Original Article

Bitemark analysis: Use of polyether in evidence collection, conservation, and comparison

Gabriel M Fonseca,
Martin A Farah[1],
Sabrina V Orellano-Blaskovich
Departments of Oral Pathology and Forensic Dentistry Team, and [1]Dental Materials and Forensic Dentistry Team, School of Dentistry, National University of Cordoba, Cordoba, Argentina

Address for correspondence:
*Dr. Gabriel M Fonseca, Artigas 818, Departamento A, Cordoba (5000), Argentina.
E-mail: gabriel_fonseca@argentina.com*

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Abstract

Background: While bitemarks are categorical identification evidence, the dynamics of biting, the anatomical location of the bite, and failures in wound records can introduce distorted images and mislead crime investigation. **Materials and Methods:** In this study, 20 bitemarks were performed on dead pig skin and subsequently photographed, excised, conserved, and analyzed using digital comparison (Adobe Photoshop™ 8.0), following the standard procedures (ABFO); physical comparison was also done using polyether (Impregum™; 3M) casts. Study plaster casts of the upper and lower jaws of each subject were taken using type IV yellow densite stone. Polyether was used as impression material to obtain bitemarks, and casts were made from densite stone and polyether. **Results:** Because of its elasticity, polyether casts can compensate for primary or secondary distortions, so that there is a better degree of match when positioning the subject's dental cast. **Conclusion:** Polyether is an alternative impression material and is an excellent option for creating positive casts of the wound for physical dynamic comparison.

Key words: Bitemarks, crime identification, forensic odontology, polyether casts, stone casts, physical comparison, skin distortion

Introduction

Bitemarks are defined as patterns made by teeth in skin, food, or firm but compressible substrates.[1,2] The nature of this bite contact has a major influence on the resultant bitemark.[3] Most bitemarks of forensic interest involve contact between human teeth and skin[1,3] and its analysis assumes that the uniqueness of dentition can be accurately recorded on skin.[2] Bitemarks are observed primarily in violent crimes, especially those involving sexual assault. The perpetrator may bite the victim or the victim may bite the assailant in self-defense. Females are bitten more often than males,[1,4–6] with most of the bites occurring on the breast (33%) and the arms (19%).[7,8]

Depending on the anatomic location, the constitution of the skin, and the victim's reaction, a bitemark may become distorted because of the dynamics of biting, particularly the arch size and shape.[2,6,9–11] In 1984, Rawson and Brooks[12] proposed a classification of human breast morphology owing to its great variability in size and resiliency, both necessary elements for understanding distortion effects. In 2001, Sheasby and MacDonald[3] conducted a forensic classification of bitemark distortions in *primary* (at the time of biting) and *secondary* (when the bitemark is examined or recorded) bites. They report that 'dynamics and tissue distortion are complex and unpredictable phenomena which are closely related because of their simultaneous occurrence during the episode of contact between the dentition and the skin.' They categorically emphasize the need for reconstruction of the victim's known position at the time of biting. However, the reconstruction of a range of positional possibilities is most suitable for the live victim. In dead victim cases, the body position is unknown and the reconstruction of a range of body positions is not readily achieved. Therefore, the potential occurrence of a posture distortion may even be more difficult to explain in the case of dead victims.

Several basic procedures to preserve the forensic dental information are to discern the injury as a potential bitemark; taking photographs and impressions and the eventual excision and preservation of the potential bitemark.[13,14] The clarity and shape of the bitemark may change in a relatively short period in both living and dead victims.[10] While photographs provide the most reliable means of preserving information, they have the inherent limitation that they seek to represent a three-dimensional object on a two-dimensional film.[10] Computer techniques have been used to analyze, calibrate, and record dental images and can prevent mistakes by pattern-associated comparison.[2,15–17] Clearly, these size-matching techniques are only applicable to bitemarks exhibiting *minimal* distortion.[3,18] The preservation of the three-dimensional nature of the bitten area by making custom trays to take impressions, which are then poured in type II stone, has therefore been described as a study aid.[10,13,19] Additional casts may be made with appropriate materials for special studies[13] to simulate bites in different body parts. Use of the suspect's dental casts has also been recommended.[6] Pig skin has been suggested as a good analogue for human skin in forensic research.[20]

