Bitemark analysis in legal medicine - literature review

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Abstract: Bitemark analysis is a complex and time consuming task, as each bite produces individual, well defined aspects, different even from one bite to another. In order to analyze a bitemark three main characteristic types are to be used: class characteristics, variations from the standard human bitemark model and individual characteristics. Often the quality of a certain bitemark is very poor so that every single quantifiable aspect is of the utmost importance.

This review tries to provide a few essential tools in managing a bitemark morphological analysis from a medical-legal point of view. Other techniques, such as specialized photograph techniques, impression, DNA analysis, histopathology etc even tough are not detailed here can also provide crucial data in finding out the perpetrator; their exhaustive presentation is not feasible in a single article.

Key words: bitemarks, variations, class characteristics, distortions, dental characteristics

In order to properly diagnose a bitemark and to make it usable in a forensic case the expert should answer to the following answers: Is it a bite mark?, Is it a human bitemark? Is it an adult or child bitemark? Does it have individual traits that can be of use in identifying the perpetrator? The answer to these questions often resides in a proper bitemark analysis and it cannot be done without an in depth knowledge of the basic bitemark characteristics. This review tries to provide a few essential tools in managing a bitemark analysis from a medical-legal point of view.

Human dental characteristics and nomenclature

In order to analyze a bitemark three main characteristic types are to be used: class characteristics (gross, obvious characteristics, useful for determining if a certain lesion is a bitemark and if it is human), variations from the standard human bitemark model (e.g. central ecchymosis, pale lingual area, etc), and individual characteristics (useful in determining the aggressor).

The basic human dental anatomy, useful in bitemark characteristics determination is presented in tables 1, 2. The nomenclature for adult (tables 1, 2) and child (tables 3, 4) denture are also given.

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### Table 1. Characteristics of upper arch teeth [1, 2, 3, 4, 5]

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| Morphology |  
|---|---
| Widest tooth mesiodistally; larger than the lateral incisor and not as convex on its labial surface, appearing more rectangular or square. Has a sharper mesial incisel than distal incisel angle. When newly erupted into the mouth, the incisel edges have three rounded features called mammelons that disappear with time as the enamel wears away by friction. Two developmental grooves are on the facial surface; are leaving linear/rectangular traumatic marks of about 8-9 mm |
| Aspect much like the maxillary central incisor, except in size: it is shorter, narrower, and thinner; distoincisal angle is well-rounded with its curvature continuing to the cervical line; are leaving linear traumatic marks of about 6-7 mm; being shorter than CI; the traumatic marks are less intense, sometimes even missing |
| It’s the longest human tooth. The incisel edges of the central and lateral incisor are nearly strait, the cuspid has a definite point, or cusp; there are two cutting edges, the mesioincisal and the distoincisal, the latter being the longer of the two; are leaving well defined traumatic marks, rounded, right at the place where the dental arches are making the sharpest angle. |
| Two cusps on maxillary first premolars, the buccal (closest to the cheek) cusp being sharp enough to resemble the prehensile teeth found in carnivorous animals. (Ash, 2003).There are no deciduous maxillary premolars; instead, the teeth that precede the permanent maxillary premolars are the deciduous maxillary molars. The traumatic mark is located (if present) to the edges of the bite mark; it consists of a lateral mark produced by the buccal cusp that is in line with the others and sometimes a smaller, medial mark produced by the lingual cusps |
| The maxillary second bicuspid, resembles the first bicuspid very closely, just a little smaller (Dental Volume 1 - Dentist training manual for military dentists, 2008). Not present in deciduous dentition. The cusps are not as sharp as the maxillary first bicuspid and have only one root. It usually doesn’t leave traumatic marks |
| There are usually four cusps on maxillary molars, two on the buccal and two on the palatal side. There may also be a fifth smaller cusp on the palatal side known as the Cusp of Carabelli. The cusps are large and prominent, and the broad grinding surfaces are broken up into rugged appearing ridges and well-defined grooves. An oblique ridge, which is not present on the bicusps, appears here (it also appears on maxillary second and third molars) |
| There are usually four cusps on maxillary molars, two on the buccal and two palatal (Ash, 2003). Because it has the same function as the maxillary first molar, its characteristics are basically the same. The second molar is smaller, the occasional fifth cusp of Carabelli does not appear, and there is a marked reduction in the size of the distolingual cusp |

| Basic characteristics |  
|---|---
| The tooth is much smaller than the maxillary first or second molars, with an occlusal outline that is nearly circular |
These are the first permanent teeth to erupt, replacing deciduous teeth, and are the smallest teeth in either arch; are leaving small linear or rectangular traumatic marks of about 5,5 mm

