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Toneline Bite Mark Photography

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ABSTRACT: In bite mark analyses, the initial photograph is critical for the collection and presentation of evidence. A high-contrast film technique previously used primarily in the graphic arts field has been refined and applied to forensic odontology. The process, called *toneline*, reduces the interpretational bias of the investigator and yields a transparent overlay with a photographic outline of the bite mark which can be directly compared with models of the suspect's teeth.

KEYWORDS: odontology, bite marks, photography, toneline

From the onset of human hostility man has used his teeth as a weapon to bite his victims. Teeth have also been used as a means of defense. It has long been recognized that bite marks are unique and can be attributed to specific individuals. Although unverified by the British Dental Association, it is believed that William the Conqueror was aware of the distinctiveness of his malaligned teeth and used them to mark the wax of the official seal of England [*1*].

A recent study has established dental uniqueness beyond a reasonable doubt [*2*]. Another investigation has concluded that even the dentition of identical twins is not identical [*3*].

A *bite mark* is defined as the mark created by teeth, either alone or in combination with other oral structures [*4*]. We observe bite marks on victims of assault, rape, child abuse, and homicide. They are found on virtually all areas of the body, with more than one bite occurring in 40% of the instances [*5*]. Female victims are most commonly bitten on the breasts, arms, and legs. Male victims are generally bitten on the arms and shoulders, which suggests that a significant proportion of these injuries are the result of homosexual encounters [*5*].

The first use of bite mark evidence in the conviction of a wrongdoer occurred in 1906 in England and involved a mark left in a piece of cheese during a burglary. A match between the burglar's teeth and the mark in the cheese was convincingly demonstrated [*1*]. The earliest bite mark evidence in the United States for which we have a legal citation was in *Doyle v. State of Texas*. Again the bite mark involved cheese [*6*].

Bite marks are now accepted as evidence in courts of law. Life-and-death decisions can hinge upon the accuracy with which such evidence is interpreted. Courts have ad-

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mitted bite mark evidence in several different types of cases. Gianelli has stated, "No reported case has rejected bite mark evidence. Indeed, its acceptance is so well established that the New York Court of Appeals has held that its validity need not be proved in every case" [*7*].

At present, there are several methods of analyzing bite marks. Photographing, tracing, or making models are the most common methods of examination and study. Regardless of the method of analysis used, photographs of the bite mark are always included, enlarged to life-size dimensions for comparison with models of the suspect's teeth. Much current research has centered on investigation of the suspect's teeth. We undertook the present study to find a method of isolating useful photographic information while initially recording evidence.

Current photographic methods involve continuous-tone (black-and-white or color) prints or slides [*8*]. Reference scales, rulers, or an American Board of Forensic Odontology (ABFO) No. 2 Reference Scale [*9,10*] are frequently included in the photographic exhibit to show size and proportion. By selectively controlling the photography of the original image, the authors hope to improve the contrast between the bite mark discoloration and the surrounding tissues. The resulting high-contrast negatives can be used to generate graphic toneline images of the bite mark perimeter.

Toneline (sometimes called a line print) is a relatively common, high-contrast technique that yields a thin black outline of the photographed subject, often resembling a pen-and-ink sketch [*11*]. It is a method that can prove useful to photographers and odontologists in documenting and analyzing the evidence in an unbiased fashion. We believe that the technique can be applied to any injury, mark, or pattern resulting in skin discoloration.

Accordingly, our investigation concentrated on the search for the optimum negatives to be enlarged onto lithographic film to achieve a black "pen-and-ink" line around the bite mark. We also wanted to demonstrate the subjective qualities of currently accepted examination methodology.

Methods

Our research involved fourteen bite marks. Five were self-inflicted by a researcher because of a lack of timely coroner's cases. Nine were present on four decedents. All fourteen bite marks were initially recorded in conventional fashion on 35-mm Kodak Vericolor III Professional film; 1:1 enlargements on 5- by 7-in. Kodak Ektacolor Plus paper were made on each injury. The methodology devoted exclusively to refining the toneline technique for bite mark application was complex and evolved as our findings confirmed or negated our approach. A fact to be kept in mind is that a toneline film overlay is the result of a film positive and a negative [*11*] and contains qualities present in both. Therefore, it is technically neither positive nor negative. Since the product of the film positive and negative is in our desired overlay format, and since an intermediate negative is required to make a toneline print, we will use the nomenclature *toneline film positive* to describe the resultant film image, which has a black outline on a transparent background.