In its guidelines the American Board of Forensic Odontology (ABFO) recommends taking dental impressions of the bite site; the impression materials used should have American Dental Association specifications and must be prepared according to the manufacturer's instructions.[13] The common impression materials listed are hydrocolloids and light-body vinyl polysiloxane (VPS).[19] Polyether, has been reported to have excellent accuracy, long-term stability, good elastic recovery, and excellent tear resistance.[21,22] Its excellent hydrophilicity ensures impressions with superior detail reproduction in wet surfaces, including areas that are difficult to access.[23–28] The objective of this report is to demonstrate the accuracy of bitemark impressions obtained using a polyether impression material composing elastic casts. As the material has similar elasticity to that of human skin, it is useful in the analysis of bitemarks having the potential for distortion.

Materials and Methods

Twenty bitemarks were performed by different human subjects on selected resilient-consistency dead pig skin according to the ethical standards of the committee on human experimentation. The pig skin was excised prior to biting. The evidence collection and conservation procedures were undertaken as described in the bitemark investigation protocol. This protocol is designed according to the chronologic basic steps in forensic investigation.

Evidence collection

The bitemark: All 20 bitemarks were photographed by the same operator with a digital camera (Coolpix 2100 Nikon™) using the ABFO No. 2 scale in 300 dpi resolution [Figure 1]. Polyether light-bodied consistency (Impregum™ 31750 – Refill Pack; 3M) and heavy-bodied consistency (Impregum™ 31749 – Refill Pack; 3M) were used as impression material of the skin bitemarks as shown in Figure 2. Only one impression from the bitemark was taken to avoid unnecessary manipulation, distortion, and loss of evidence. This procedure to record the marks (evidence preservation) was done as bitemarks have a natural tendency to disappear due to tissue regeneration (live victim) or putrefaction (dead body). A monophase technique was performed according to the manufacturer's recommendations[29] and custom trays were hot-water adapted (60°C) with extra-hard pink wax (Beauty Pink™, Moyco Technologies Inc.). As this was an experimental design, no swabs for DNA recovery were considered. However, the authors recommend that in actual investigations the basic steps and protocols be followed.

The biter suspect: Study plaster casts of the upper and lower jaw from each individual were made using type IV yellow densite stone (Prima Rock™). Casts were scanned using a flatbed scanner (Hewlett-Packard™ Scanjet 3770) with the same metric reference as shown in Figure 3a and b.

First die cast (densite stone casts – control sample): Each polyether impression was carefully poured using type IV yellow densite stone (Prima Rock™) and slight vibration. The densite type IV die stone was chosen for its good physical properties. The small particle size as well as the powder/water ratio (100 gr/20 ml) shows the quality of the material. The working time is approximately 6–8 min, while the setting time is 12 min. Another characteristic of the densite type IV die stone is its low expansion, which reaches 0.13%. Furthermore, its compressive strength increases from 55 to 117 Mpa in just 48 h. These properties ensure dimensional stability and durability. Two densite stone casts were poured. The first one was considered as an 'examination cast' and second one as an 'untouched cast' (preserved and stored in a secure place). The examination casts were scanned using ABFO No. 2 scale as shown in Figure 3c.

Second die cast (polyether model): After the examination and the creation of the densite stone casts, their impressions were obtained using the polyether technique as described in the section A above. Positive casts were poured with polyether light-bodied consistency (Impregum™ 31750 – Refill Pack; 3M) using a paintbrush and slight vibration to ensure the flow of the polyether. Figure 3d shows models scanned using the ABFO No. 2 scale.

