have been in use before Gustafson published his seminal book.

In fact, although, Gustafson did refer to another method of creating photographic overlays attributed to Morgen in 1943. Morgen’s method was to paint every part of the stone model and of the impression of the bitemark or exemplar black *except* the incisal and occlusal surfaces of teeth. Photographs were made of the stone model and of the bite, and then the photographic negatives were appropriately scaled and superimposed for comparison (2).

Xerography has been widely used to make a 1-to-1 image, with a photocopier, of the incisal edges of teeth from a plaster model, which are then traced by hand or with image-processing software onto transparent film to make an overlay for analysis—the so-called “hollow-volume tracing.”

Dr. Curtis Dailey has presented a novel method where a dental stone cast of the suspect’s dentition was embedded in stone of a contrasting color, and then what are essentially serial horizontal sections are made through the occlusal plane with a dental model

trimmer and these are sequentially photographed (personal communication). This method is an important development because it captures some 3-dimensional (3-D) information in the Z-axis about the distance of the incisal edges of the teeth from the occlusal plane.

Overlays of the incisal edges of the suspect’s dentition have been made with computer image-processing software, such as the Adobe Photoshop® “magic wand” tool (Adobe Systems, San Jose, CA, <http://www.adobe.com>) by creating a mask of selected areas of the anterior teeth from an exemplar or stone model and, in turn, creating a hollow-volume tracing from the mask (3).

Pink dental baseplate wax “bites,” or exemplars, can be transilluminated on a light-box and photographed to record the arrangement of the anterior teeth of a suspect. The resulting photograph may be imported into an imaging software program and the “magic wand” tool used to create a hollow-volume tracing from this exemplar per previously well-described procedures. There is one particular characteristic of this transilluminated wax bite that is both positive and negative for this analysis. On the positive side, some 3-D information about the location of the teeth in the Z-axis is captured and is represented in the photograph as intensity variation—the closer the incisal edge of the tooth is to the occlusal plane, the brighter the image will be because the baseplate wax is thinner in that area. On the negative side, however, selecting the “proper” area of the incisal edge in the wax bite to highlight with the “magic wand” is very subjective due to this intensity variation.

There is a significant inherent disadvantage with most of these methods: when making a hollow-volume tracing of the exemplar or stone model by hand from a xerographic image, for example, operator subjectivity is introduced by hand tracing. Even when using software such as Photoshop®, there is still operator subjectivity introduced when selecting the exact area of a tooth to be highlighted with the “magic wand” tool. A method is now presented for making overlays taking advantage of features available in the ImageJ public-domain image processing computer program available from the National Institutes of Health (<http://rsb.info.nih.gov/ij/>). The author contends that this method greatly reduces operator subjectivity when creating hollow-volume tracings of the incisal edges of anterior teeth of exemplars or stone models for bitemark analysis.

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This technique combines elements of both the method of “painting the edges” and of using the Photoshop® “magic wand” tool, which is admittedly an intuitive and obvious combination briefly touched on previously by others. What is distinctive about the present technique is the ink and the illumination used to mark and highlight the incisal edges of the teeth on the stone model. The author uses an ink that is not visible in normal room light, but fluoresces under appropriate ultraviolet (UV) illumination. (This is popularly called “invisible ink.”) Highlighting the incisal edges of the teeth on the model with this ink leaves no visible marks—the edges of the model’s teeth are left in pristine condition with no thick coating of “paint” on them. However, under UV illumination of the appropriate wavelength, the incisal edges contrast greatly with the remainder of the cast. This greatly increased contrast makes creation of a mask with the “magic wand” tool or other computer software more predictable and repeatable, and decreases operator subjectivity.

### Materials and Methods

Fiber-tipped markers containing “invisible ink” that fluoresces under UV illumination were obtained from LDP LLC (Carlstad, NJ, <http://www.maxmax.com>) (Fig. 1). The markers evaluated were the “UVInkPenLg,” which contained an isopropyl-alcohol-based ink that glowed bluish-white under 395 nm UV illumination, and the “UVInkPenYL,” which had a ketone-based ink that glowed greenish-yellow under 365 nm UV illumination.

LDP recommended the alcohol-based UVInkPenLg marker as suitable for porous surfaces, and this marker was found to work very well for this application on typical dental stone or plaster models. The ketone-based UVInkPenYL worked well on orthodontic models that had been treated with soap to have a “shiny” surface finish. LDP advised the ketone-based markers fluoresce best under 365 nm illumination.

