

Methods in bitemark analysis

Literature review

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MASTER THESIS

UNIVERSITETET I OSLO

May 2017

Foreword

I have written master thesis about different methods in bitemark analysis. I was interested to know about the role of dental professionals in forensic team and how dental findings can serve the justice system.

Bitemark analysis is used widely in the judicial system to establish a connection between the suspect and a crime. Experts believe that the bitemark that is registered in the skin captures the uniqueness and characteristics of the dentition. In recent years, new techniques have been introduced to this field to make the bitemark analysis more reliable and precise. In this literature review, I have discussed the conventional and new methods that are used in bitemark analysis.

I would like to thank my supervisor Sigrid Ingeborg Kvaal, Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Thank you for your supportive guidance.

Oslo, 12 May 2017

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Abstract

Bitemark analysis have a significant role in forensic dentistry. There are different methods of bitemark analysis. Irrespective of the method used, bitemark analysis include registration of both the bitemark and the suspect dentition, comparison of the dentition and the bitemark, inspection of similarities and dissimilarities. There have been a lot of research happening in recent years to increase the reliability of bitemark analysis in legal systems. Many of the new techniques in dentistry like 3D scanning and imaging are incorporated to improve the accuracy of bitemark analysis. The conventional methods as well as the new methods are summarized in this literature review. The advantages and disadvantages of new digital techniques over conventional methods are discussed. In conclusion, considering the three dimensional nature of the bitemark, new technologies like 3D comparison shows to improve the scientific validity of bitemark analysis and further research in this field is necessary.

1 Introduction



Fig .1 Human bitemark (www.wikihow.com)

A bitemark has been defined as “the physical end product of a complex set of events that occur when human or animal teeth are applied to the skin or foodstuff (1). In bitemark analysis , uniqueness of the human dentition is the fundamental premise (2). Bitemark analysis is mainly supported by two assumptions. The first one is the uniqueness of human dentition when it comes to positioning of teeth in the jaw and the second is that how that individuality is replicated on the human skin (3). In the administration of justice, bitemark analysis may be used as an evidence in the judicial system. Forensic odontology have always been a part of human identification process of both victims and suspects. In bitemark cases, the registered bitemark injuries is compared to a suspect’s dentition where as in human identification it is comparison of victim’s post-mortem dental registration and ante-mortem dental data (4). To discriminate the biter and exclude others is the most useful outcome of bitemark interpretation (5). There are three moving systems that are involved in the dynamic act of biting : the maxilla, the mandible and the reaction of the victim (3). During the act of

biting the upper jaw, the maxilla, is stationary, it holds and stretches the skin were as the lower jaw, the mandible, is moving and delivers the most biting force. Several factors like the mechanics of the jaw movement and the use of tongue varies from case to case. During the process of biting, the skin that is highly viscoelastic deforms to accommodate the shape of the teeth (3).

One of the most common method that have been used in the determination of bitemarks is techniques to compare the morphology of the dentition (the shape, size and the position of the teeth, together with the shape of dental arches) with the characteristics that are presented in the life sized photographs of the injury using transparent overlays or with the help of software programs (6). Other comparison methods include direct comparison of the bitemark photographs to the suspect's study cast, comparing the suspect's test teeth bite to actual bitemark and radiographic imaging and electron microscopy (6). Recently, researchers are more focused on the use of 3D technology in bitemark analysis as both dentition of the biter and the bitemark formed are 3D phenomena (7). The 3D methodology may reduce subjective bias and improve the accuracy of bitemark analysis (8). The use of digital techniques may play an important role in increasing the validity of bitemark interpretation in judicial system. The preservation of the evidence becomes easier with use of digital techniques.

2 Methods

A systematic review of literature was performed using an online search in different scientific databases like PubMed, Ovid MEDLINE and Cochrane library. In order to detect the relevant articles, a search string of keywords were selected like “bitemark”, “analysis”, “forensic odontology”. Special terms of interest like “3D technology”, “digital”, “scanning”, “software” were implemented to narrow the search. The included articles were filtered and selected based on the title and abstract information. One additional article on digital photography was detected during the search that became eligible after full text reading. There was only one article detected with information about software in bite mark analysis and that was selected from Cochrane library after full text reading. Thirteen articles were selected for the review article. The book “Bitemark evidence” written by Robert B. J. Dorion (5) is used as reference for the Introduction to bitemark analysis.