A little wider mesiodistal than the mandible central incisor, and the crown is slightly longer from the incisal edge to the cervical line; are leaving linear/rectangular traumatic marks of about 6 mm

Has a single cusp, resembling the prehensile teeth found in carnivorous animals; located at the inflexion angle on the bite mark; the marks are prominent, circular, triangular or rectangular

Has two cusps, one buccal large and sharp and one lingual small and resembling a small canine. The traumatic mark is usually located at the edge of the dental arcade and has only one impression, given by the buccal cusp

Has three cusps, one buccal and two lingual, well developed, arranged in a Y pattern

First permanent tooth to erupt. Usually presents five well-developed cusps two buccal, two palatal and one distal. The mandible first molars are the most common carious teeth and the most common teeth to undergo endodontic treatment or extraction. Up to 45% of all extracted teeth are mandible first molars (Zadik Y, 2008)

There are usually four cusps on maxillary molars, two buccal and two palatal

There is great variance among third molars, and a specific description cannot be made accurately
Main class characteristics used in bitemark analysis are:
(1) **Shape** of the traumatic mark, usually rounded, rounded-ovular, doughnut-like or mirrored U-shaped arcades;
(2) **Arcade dimensions**: male superior arcade (measured between cuspidal midpoints) usually is about 32.3-32.6 +/- 2.3 mm\(^6\) with limits between 21.3-41 mm\(^7\). Male inferior arcade is smaller, having in average about 25 mm +/-1.85 with limits between 11.6 and 33 mm\(^7,8\). Female dental arches are smaller than males in average with 1.6 mm for the superior arch and 1 mm for the inferior one, but there is a strong overlap between these values making it practically impossible to differentiate one another. Also interracial and age group difference (over 12 years) are not significant statistically.
(3) **Bitemark dimensions**: between arcade edges the distance is about 35 - 40 mm. The average maximum opening diameter (between superior and inferior central incisors) is usually 42 - 45 mm but it can overlap 70 mm if prominent skin folding, lax temporo-mandibular articulation etc. are present\(^4\). Skin surface may alter bitemark dimensions - if the bitten surface is plane the maximum opening is smaller than if it is made on a curved surface (breast, buttocks)
(4) **Teeth marks present**: in bitemarks usually there are up to six teeth traumatic marks on each arcade (four incisors and two canines). Less frequent are found premolars and only in very rare cases molars; the shape of the traumatic marks depends on the specific characteristics of the teeth and is presented in Tables 1 and 2; the type of lesions and degrees of impression are presented in Table 5.

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Description</th>
<th>Impression</th>
<th>Description</th>
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<tbody>
<tr>
<td>Hemorrhage</td>
<td>Small bleeding spot</td>
<td>Clearly defined</td>
<td>Significant pressure</td>
</tr>
<tr>
<td>Abrasion</td>
<td>Undamaging mark of skin</td>
<td>Obviously defined</td>
<td>First degree pressure</td>
</tr>
<tr>
<td>Contusion (bruise)</td>
<td>Blood vessel rupture</td>
<td>Quite noticeable</td>
<td>Violent pressure</td>
</tr>
<tr>
<td>Laceration</td>
<td>Punctured or torn skin</td>
<td>Lacerated</td>
<td>Skin violently torn from body</td>
</tr>
<tr>
<td>Incision</td>
<td>Neat skin puncture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avulsion</td>
<td>Removed skin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artifact</td>
<td>Bitten-off piece of body</td>
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(5) **Teeth arrangement**: medial, on each arch there are four rectangular or linear marks corresponding to the incisors in a wide circle arch; lateral and posterior are the canine marks, more prominent, rectangular, triangular or rounded; here arch curves most sharply; posterior and lateral are the premolar and molar marks (if present). Details are presented in Tables 1 and 2.
(6) **Dental formula**: adult dental formula is I2/2, C1/1, P2/2, M3/3; determining it is very useful in differential diagnosis with animal bite marks.
(7) **Arch impression**: usually the maxillary teeth are leaving bigger traumatic marks and the mandible teeth more intense ones.

By using class characteristics one can differentiate adult human bite marks from children bite marks, animal bite marks or other traumatic lesions with similar characteristics.