UV illumination was provided by simple light-emitting diode (l.e.d.) “forensic flashlights” widely available from various vendors on-line via the Internet. The author suggests choosing a flashlight with at least 20 l.e.d.s and preferably 32 l.e.d.s or more (Fig. 2). Flashlights were arbitrarily selected that had peak UV emission at 395, 380, and 365 nm.

The incisal edges of the incisors and the canines on the dental stone cast were marked using the flat side of the marker—not the pointed tip. This produced an even, uniform, predictable “painting” of the edges. The ink had sufficient time to dry while the cast was being positioned for photography. (This ink does not fluoresce well while wet.) Operator subjectivity is admittedly present and critical in this step of marking the portion of the incisal edge to be highlighted. But once the incisal edge is carefully marked, the author submits that the remainder of this technique is objective and easily repeatable by others. Because the marker’s fiber tip is firm and the



FIG. 2—Ultraviolet-light-emitting-diode “forensic flashlights.” These particular units are modified, commercially available standard flashlights that operate on 3 “C” batteries.

ink does not “bleed” much, a very small area of the tooth edge can be selected and painted at any one time, if desired.

A digital camera is preferable for this method for a number of reasons. Chief among them are the following: images can be seen, evaluated, and kept or discarded right away, and transferring digital images to the computer for analysis is much easier and quicker than scanning conventional film negatives or photographic prints.

Three digital cameras were on hand in the author’s lab and were evaluated for this procedure: a Fuji S-3 Pro camera with 60 mm/f2.8 Nikon AF Micro Nikkor lens (Fujifilm, Minato-ku, Tokyo, Japan, <http://www.fujifilm.com>; Nikon, Chiyoda-ku, Tokyo, Japan, <http://www.nikon.com>), a Canon 30D camera with 60 mm/f2.8 Canon Macro EF-S USM lens (Canon, Ohta-ku, Tokyo, Japan, <http://www.canon.com>), and an Olympus Camedia C-5060 with noninterchangeable Olympus AF Zoom 5.7–22.9 mm/f2.8–4.8 lens (Olympus, Shinjuku Monolith, Shinjuku-ku, Tokyo, Japan, <http://www.olympus-global.com>). Interestingly, the author found the less expensive Olympus camera to produce excellent results for this application. It was noted that the Olympus’s sensor seemed, subjectively, to be more sensitive than the Fuji’s or the Canon’s in the UV range used (i.e., presumably, the Fuji and Canon cameras likely had more effective UV filtration), and the Olympus’ exposure meter was able to determine proper exposures under UV illumination quite well. At the beginning of the project, the UV exposures were widely bracketed with all three cameras, but it soon became apparent that the Olympus’s exposure meter was capable of providing a well-exposed photograph under UV illumination without problem. (This particular technique actually does not require very accurate UV exposure metering in any case.) The Fuji S-3 and the Canon 30D certainly did produce excellent images as well, and it should be kept in mind that the goal of this method was not any sort of quantitative evaluation about which camera is “best” for UV photography—the goal is to get a dimensionally accurate image with the incisal edges of the stone model’s teeth clearly and cleanly separated from the background. It is likely the particular brand of camera and lens used is of little import for this procedure.

The camera should be set up on a typical small tripod on a lab table or, preferably, on a sturdy photographic copystand because the exposure time will be long (Fig. 3). The dental cast and A.B.F.O. #2 scale are placed appropriately on the base of the stand. The author used stacks of flat, disc shaped magnets as easily-adjustable supports under the A.B.F.O. ruler to raise its level with



FIG. 1—“Invisible ink” markers available from LDP LLC.



FIG. 3—Photographic copy stand. (The camera's flash unit is not used in this technique.)

the occlusal plane of the dental model. Additionally, a steel sphere of known diameter (a.k.a. "ball-bearing") was placed near the cast to be photographed. Even if the "film"-plane of the camera was not perfectly parallel with the copystand base, the sphere will still be recorded as a circle of known diameter (within distortion limits of the camera's lens), which could be useful as a secondary dimensional reference.