It is further necessary to understand that a toneline film positive is the result of a continuous-tone film negative, a lithographic film positive, and a lithographic film negative (Fig. 1). Accordingly, refining the toneline technique required investigation and controls at two of four involved steps:

(*a*) the initial panchromatic film negative and
(*b*) the toneline film positive.

All of our photographic supplies (film, paper, developer, filters, and so forth) were manufactured by the Eastman Kodak Co. We chose Kodak materials because of their

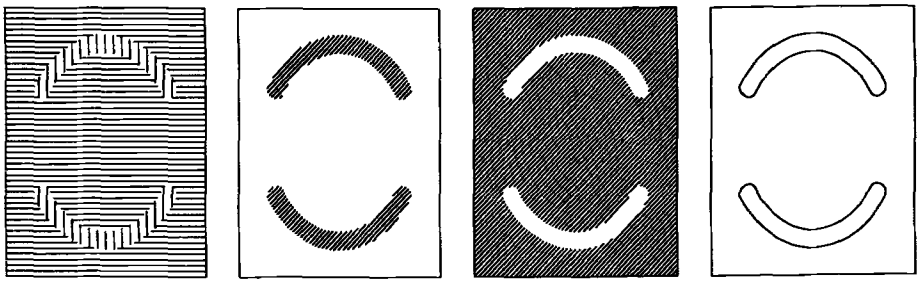

FIG. 1—*Illustration depicting the steps necessary to produce a toneline film positive:* (a) *a continuous-tone film negative,* (b) *a Kodalith film positive,* (c) *a Kodalith film negative, and* (d) *the resulting toneline film positive.*

widespread availability, the amount of published documentation regarding them, the excellent technical support provided by the company, and the consistency of the emulsion quality.

The equipment necessary for our methodology is straightforward, minimal, and easily available to any law enforcement agency with access to a darkroom (Table 1). Because of the relatively small exposure latitude of Kodak Kodalith Ortho Film 2556, Type 3 [*12*], used extensively in this project, we used a digital darkroom timer accurate to 0.1 s. We believe the technique can be repeated with a less precise timer.

When an original continuous-tone negative is enlarged onto lithographic film (in our project, Kodalith), properties within the film convert all intermediate gray tones present on the negative into either white (clear) or black [*11*]. The point at which one gray becomes black while another becomes white is called the *tonal break* (Fig. 2). By varying the exposure and development times, we have limited control over the point at which tonal breaks occur.

TABLE 1—*Equipment list, with the equipment specifically used at Cuyahoga County Coroner's Office inside the parentheses (a power pack for the flash is not necessary).*

TECHNICAL PAN NEGATIVE
1. SLR camera body (Nikon F3).
2. 105-mm Lens (Nikon Micro NIKKOR 105 mm. *f*/4).
3. Camera-mounted electronic flash (Vivitar 285 HV auto electronic flash. The flash was used on manual setting at full power, 100 ASA, with the head set at 0°).
4. External battery pack (Vivitar HPV-1 high-voltage battery pack, optional).
5. Kodak Wratten No. 58 green tri-color filter.
KODALITH POSITIVE
1. Enlarger (Leitz/Wetzlar Focomat IIc condenser-type enlarger with a 95-mm Focotar *f*/4.5 lens).
2. 4- by 5-in. film easel.
KODALITH NEGATIVE
1. Light source (Leitz enlarger above with a 60-mm lens).
2. Contact print frame.
KODALITH TONELINE FILM POSITIVE
1. Light source (200-W bulb).
2. Contact print frame.