3 Collection of bitemark evidence from victim

3.1 Saliva swabs of bite site

The use of bitemark as biological evidence, is an objective method in forensic odontology. The focus is on the salivary contents on the bitemark that may help to identify the suspect (5). It is possible with the advanced photography techniques to locate the stains of saliva, even in the absence of bitemarks (5). Bitemarks are considered as potential source of DNA evidence. DNA analysis, uniqueness of the DNA molecule has high potential to identify the suspect (5). One of the most widely used technique in saliva swabbing is the double swab method, using wet and dry sterile cotton swabs. Saliva swabbing is done prior to photography (5). DNA samples are also collected from the victim to analyse the interpretation of possible mixtures (5). The sample materials should be analysed as soon as possible, or else frozen storage and cold transportation is recommended (5).

3.2 Photographs

The first of the non-invasive techniques and may be the only opportunity for the investigator to document the bitemark is the photography (5). The most crucial aspect of the management of the most forensic odontology cases as they move forward to become a part of a future legal proceeding is evidence collection and preservation using photography (9).



Fig 2 Bitemark (www.thinglink.com)

3.2.1 Visible light photography

The use of conventional camera equipment manufactured for the visible light spectrum is the most common method of documenting bitemarks (5). The image is recorded as it is seen by the human eye at the time when the image is captured. In traditional colour photography, the visible light that strikes the skin exhibits four phenomena: reflection, absorption, fluorescence and diffusion. What appears in the bitemark photographs is the combination of all these phenomena (5). Creating a photograph under normal conditions is relatively simple. Recently there have been a lot of developments in technology, which have made it even easier for us to take high quality photographs. It is not only the technologies in the camera equipment but also the processing and preservation of the photographs have been lot easier in recent times. The resultant photographs in bitemark documentation shall accurately depict the bitemark pattern on the skin (5). Various kinds of photographic scales are used in forensic photography. As it provides a visible reference showing the dimensional size of the bitemark, the use of photographic scale is mandatory (5). The ABFO no. 2 scale that is designed by Hyzer and Krauss is most widely used for bitemark photography (5).

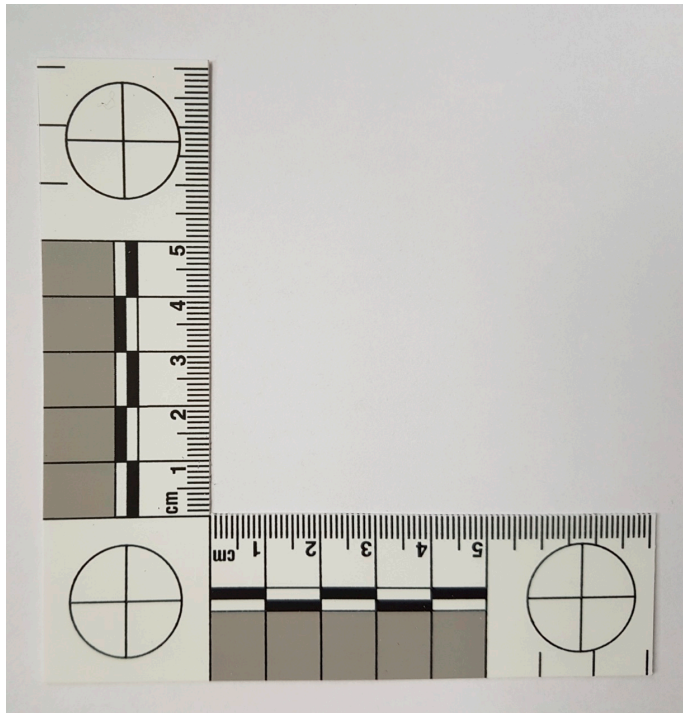


Fig 3 ABFO scale

3.2.2 Non-visible light photography

Infrared photography

Infrared light (IR) is used in photography of injured tissues because of some special properties. When teeth or other objects crush tissue that leads to subdermal haemorrhage (5). The extravasation of blood beneath the skin surface is captured using infrared photography. The infrared technique make use of the light resorption properties in areas of bruising and in resultant photographs it appears as black (5). Infrared photography is also used in decomposing or mummified skin to locate and document bleeding points below the skin surface and to enhance details of tattoos (9).