The same operator performed all the impressions, and mixed and poured all the casts according to the manufacturer's instructions.

Bitemark comparison

Digital method

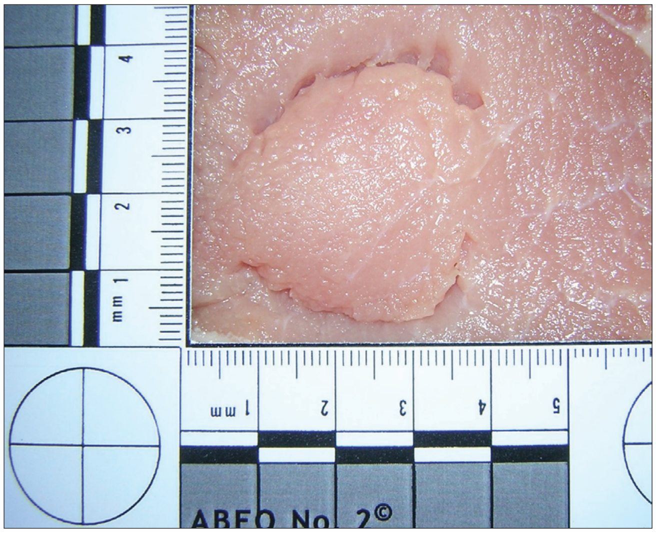

Figure 1: Bitemark on pig skin photographed using ABFO No. 2 scale

Figure 2: Polyether light- and heavy-body consistency (Impregum™) used as impression material on custom trays (made of extra-hard pink wax)

Table 1: Degrees of match using digital and manual comparison for each case

Case# (n)	Digital comparison (Adobe Photoshop™ 8.0) degree			Manual comparison degree	
	BM photograph	1st die cast (DS)	2nd die cast (PE)	1st die cast (DS)	2nd die cast (PE)*
1	2	3	3	2	2
2	3	3	3	3	1
3	5	4	4	4	2
4	5	5	4	4	2
5	3	3	3	3	2
6	4	4	3	5	2
7	4	4	4	4	2
8	2	2	2	2	1
9	1	1	1	1	1
10	3	3	3	4	2
11	4	3	4	3	1
12	2	2	2	2	2
13	4	3	3	3	2
14	2	2	1	2	1
15	2	2	2	2	1
16	3	4	3	3	2
17	4	4	3	4	2
18	5	5	5	5	2
19	2	2	2	2	2
20	3	2	2	2	2

BM = bitemark; DS= densite stone; PE: polyether; *shows better degrees of match (1/2) than the other comparisons (manual comparison with polyether die casts)

Table 2: Total degrees of match discriminated by comparison mode

Degrees of match	Digital comparison (Adobe Photoshop™ 8.0) *n* = *20*			Manual comparison *n* = *20*	
	BM photograph	1st die cast (DS)	2nd die cast (PE)	1st die cast (DS)	2nd die cast (PE)*
1	1	1	2	1	6
2	6	6	5	7	14
3	5	6	8	5	0
4	5	5	4	5	0
5	3	2	1	2	0

BM = bitemarks; DS= densite stone; PE= polyether; *shows absence of 3, 4, or 5 degrees (manual comparison with polyether die casts) (probable-, poor-, or dissimilar-degree)

Digital photographs of skin bitemarks and the scanned images of first and second (densite stone and polyether) die casts of the same subject were compared using Adobe Photoshop 8.0™ software (Adobe System Inc., USA) with superimposition as the method. Metric references were calibrated, but no digital imaging methods were used to adjust for angular distortion.

Traits were categorized by three operators (to assess inter- and intra-observer agreement) into one of the following types:

1. Extreme-degree match
2. High-degree match
3. Probable-degree match
4. Poor-degree match
5. Dissimilar-degree match

Manual method

The subjects' dental casts were positioned on the bitemarks in the polyether and plaster casts and categorized (degree of match) using the described method. The procedure was performed to minimize the initially distorted patterns of skin. Finger pressure was applied in the polyether casts on the side opposite the bitemark, thus attenuating the expanded areas. Matches need to be achieved easily and should be unforced (accuracy factor).