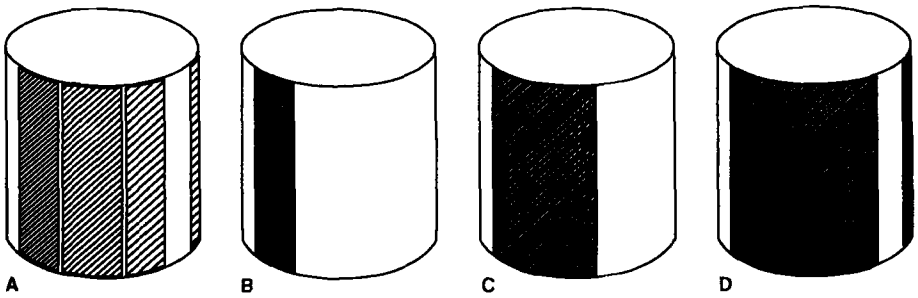

FIG. 2—*Hypothetical tonal breaks of a continuous tone image* (a). *Depending on the exposure and development, several possible resulting high-contrast images are possible* (b, c, *and* d).

Unfortunately, lithographic film is very easily overexposed or underexposed, and controlling the tonal breaks is difficult. Our efforts, therefore, were concentrated on separating the gray middle tones on the original continuous-tone negative. Continuous-tone films have significantly reduced compression of tones, and image contrast can be more easily controlled by varying the film exposure, developer, development time, and selective filtration of incoming light [*13,14*].

To begin our research, bite mark No. 1 (BM1) was photographed with 24 rolls of film. There were 4 rolls of each of the following continuous-tone film types: T-Max 100, T-Max 400, Tri-X Pan, Plus-X Pan, Panatomic-X, and Technical Pan. The focusing ring on the camera lens was taped so that the subject-to-image distance was constant at 2 ft (0.6 m). Each roll of film was exposed identically, with consideration given to the flash recharge time [*13*].

The four rolls of each film type were processed in four different developers [D-19, Technidol LC, T-Max, and HC-110 (dilution B)] at the manufacturers' recommended developing times at 68°F (20°C). In some cases, the film/developer combinations were not specified, so the development times were extrapolated.

The film/developer methodology for BM2 was identical to that for BM1. We altered exposures based on results obtained from BM1. We also switched from a 55-mm to a 105-mm lens in order to increase the size of the bite mark image on the 35-mm negatives. We, again, secured the focusing scale at 2 ft (0.6 m).

BM3 was simply photographed with T-Max 100 and processed in D-19 developer. BM3 explored the use of contrast control filters. Since the ultimate goal was to isolate the red and magenta skin discoloration associated with bite marks, No. 47 blue tricolor and No. 58 green tricolor Wratten filters were selected for testing [*11,15*]. BM3 was photographed with and without filters in order to determine the best image contrast and the most useful exposure compensation factor for each filter [*16*].

BM4 was photographed using four rolls of Panatomic-X, T-Max 100, and Technical Pan at varying (bracketed) exposures with and without a No. 58 filter. Again, each roll of similar film was exposed identically. Because of the low image contrast on Plus-X, T-Max 400, and Tri-X, we excluded them from further study. The T-Max and Technidol LC developers were also discontinued because they failed to improve the image contrast to a useful degree. Two rolls of each film were processed in D-19 and HC-110. At this point, the development time for one roll of each film type was increased 15% (pushing) to investigate the effect on image contrast [*11,13,17*].

Bite marks BM5A, BM5B, BM5C, and BM5D (four different bite marks on the same decedent) were bracketed with and without a No. 58 filter. While we were able to produce reasonable image contrast on Panatomic-X film negatives, this contrast did not yield a usable image when enlarged onto Kodalith film, so Panatomic-X was dropped from the study. The development time for the pushed film was increased an additional 5%.

Bite marks BM6A, BM6B, BM7, BM8, BM9A, and BM9B were each photographed and processed identically in order to confirm our findings and establish the repeat capability of the technique. Unexpectedly, the investigators were absent when BM9A and BM9B came up, and these bite marks were photographed by an independent forensic photographer using the written prescribed technique. His results were consistent with our findings.