**Children bite marks** (below six years). They have small, more rounded arches, smaller teeth (central maxillary incisors of about 6.5 mm, lateral maxillary incisors of about 5.3 mm,
mandible incisors of about 4 – 4.5 mm), greater spaces between teeth, medium inter-canine distance of about 28-29 mm (maxillary arch) and 22.6 mm (mandible arch) (values for children of 3-6 years [8] and bitemark dimension of about 30 – 35 mm. For children of 7-11 years of age the bitemark typically is mixed with larger incisors (permanent dentition) and smaller posterior teeth (deciduous dentition) [1]

**Animal bite marks** are presenting various traumatic aspects depending on species, race, feeding behavior, dimensions, etc. Dogs make the commonest life threatening animal bite-marks in Romania, others being met only accidentally (horse, lynx, bear, etc). Dog bitemark morphological variation is quite large depending on teeth dimension, arch dimension and form or aggression type, but has several distinctive characteristics, detailed below:

- **Dental formula**: I3/3, C1/1, P4/4, M2/3;
- **Teeth arrangement and description**: six small incisors, places on a slightly curved circle arch; between incisors and canines is a space, larger on the maxilla; here the arch is curving the biting.
- **Arch shape**: typical they are long and narrow
- **Teeth marks**: The incisors are leaving up to 6 small traumatic marks, linear or rectangular; usually present in defensive bites; often aren’t present because the incisors are much smaller than the canines; if present (all 6) a human bite can be excluded. Canines are making prominent traumatic marks (punctures, lacerations, avulsions). Premolars and molars are often leaving traumatic wounds because the dog’s mouth aperture is very large (more frequent in offensive biting)
- **Claw traces** – often present in dog aggression; sometimes the differential diagnosis with bite marks is quite difficult.
- **Trauma mimicking bite marks**
- Often in literature are cited lesions mimicking human or animal bite marks whose differential diagnosis is quite difficult:
  - **Traumatic lesions**: burns (cigarette burns, electrical marks, cao gio), passive compression (pennies, end of a steel pipe, base of an ashtray);
  - **Animal lesions on the living**: hoof marks – cows, horses, claws or on the dead (insect bites, other scavengers) [4]
  - **Weapon lesions**: bullets, knifes, tasers [9]
  - **Medical interventions**: defibrillators, EKG electrodes;
  - **Medical conditions** (Tenia circinata (ringworm), impetigo, erythema multiforme, erythema annulare, granuloma annulare, pityriasis rosea annular lichen planus, contact allergy, urticaria, herpes, etc [4, 10]

**Individual characteristics**

An individual characteristic is a differentiating feature, useful in perpetrator identification, suspect elimination or narrowing down the suspect list, depending on their distinctiveness. The use of digital photography allows the examiner to establish a set of parameters and with them to further compare a certain bitemark with suspect’s dentition. The used parameters depend mostly on the quality of the bitemark: a complete one, with many distinctive features is more useful than an incomplete one; a incomplete one but with distinctive features is extremely useful in perpetrator identification; a complete one but without distinctive features may be of a less help than an incomplete one but with clearly distinctive features.
Most used individual characteristics are:
tooth morphology (cuspid to cuspid, x/y axis, width, thickness, rotation, labio-lingual position), arch width (measured between cuspids) arch shape (usually C, U or oval shaped), intertooth distance, missing teeth, spatial analysis - distances between different teeth from the same arch (quantified from tooth shape center, very useful as every distance is a separate parameter).

Fig. 1 Individual characteristics of a human bite.

Variations from the standard human bitemark model

Only rarely a bitemark presents all class characteristics with no variation or distortion. A distortion is called a modifying bitemark event. There are two main distortion types: primary, determined by an actual bitemark event and secondary, due to incorrect bitemark examination or recording [11]. A primary distortion result is called variation; a variation is obtained by combining in various degrees different types of primary distortions, directly or mediated by secondary ones, as presented in Figure 3.

Primary distortions are determined by the biting per se. They are seen in almost every bitemark and are presenting a high morphological variation. They have two main components: (1) dynamic distortion, due to the movements appearing in the biting process and (2) tissue distortion, due to skin characteristics [11].

1. Dynamic distortion. The degree of movement between the teeth and the victim’s skin can range from practically none (case in which the number of variations is usually minimal) to maximum, in violent altercations with a high degree of movement from both the victim and the perpetrator.
Also in dynamic distortion there can be other factors involved, like the perpetrator’s tongue
or lips, victim’s clothes, etc. Dynamic distortion are determined mainly by: victim movements, victim’s clothes, biting force, biting adhesion, biting particularities, perpetrator tongue and lips use, associated traumatic lesions and mechanisms.

2. **Tissue distortions** are determined by different physiological, pathological or posttraumatic characteristics of the bitten tissue. The phenomenon of stretching and relaxing produces a variable degree of tissue distortion in every bite mark. Also tissue distortions can be involved in the appearance of particular types of secondary distortions, as they can be associated with either anatomical localisation (postural distortions) or skin characteristics (postural and time-related distortions).