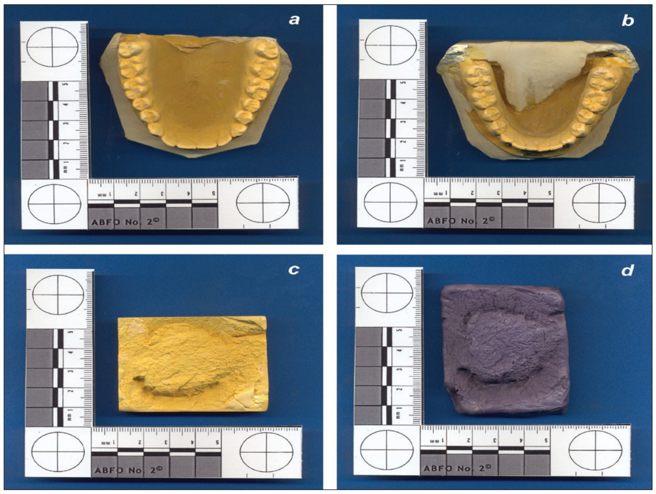

Figure 3: Scanned images of plaster cast of the upper (a) and lower (b) jaw, densite stone cast (c), and polyether cast (d), using ABFO No. 2 scale

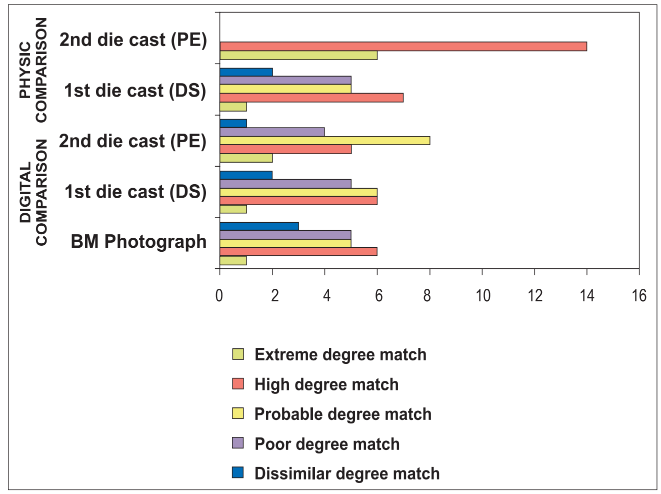

Figure 4: Total degrees discriminated by comparison mode. BM = bitemark; DS= densite stone; PE = polyether

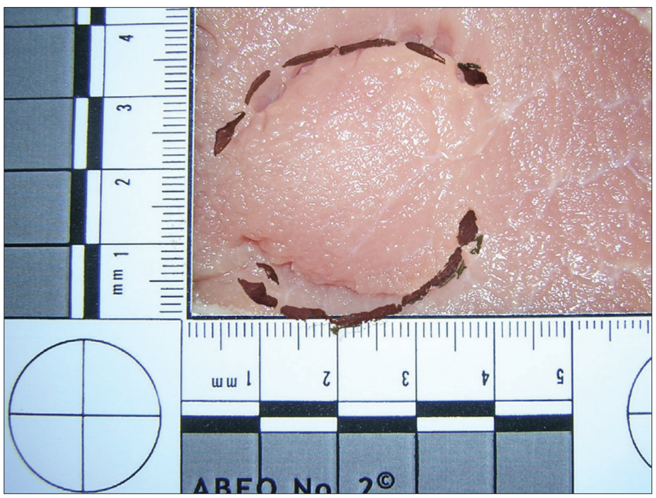

Figure 5: Superimposition of scanned jaws model on bitemark photograph (Adobe Photoshop™ 8.0). Primary distortion (at the time of biting) is shown on the left side