Throughout the film and developer investigation, the negatives were visually inspected, contact printed, and enlarged 1:1 onto 4 by 5-in. Kodalith film. Kodalith film positives at a variety of exposures were examined, and those clearly isolating the bite mark from the surrounding skin were contact printed (emulsion-to-emulsion) onto another sheet of Kodalith. All Kodalith film was processed in Kodalith developer (1:3) at 70°F (21°C) for $2\frac{3}{4}$ min. Once a dry Kodalith positive and negative were obtained, they were carefully registered and taped together with silver mylar photographic tape (base-to-base). When viewed from perpendicular to the film plane, no light should pass through. Finally, second contact prints were made at varying exposures. During exposure, the film must be rotated uniformly so that light passes through all of the tonal breaks (Fig. 3). Exposing the film is best done with a point light source. For economy and availability we used a 200-W bulb. Variations in the angle of bulb placement were explored, and we found the results most useful when the bulb was placed 6 ft (1.8 m) from the film at a 45° angle above the film plane. Our exposure times varied from 10 to 40 s depending on the film density. After processing the last sheet of Kodalith, we now had a toneline film positive of the photographed bite mark. We later used these with models of the suspect's teeth for direct comparison.

In order to demonstrate examiner bias, color prints of four bite marks were given to four different individuals for tracing. For our purposes, we chose persons in different occupations (secretary, police officer, artist, and dentist). They were each given the same photographs, four sheets of ortho tracing acetate, and a No. 2 pencil. They were instructed only to trace the perimeter of each bite mark carefully. No time limit was specified. The tracings were later compared with photographs and with each other.

Results

Our research produced 716 panchromatic film negatives (51 per bite mark), 463 orthographic film positives (33 per bite mark), 67 orthographic film negatives (5 per bite

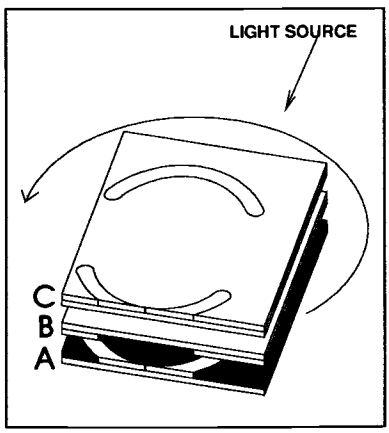

FIG. 3—*Illustration demonstrating the Kodalith "sandwich."* (a) *is the Kodalith film positive image (emulsion side up);* (b) *is the Kodalith negative (emulsion side down); and* (c) *is the toneline film positive (emulsion side up).*

TABLE 2—*Procedure for producing toneline film positives: all Kodalith should be processed as described in Point 2 of the procedure outline; all necessary equipment is described in Table 1.*

Film	Exposure without No. 58					Exposure with No. 58					Developer	Development Time	Temperature, °F (°C)
	f/32		22		16	16		11		8			
Technical Pan	X	X	X	X	X	X	X	X	X	X	D-19	5 min	68 (20)
Technical Pan	X	X	X	X	X	X	X	X	X	X	HC-110	7.25 min	68 (20)
T-Max	X	X	X	X	X	X	X	X	X	X	D-19	5.75 min	68 (20)
T-Max	X	X	X	X	X	X	X	X	X	X	HC-110	8.5 min	68 (20)

1. Expose Technical Pan film using the exposures listed above. Process the negatives at the recommended development time in D-19.
2. Enlarge the image from the Technical Pan film onto Kodalith at 1:1 (exposure times vary from 0.5 to 6 s at f/4.5 with a 95-mm lens. Process on Kodalith (1:3) developer for 2.75 min at 70°F (21°C).
3. Contact the print Kodalith positive onto another sheet of Kodalith film (emulsion-to-emulsion).
4. Contact the print registered Kodalith positive and negative (base-to-base) onto a third sheet of Kodalith, rotating the film during exposure.

mark), and 23 toneline film positives (2 per bite mark). We met our goal of establishing a repeatable combination of film, developer, development time, exposure, and filtration for toneline examination of bite marks. We also were able successfully to demonstrate examiner bias in the currently accepted methods used routinely by forensic odontologists.

We found the film of choice to be Kodak Technical Pan panchomatic film. When processed in D-19 developer, it exhibited excellent separation of tones in and around the bite mark. We found it best to increase development time approximately 20% in the D-19 developer. We have also found that, at times, T-Max 100 worked reasonably well as a film substitute and HC-110 (dilution B) can be used in place of D-19 if D-19 cannot be obtained. We call attention to the fact that T-Max 100 and HC-110 are *not as effective* and should be used *only* if Technical Pan or D-19 are not available.