2.1 **Physiological characteristics** are represented by: skin thickness (on a thinner skin is easier to notice and the lesions are more obvious, more intense than on a thicker tissue), anatomic localization, skin elasticity, age (elderly or children skin is easier to traumatize), sex, etc.

2.2 **Pathological characteristics** are those produced by various cutaneous or general pathological conditions that can alter the bite mark appearance:

- **Coagulation factors disorders**, congenital (hemophilia, Von Willebrand disease, Bernard-Soulier syndrome, Glanzmann thrombasthenia) or acquired (acute or chronic hepatic insufficiency, Vitamin K deficiency, etc)
- **Platelet disorders** both congenital (Glanzmann's thrombasthenia, Bernard-Soulier syndrome, gray platelet syndrome, delta storage pool deficiency) or acquired myelodysplastic syndrome or other bone marrow disorders, immune thrombocytopenic purpura /ITP, thrombotic thrombocytopenic purpura /TTP, hemolytic-uremic syndrome/HUS, paroxysmal nocturnal hemoglobinuria /PNH, disseminated intravascular coagulation /DIC, heparin-induced thrombocytopenia /HIT).
- **Elastic fiber disorders** (Ehlers-Danlos syndrome, Marfan syndrome, etc)
- **Small vessel disorders**, etc

2.3 **Posttraumatic characteristics** are tissue alterations due to the traumatic event not directly connected with the biting kinetics:

- Tissue edema as well as other inflammation signs
- Scarring and healing phenomena.

**Variations and distortions**

As stated above by combining in various degrees different types of primary and secondary distortions are obtained different variations from the standard bite mark. These variations can modify significantly both individual and class characteristics, making it difficult to identify correctly the perpetrator or even to say if a certain lesion is a bite mark.

Usually every variation is produced by one or two main and one or more ancillary mechanism/s (distortion/s). We will try to categorize them by the main involved distortion/s:
Variations mainly due to primary dynamic distortions can also be categorised in three main types: associated-events distortions, when after a bitemark a supplemental lesion appears (variations 1-5), number-variations, when the number of lesions is different from 1 (multiple bites or incomplete ones, variations 6 - 10) and other, with mixed, incomplete or specific characteristics (11-14)

1. **Central ecchymosis (contusion).** It appears like a central ecchymosis between the two dental arches, mainly produced by tissue compression between the arches.

2. **Pale lingual area (tongue thrusting).** Appears like a pale area inside the central ecchymosis; it is determined by blood extravasations due to tongue pressure during central ecchymosis formation, leaving the pressured area pale.

3. **Linear abrasions/contusions.** Appearing like eccentric contusions, radiating from the dental arch impressions; are sliding wounds, made by the teeth as they are trying to grasp the skin between them. All three above are not very useful in bitemark characteristics determination, but their presence may help the differential diagnosis with bitemark mimicking traumas.

4. **Lingual markings:** They are centripetal lesions, radiating inward from the dental arch impressions, representing the outlines of teeth’s lingual surface; they may appear as small contusions, abrasions or pale areas outlined by thin red or violet-red ecchymosis. They are useful mainly for individual characteristics determination as they can reveal particular teeth aspects.

5. **Weave patterns:** sometimes bitemarks can have a textured aspect, due to biting throughout different fabric types; usually not very useful as they are distorting the pattern and preventing saliva deposition.

6. **Partial bitemarks:** dental arch impressions are not complete; there are three main variants: (1) **one-sided** bitemarks (left or right), usually determined by anatomical geography variations, (2) **one arch(unilateral)** bitemarks, determined by missing removable dentition, interposed clothing, anatomical geography variations, etc and (3) **randomly missing teeth** bitemarks, due to missing teeth in the bitter, poorly inflicted wounds, interposed clothing, etc. Usually they are not very useful for characteristics determination as the bitemarks are incomplete; but, if one can find a repetitive pattern of expression, if the victim has been bitten more than once, this can be useful for individual characteristics determination.

7. **Faded bitemarks:** opposed dental arches can be seen but individual tooth marks are not present; usually present in thin skin areas, especially in children and women or during bitemark healing. As some important characteristics are faded, their presence makes the identification more difficult.

8. **Double bite (bitemark within bitemark):** two concentric bitemarks are present, usually associated with linear abrasions; it occurs when, after the victim’s skin in captured between the teeth, it partially pulls free and a second bite is applied in the same place.