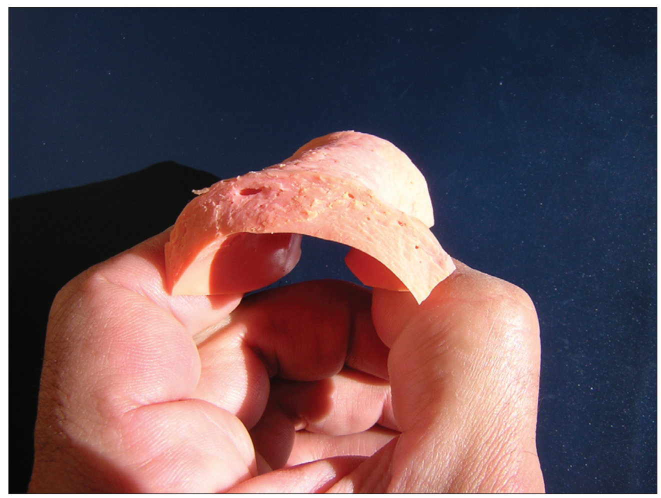

Figure 6: Elasticity of polyether cast (Impregum™)

Figure 7: Subject's dental cast positioned on plaster cast (densite stone - control sample). This manual comparison was categorized as a poor-degree match

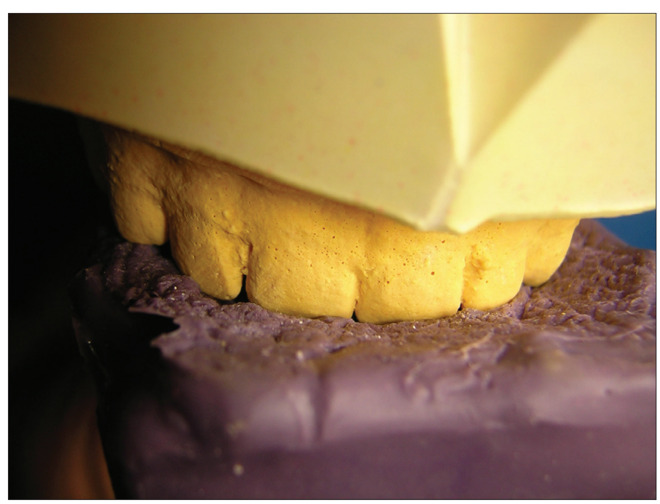

Figure 8: Subject's dental cast positioned on polyether cast (same case as in Figure 7). Elasticity of polyether allows a high-degree match

Table 3: Descriptive statistics of the degrees of match in digital and manual comparison

Measures	Digital comparison (Adobe Photoshop™ 8.0)			Manual comparison	
	BM photograph	1st die cast (DS)	2nd die cast (PE)	1st die cast (DS)	2nd die cast (PE)
μ	3.150	3.050	2.850	3.000	1.700
σ	1.182	1.099	1.040	1.124	0.470
σ^2	1.397	1.208	1.082	1.263	0.221
Range	4.000	4.000	4.000	4.000	1.000
Max	1.000	1.000	1.000	1.000	1.000
Min	5.000	5.000	5.000	5.000	2.000

μ = Mean; σ = standard deviation; σ^2 = variance; BM = bitemark; DS = densite stone; PE = polyether

Statistics

Descriptive statistics (i.e., arithmetic mean, standard deviation, variance, range, maxima, and minima) were used to describe the obtained data. Tabular description and graphical display of data were used to facilitate comparisons.

False-positive

The manual comparison of the polyether models of all 20 subjects was categorized into one of five types according to degree of match. Category 5 (dissimilar-degree match) was considered a negative match and categories 1–4 (extreme-/high-/probable-/poor-degree match) were considered false-positive matches.