Table 2 is our recommended procedure for photographing and processing a bite mark. We offer four different developer/film combinations, with our strongest recommendations first and the other combinations following in order of decreasing effectiveness. As shown in Table 2, we recommend a minimum of ten exposures (five with and five without a

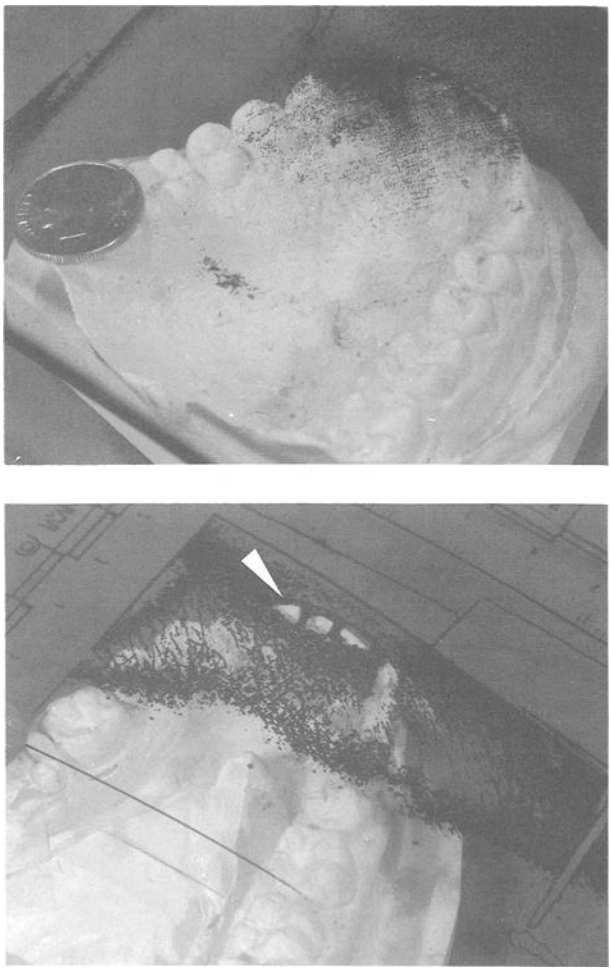

FIG. 4—*Toneline film positives of bite marks from two different coroner's cases [204824 (BM9B) and 204129 (BM6A)] atop models of corresponding suspects' teeth. The arrow indicates an unusual "T"-shaped mark produced by tooth 23. The "T" mark was also amenable to wax duplication from impressions of the model. The dime serves as a reference scale.*