Ultraviolet photography

Ultraviolet photography (UV) is used in bite mark documentation because of its ability to accentuate the surface details of disrupted skin (5). The sub epithelial surface as well as the surface of the skin is damaged during the act of biting. Blood products like haemoglobin and melanin is released in the injured site. As the wound heals these products migrate to the surface of the skin. The increased absorption and less reflection of ultraviolet light is because of the increased melanin deposition on the surface of the skin (5). The appearance of injury pattern is enhanced in ultraviolet photographs (5). Special equipment and techniques are

needed for UV photography. UV photography is used to record the details of the bitemark on skin that appears healed in visible light for human eye (9).

Alternate Light Imaging

Alternate Light Imaging (ALI) is special photographic techniques used to document injuries that are not visible to the naked eye. Fluorescent photographic techniques can be used to distinguish between the healthy adjacent skin and the injured skin (9). In contrast with the injured skin, the healthy skin will fluoresce (9). It is usually performed in a totally darkened environment using specifically tuned ALI light source

Full spectrum photography

Full spectrum photography is used to collect all available evidences in human abuse and bitemark cases. All four reactions of the skin when struck by electromagnetic radiation is utilized in full spectrum digital photography of patterned injuries (9). The most significant use of full spectrum digital photography in forensic odontology is in bitemark cases. In bitemark analysis the life sized photographic image is used to compare with many suspected biters. When captured in visible, UV, IR and ALI photographic protocols , the details of the bitemark injuries appears different (9). The volume of evidence to analyse increases when all four protocols are used in creating photographic images (9). And this in turn will increase the value and strength of the evidence as it move towards legal resolution (9).

3.3 Bitemark impressions

Different types of impression materials are used for the bitemark impressions. The most widely used are plaster of Paris, alginate, silicones, casting stone etc. In bitemark protocol, photography and salivary swabbing for DNA precede impression taking (5). Full arch impressions are made. The body should be free of contaminants before taking the impressions (5). As impression materials have only limited shelf life, the batch number and the expiry date of the material should be monitored and registered (5).

3.4 3D scanning of bitemark impression

The use of 3D technology is highly recognized and improves the accuracy of the bitemark impressions. Description of this technique is found in chapter 6.

3.5 Study casts

Study casts are made from the impressions of the bitemark. It is important to identify, preserve and store the initial pour master model in a secure area in a specific container(5). The suspect's dental cast is also made and recorded for either direct or indirect comparison.



Fig. 4 Dental cast (www.dentona.de)

4 Collection of evidence from suspect

4.1 Impression of the dental arch

Impressions of the dental arch is taken directly from the suspect using conventional method. Different types of impression materials like alginate and silicone impression materials are used.

4.2 3D scanning of the dental arch

Direct scanning and indirect scanning

The dental arch of the suspect can be directly scanned using an intraoral scanner. There are different types of intraoral scanners by different manufactures available in the market. The indirect scanning is done by scanning the cast of the dental arch, that is made by conventional methods. 3D scanning can be very efficient as it saves time and have the digital storage options. (see also chapter 6)



Fig.5 Intraoral scanner (www.carestreamdental.com)

5 Methods in bitemark analysis

5.1 Direct comparison

After identifying the potential biter his/her dental cast is used for direct comparison to the tooth indentations on the skin (5). Photographs, that are two dimensional representation of the three dimensional object are the only evidence collected in many of the bitemark cases (5). In that case three dimensional models of suspect's teeth is compared to the photographic evidence (5). It is also possible to do direct comparison of the suspect's bite either to excised tissue or to the bitemark impression (5).

5.2 Overlays

Overlays are used to compare the biting edges of a suspected biter's dentition to the bitemark photography. Colourless, transparent acetate sheets are used to transfer the information from the dental casts. The biting edges are marked on the transparent sheets. There are different types of overlays. In hollow volume overlays , only the edges are outlined whereas in filled volume overlay the edges can be filled in and in compound overlay, the actual tooth image is captured within the outline (5). The most common approach in bitemark analysis is comparison of the of photographs of the injury with overlays from suspect's teeth (3).