9. **Multiple bites:** very useful as certain repetitive pattern may be used in perpetrator identification.

10. **Superimposed bites:** the traumatic overlap can degrade bitemarks details making them more difficult to analyze.

11. **Uninterrupted arches** are usually appearing when the skin is very thin or the bite force is very high. Has a difficult differential diagnosis with traumas mimicking bitemarks.

12. **Avulsive bites:** are difficult to interpret as the lesion usually will not retain most of the class characteristics; even though are infrequent in humans the are frequently met in animal bites.

13. **Postmortem bitemarks:** are yellow, parchment-like, translucent, without vital reaction, without scabs.

14. **Bitemark associated lesions:** frequently found are grasping lesions (the victim is hold in place), scratch marks, hair rend, etc. Some of them can alter the bitemark aspect or can mimick some bitemark characteristics.

Variations mainly due to primary tissue distortions:

1. **Acute inflammatory reaction:** appears within a few minutes after bitemark infliction and usually lasts up to 24 hours. When is present other traumatic marks can be harder to identify as the entire traumatised area can appear as a solid red oval.

2. **Teeth indentations:** skin depressions determined by the teeth; usually are fading out within 20 minutes and are rarely seen in forensic services; if seen they can reveal important information about the perpetrator.

3. **Excessive ecchymosis and abrasions:** the contusion extends beyong the traumatised area, usually associated with different pathological conditions or when the trauma is made on a previously lesioned tissue.

4. **Healed bitemarks:** sometimes a hypo/hyperpigmentation can be seen at the traumatised place. Also, if lesions are deeper some scarring may occur resulting in a variation with mixed, primary and secondary distortion causes.
Secondary distortions

Secondary distortions are altering bitemark events occurring after biting, not directly related to biting dynamic nor with tissue modifications. The alterations often are not permanent as they can be corrected by modifying evidence examination and/or recording.

Three main secondary distortion types are more frequently met in practice: time-related distortion, postural distortion and recording distortion [11].

**Time related distortion** appears when certain bitemark characteristics are changing over time. Main mechanisms associated with it are extensive bruising that can alter bitemark’s shape and tissue scarring, in deep lesions, with subsequent contractions. Frequently time-related distortions are a supplemental step in the development of variations mainly due to tissue distortions: they are induced by primary distortions and contribute to the development of variations together with the primary distortion that produced them.

**Postural distortions** are appearing when a bitemark is recorded in a position different from the one it was made (fig. 4). In order to minimize it during recording the body should be in a position close to the biting position. Main types are plane, curved and intricate postural distortions:

*Plane postural distortions* – appears during linear variations of the bitten area, usually in flexor-extensor areas. Distortion in this case can be corrected with the following formula, if the position in which the biting action was performed is known: \( d = D \times x \), where \( d \) = dental area, \( D \) = distorted area, \( x \) = stretching degree.

*Curved postural distortions* – typically appearing when the bitten area is curved (breasts, buttocks, cheeks, etc). Most postural distortions are combined, postural and curved, being very hard to remove them completely.

*Intricate postural distortions* – a biting plane intersects more than one biting areas (for example the nose and cheeks, or more fingers); on every bitten surface there are partial bitemarks with both curved and plane postural distortions and also missing bitemark parts.

**Recording distortion** is due to incorrect bitemark recording. The most frequent is photographic distortion but other are also possible (impression distortion, histological distortion, etc)

**Photographic distortions** are due to incorrect photo making. In order to minimize it and to be able to correct it afterwards if a distortion is noted the following rules must be applied: the photographs are made perpendicular on the bitten surface, always use a scale that is on the same plane with the bitemark to eliminate parallax distortion. There are four types of photographic distortion as presented in Table 6. Other forms of recording distortions are much less frequent in day-to-day practice.
Table 6. Photographic distortions [5]

**Bitemark morphological analysis algorithm**

As a summary, when dealing with a traumatic lesion that probably is a bitemark the following actions must be done:

1. Photograph the lesion as noted above; always use a scale.
2. Confirm the lesion is traumatic (not determined by a disease or by cosmetic means).
3. Confirm the lesion is a bitemark (by analyzing the presence class characteristics; very useful in this stage is a bitemark quality analysis).
4. Confirm the lesion is a human bitemark (by analyzing the class characteristics).
5. Analyze and try to minimize the distortions
6. Analyze the variants and their effect on the quality of the bitemark.
7. Analyze the presence of individual characteristics and their usefulness.
8. Use all other techniques that can bring supplemental information about the perpetrator (saliva, DNA, impressions, etc)

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**References**

12. ABFO. *ABFO Bitemark Methodology*