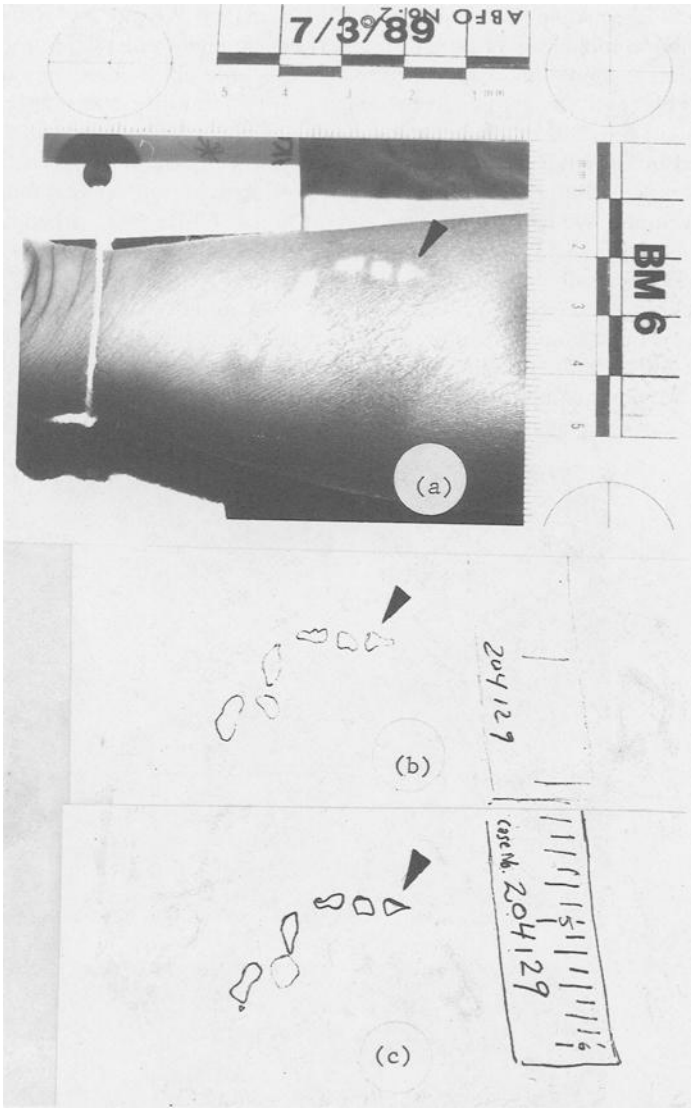

FIG. 5—*A direct comparison of a photograph* (a), *tracings* (b *through* e), *and a toneline film positive* (f) *of BM6A (Cuyahoga County Coroner's Office Case 204129). The arrows identify the "T" mark discussed in Fig. 4. Note the differences between the tracings.* (b) *was traced by the artist,* (c) *by the dentist,* (d) *by the retired police officer, and* (e) *by the secretary.*

No. 58 filter). We had hoped to develop a two- or three-exposure procedure but found that the differences in skin tonality of decedents dictated a wider bracketed range. Because of differences between the equipment of the Cuyahoga County Coroner's Office and that of other darkrooms, further bracketing may be initially required.

Our results varied as to whether or not to use a contrast control filter. In some cases there were no significant differences in tone separation; in others it was quite noticeable. We concluded that for our purposes the No. 58 green tricolor was best suited for isolating the red discoloration associated with bite marks from the surrounding intact skin.

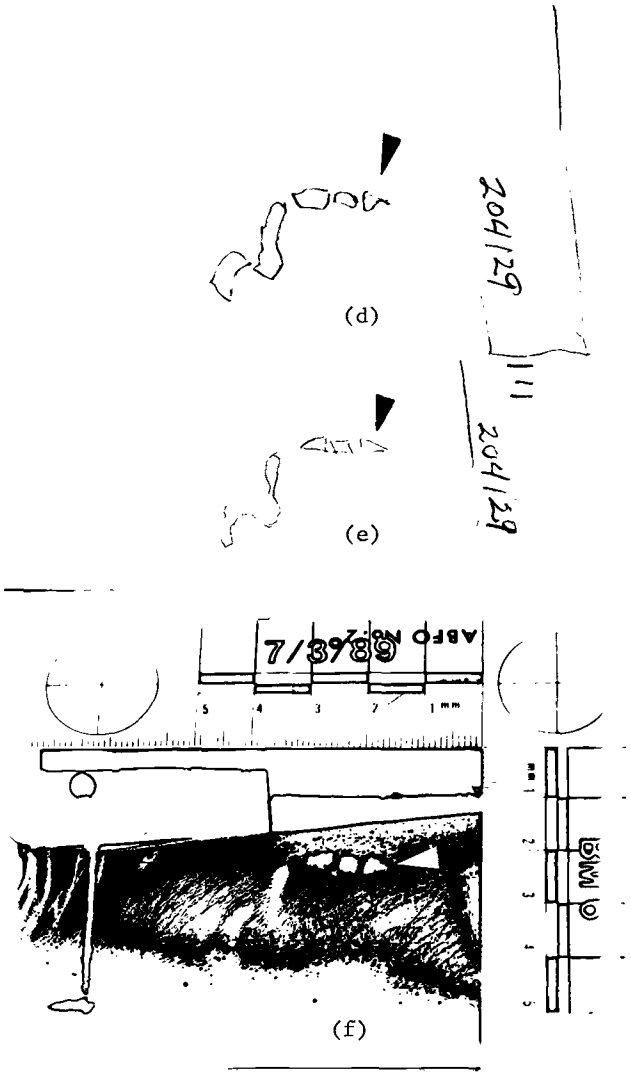

FIG. 5—*Continued.*

We found that when enlarging onto Kodalith film, our times were between 0.5 and 6 s at *f* stop 4.5. The contact printing times were approximately 6 s, and the contact printing times for generating a toneline film positive were between 10 and 40 s, depending on the film density.