It is not necessary to totally exclude all other illumination besides the UV flashlight for this method—subdued room light is fine—the object is to force the camera into a long exposure time of about 2–5 sec. or so. Release the shutter with either the self-timer or a remote shutter release to minimize vibration. While the shutter is open, the photographer's old trick of "painting with light" is used to evenly illuminate the stone model with the forensic UV flashlight. With a long exposure time and the room lighting very low, as long as the forensic flashlight is kept moving briskly across the scene, the flashlight itself will not appear in the resulting photograph. One will have to experiment with his/her own camera and illumination set-up to determine the best exposure and how quickly to "paint" the scene with the UV light—obviously, a big advantage of digital cameras is that many trial exposures can be made and evaluated quickly.

To decrease operator subjectivity when selecting the regions of the anterior teeth to be included in the hollow-volume tracing, ImageJ image-processing software was used. This software program is in the public domain and available for no-cost download from the National Institutes of Health website: <http://rsb.info.nih.gov/ij/>. Along with the program, there is a number of user-submitted "plug-ins" available on the website. Either the "MultiThresholder (Isodata, Entropy, Otsu, Mixture Modeling)" plug-in or the "Multi Otsu Threshold" plug-in may be employed for this technique. Download ImageJ and the desired plug-in filters, and install the software program and then the plug-ins according to the posted directions. Open the image of the UV-enhanced incisal edges with

ImageJ (Image J is somewhat particular about the format of the image to be opened—for this procedure an 8-bit gray-scale .jpg is suggested.) With the image open, select "Plug-ins" from the toolbar and then apply either the MultiThresholder (choose the Otsu option) or the Multi Otsu plug-in. The Otsu filter is a sort of "smart" threshold filter that produces essentially an extremely high-contrast image of the incisal edges of the anterior teeth of the model (Fig. 4). This resulting image can be imported by Photoshop®, and the incisal edges easily and quickly selected with the "magic wand" to create a hollow-volume tracing. With this method, although, there is effectively no operator subjectivity involved, the author submits that this technique is highly reliable and easily repeatable by others.

## Results and Discussion

The alcohol-based marker from LDP fluoresced well under 395 nm illumination. Both the alcohol-based and the ketone-based markers were visible under 380 nm illumination, while only the ketone-based marker fluoresced well under 365 nm illumination. These characteristics suggest that it might be possible to mark different areas of a stone cast with different inks, and, depending upon

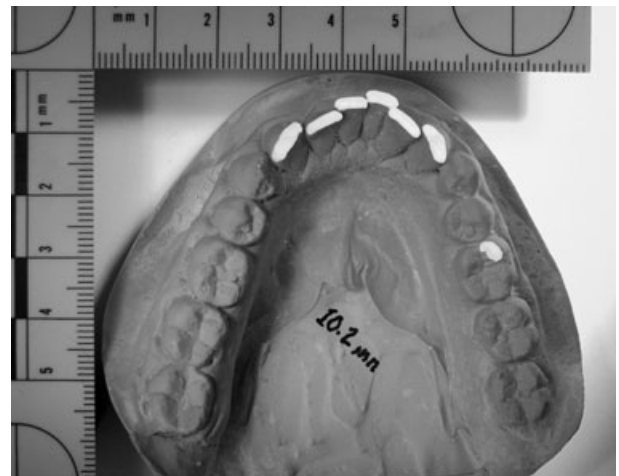


FIG. 4—Incisal edges of anterior teeth highlighted with "invisible ink" and photographed under ultraviolet illumination. (Per Dr. Paul Stimpson, the right first molar on the dental stone cast is marked with a "dot" for orientation which is, in turn, also transferred to the overlay. This dot helps lessen confusion in case either the transparent overlay or the bite-mark image itself is inadvertently "flipped".)



FIG. 5—Cropped portion of Fig. 5 with "Otsu Thresholding (Region 2)" filter plug-in applied via the ImageJ software program.

the illumination wavelength used, easily highlight different areas of the same cast in different photographs. The color the ink fluoresces was of only qualitative interest and was of no practical consequence in constructing a transparent overlay. Once an image has been made with the incisal edges of the anterior teeth highlighted by this technique (Fig. 5), computer software such as the Adobe Photoshop® “magic wand” tool or Image. J was used to select the areas for hollow volume tracing.

The significance of this method using “invisible ink” is that there are no marks visible left on the stone casts under normal room lighting, and high contrast images of the incisal edges are created, making it straightforward for computer software imaging programs to highlight and select the incisal edges of the anterior teeth for overlay construction. Coupled with ImageJ software and its Otsu thresholding plug-in, the method is easily repeatable and decreases operator subjectivity in overlay construction. The incisal

edges of the anterior teeth on the stone model are left in pristine condition for further examination.

## References

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