Results

Tables 1-3 and Figure 4 show the differences between the manual comparison with polyether models and the other comparisons. The digital and manual comparisons of the densite stone casts reveal the distortions at the time of biting (primary distortions) [Figure 5]. Figure 6 shows that the polyether cast compensates for these distortions because of its elasticity, providing a better degree match when positioning the subject's dental cast.

After digital comparison of the bitemark photographs, cases 1, 8, 9, 12, 14, 15, and 19 (35%) were categorized as type 1 or 2 (i.e., extreme- or high-degree match); cases 2, 5, 10, 16, and 20 (25%) were categorized as type 3 (i.e., probable-degree match); and cases 3, 4, 6, 7, 11, 13, 17, and 18 (40%) were categorized as type 4 or 5 (i.e., poor-degree or dissimilar-degree match).

There are no substantial differences between digital comparison of densite stone casts, and polyether casts. Cases 3, 11, and 13 (15%) achieved better matches in digital comparisons of densite stone casts and polyether models than the digital comparison with photographs.

While manual comparison with densite stone casts did not show better results than with digital comparison as shown in Figure 7, the polyether models (on manual comparison) show type 1 or 2 matches (i.e., extreme- or high-degree matches) in 100% of the cases [Figure 8].

Comparison of the results of all 20 subjects show that there were no false-positive matches.

Discussion

While bitemarks produced in a firm substrate such as cheese or chocolate can be analyzed by the standard quantitative techniques because there is minimal distortion, bitemarks on a highly deformable substrate like skin are more difficult to analyze.[3,30,31] In fact, many authors have established that human skin is a very poor substrate for retaining clear impressions, making it impossible to use in a scientific analysis of skin wounds.[10,32,33] In the authors' experience, primary distortions have been found in photographs, densite stone casts, polyether casts, and all the comparisons of the subject's plaster casts. The scanning of casts may decrease the risk of error in the bitemark photographic record (secondary distortions) as seen in cases 3, 11, and 13. In forensics, there are invasive procedures that allow the preservation of three-dimensional images of bitten areas;[34,35] obviously, this may be performed on a deceased victim's skin and after the pathologist has completed the autopsy.[10,36]

According to Pretty and Sweet,[37] bitemark evidence is not sufficiently reliable, given the inaccuracy of techniques and errors in protocol. Literature reports many cases of technical infractions in the processing and recording of bitemarks.[10,38–40] Pretty also[41] indicates that there are over 60 reported bitemarks per year, of which only an average of 15 are suitable for further work and only 10 hold sufficient unique detail for a precise analysis.

When investigators or authorities have identified the potential biter, his or her dental records provide the basis for comparison with the bitemark. Ideally, a suspect's dental casts would be directly compared to the tooth-created indentations in the patterned injury on the skin, but this situation is extremely rare.[42] Impression of the mark poured in dental stone to create models is the first step for comparison.[10,13] According to the literature, since 1963 it has become customary to construct two casts (untouched and examination casts) and to use a rubber model to study dynamic bite action.[43] The ABFO has recommended the creation of additional casts in appropriate materials for special studies.[13] A first die stone cast provides primary bitemark conservation because of its dimensional stability. The need for reproducing the elasticity and deformability of skin surface is achieved using polyether die-cast impressions of the densite stone casts, which can withstand longer time periods benefiting comparison procedures. Because it can attain its original size and shape even in highly deformable rates, polyether is a good alternative both as an impression and pouring material. It has the capacity for superior detail reproduction. When correctly processed, it is an excellent option when obtaining positive models of the wound for physical dynamic comparison.

Blackwell *et al*. affirm 'the natural tendency to see what one wants to see, thereby tempting examiners to over-interpret bitemark evidence, has led to serious difficulties when bringing such evidence before the courts.'[30] This work does not intend to suggest that the conventional impression, photographic, or digital techniques be replaced. While an objective method[44] of analysis has emerged with the advent of DNA analysis, polyether may supplement DNA procedures within the limits of its application because of its strength in recovering bitemarks.

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