Our final six bite marks on four coroner's cases were photographed using our previously recommended procedure. Of those, five (83%) yielded useful toneline overlays. The "useful toneline overlays" varied from bite mark to bite mark. Figure 4 shows bite marks from two different coroner's cases. Although the quality and clarity differ, they are equally

effective. When the toneline procedure fails, it does so totally, providing no usable visual information.

Our procedure seems to work better on black skin than on white skin, although our only bite marks on whites were on living "victims," inasmuch as we had no non-black coroner's cases.

The portion of our study dedicated to demonstrating the subjectivity of current dental examination methods is quite convincing. The tracings made by our four volunteers were compared with each other, a toneline film positive, and a photograph of the traced bite mark (Fig. 5). All four tracings were relatively accurate, and a general outline of the teeth was drawn by each observer.

Evaluation was based on the detail, shape, size, and selection of marks that were traced. In all four bite marks, the most accurate tracings were produced by the artist, who was the most able to look at the photographs and record minute subtleties in a mark. The dentist was also able to trace the bite marks accurately, yet his drawings lacked the details present on the artist's renderings and those on the toneline film positives. The retired police officer recorded only basic shapes, while the secretary sometimes missed basic shapes entirely.

When the four tracings were superimposed, an excellent impression of the mark materialized. Differences in the tracings appeared as well. Methods of identifying a tooth varied from simply drawing a square to sketching three independent circles. These subtleties in a mark can be crucial. All four participants drew various teeth at dissimilar angles. Alone, this factor of the alignment of the teeth in the arch could exclude a prime suspect or include an otherwise innocent individual.

The significance is not the *degree* of disparity between tracings. The fact that there *are* differences, regardless of the extent, is sufficient to illustrate examiner bias. Conversely, toneline film positives *photographically* document tonal breaks. Artistic ability, knowledge of dental anatomy, and personal bias do not influence the result.

Discussion

From the outset it is important to point out that we wanted to develop a method that was portable and inexpensive, thus permitting any facility with a camera and a darkroom the opportunity to use this technique. Although we suspect that better results are possible with studio lighting, we utilized a camera-mounted flash to increase use of the technique. Furthermore, we wished to eliminate or minimize the human element. More convincing and better results are possible by using manipulative techniques such as "dodging" and "burning"; however, such manipulation would reintroduce subjective interpretation, which we wanted to eliminate.

As one of many methods of comparison, we found the film overlay worked very well (Fig. 6). In analyzing bite marks, we have data which tell us that no two sets of teeth are alike, thanks to differences in the amount of eruption, wear, degree of overjet, and anatomy [*18*]. We also have studies in 1984 by Rawson which indicate that bite marks by human dentition are unique [*2*]. The next problem in analysis is whether the bruising or impression on the skin matches the assailant's dentition.

Furness states that the use of photographs in forensic science studies on bite marks is a satisfactory means of recording the characteristics of a bite, and that it has been used by many forensic odontologists in making comparisons [*19,20*]. Whittaker used photographs and study models and compared them with marks made in wax and on pig skin [*21*]. Bites in wax can be useful but present problems of how hard to press the wax down on the model. Moreover, the mental state of the suspect biting into human flesh cannot be replicated.

Havel started with color slide film, from which he made prints, intermediate negatives, and overlays. He later pressed models of the teeth on articulating paper into soft dental

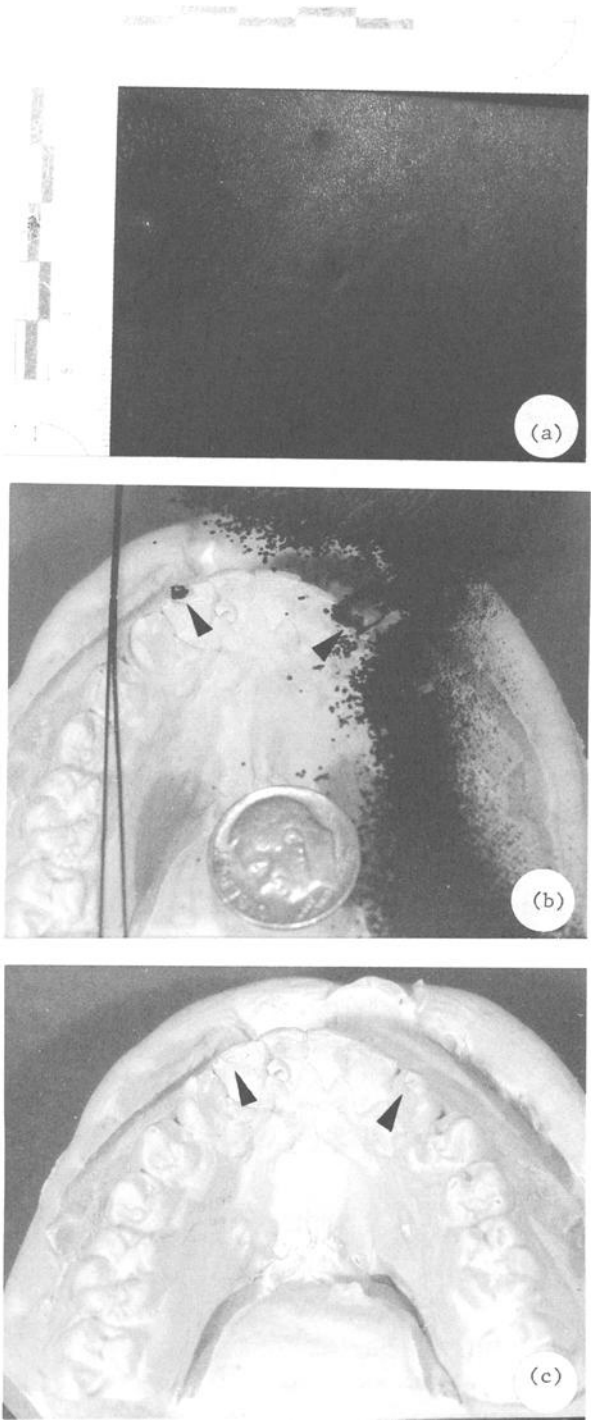

FIG. 6—*A photograph* (a) *of BM9A (Case 204824) and a toneline film positive* (b) *compared. Notice the alignment of teeth 23 and 27 (arrows) on the toneline film positive* (b) *and on the model* (c).

wax. Toneline photographs of the depressions in the wax were then placed on photographs of the bite mark [*22*]. This methodology certainly has possibilities. However, there is still the problem as to how hard one should press the model into the wax. The wax is inanimate and the model has no emotions. If a tooth does not register, does it mean that the suspect couldn't have made the mark, or does one simply try again, pushing harder on subsequent attempts? We found that starting with Technical Pan film negatives of the bite mark, we could make use of black-and-white film's versatility, generate prints when necessary, and make transparencies. We were able to outline photographically what we observed on the body and to place a toneline film positive directly on models of the suspect's teeth for comparison.

David used a scanning electron microscope to analyze bite marks [*23*]. This technique can prove most useful when *depth* is present, but, in the majority of our cases, there have been abrasions without real depth involvement. Moreover, not every coroner's office has a scanning electron microscope available. Our technique can still be used.

Our technique does not resolve all the problems, but it does make the analysis unbiased, since the bite mark itself, as recorded by the camera, is placed over the model, allowing one to peer at the teeth that could have made the mark.

Conclusion

Our studies have shown that toneline photography can outline a bite mark. Moreover, the procedure is inexpensive. It has already proven itself to be a valuable tool in a child abuse case, where it has been accepted in evidence (*Leonard Bradley Sr. v. State of Ohio*). The toneline photograph, along with the already accepted procedure of drawing the mark on an acetate overlay, allowed the judge to come to the decision that the defendent had made the bites. However, there are problems with it inasmuch as there is a loss of detail in shadows and the technique does not always work. It *is* a powerful tool which can be easily duplicated by following our procedure. Its value lies in its ease of implementation as well as in its aid to a judge or jury.

Acknowledgments

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