5.3 Three – dimensional (3D) comparison

Three dimensional technology is used to analyse the infliction of a bite, which is a four dimensional space time event (3). For three-dimensional analysis, all the study materials, the teeth and the bitemarks must be digitized by 3-D scanner. An object can be scanned either by a mobile arm that is manually positioned or by one that is totally machine controlled (10). Different types of comparative softwares are used in 3D analysis. Three-dimensional comparison is done by using 3D overlays and geometric morphometric analysis.

5.4 Softwares in bitemark analysis

Bitemark analysis with the help of computer base technique requires software. One of the most widely used software in bitemark comparison overlay is Adobe Photoshop software. Another software, DentalPrint, was developed by the Department of Forensic Medicine and Forensic Odontology, University of Granada, to generate comparison overlays from 3D image of the suspect's dental casts (14). Martin-de las Heras et.al conducted a study to determine values of intra and inter examiner reliability, sensitivity, specificity and validity for the DentalPrint software and compared it with Adobe Photoshop software. The study concluded that bitemark examination with DentalPrint is an accurate forensic technique (14). In the study, they also found that the best results were obtained when DentalPrint software was used to produce the comparison overlays (14).

6 New methods in bitemark analysis

6.1 3D scanners in tooth mark analysis

A 3D scanner gathers geometric data from the surface of an object and helps in reconstruction of the object's shape. The two types of 3D scanners that are used in tooth mark analysis are contact and laser scanners (11). Contact 3D scanners (point to point or linear) analyse the surface of the object with the help of a probe with a hard steel or sapphire tip and the spatial position of the probe is determined by a series of internal sensors which in turn result in the reconstruction of the object from the point clouds (11). In 3D laser scanners, a laser beam is emitted and detect its return to record the geometry of the object by triangulation (11). To gather data from all sides and to reconstruct the object, multiple shots are made from different positions. A reference system is used to coordinate all the shots and to create a complete model by bringing together the individual scans (11). Molina et.al conducted a study to compare the accuracy of contact and laser scanners that are used in tooth mark analysis (11).



Fig.6 3D Scanner (news.mit.edu)

One of the major drawbacks of contact 3D scanning is the long time needed to collect an adequate number of point, specifically while scanning a complex geometry (11). The fastest contact scanner can only operate at a few hundred Hertz where as a laser scanner can operate at 10- 1000kHz. Contact scanners have also difficulty in scanning concave surfaces (11). Another disadvantage is the need for physical contact with object. Laser 3D scanning have many advantages and several efforts are done to improve the precision. In the study conducted by Molina et.al, they did not find any statistically significant difference between contact and laser scanners in uncertainty values for the 3D images (11).

6.2 Geometric morphometric analysis

Geometric morphometric (GM) analysis is used to describe and compare biological forms and has been used in bitemark analysis (8). The significant contribution of GM is the clear mathematical definition of shape and size (12). Quantitative analysis of shape is done by capturing the geometry of morphological structures of interest and the information is preserved by statistical analysis (2). New techniques in digital imaging have promoted the landmark locations as coordinates. GM method helps with evaluation of these landmark configurations that concede investigation of both shape and size (12). The landmark points, curves and surfaces are placed in three dimensions with the help of software and are used to portray dental features like inter canine width, mesial-distal lengths, rotations and tooth height variation (2).

Several studies in bitemark analysis are carried out with the help of landmarking process. Reference points are placed on the surface of an object to study the measurements between the considered points. Kieser et al. (12) used geometric morphometric method based on landmark and semi landmark data in order to study the size and shape differences of the upper and lower anterior teeth. The advantage of landmarking is the optimal measurement reproducibility and the possibility of performing geometric morphometric analyses (12). To facilitate the morphological capture of a virtual object, landmarks are converted to Cartesian coordinates (12). Different types of specific softwares are used in creating landmarks.

In order to compare shapes, that are represented as a set of landmark data it is mandatory to superimpose the sets of data (13). In GM method, the shape of the object is separated from the size of the object. Procrustes method and Procrustes –SP are used in superimposing of

data. In Procrustes method, the size of the object is not regarded as an important factor but in Procrustes –SP , also called size and shape analysis, size is also regarded as an important aspect of data (13). Both methods act by minimizing the summed squared distances between corresponding landmarks on two or more specimens by translating and rotating the specimens to match one another as well as possible (13). Procrustes distance is defined as the standard descriptor of difference in two shapes. Procrustes distance is created, illustrating a morphological variation, while superimposing non -fitting objects (4).

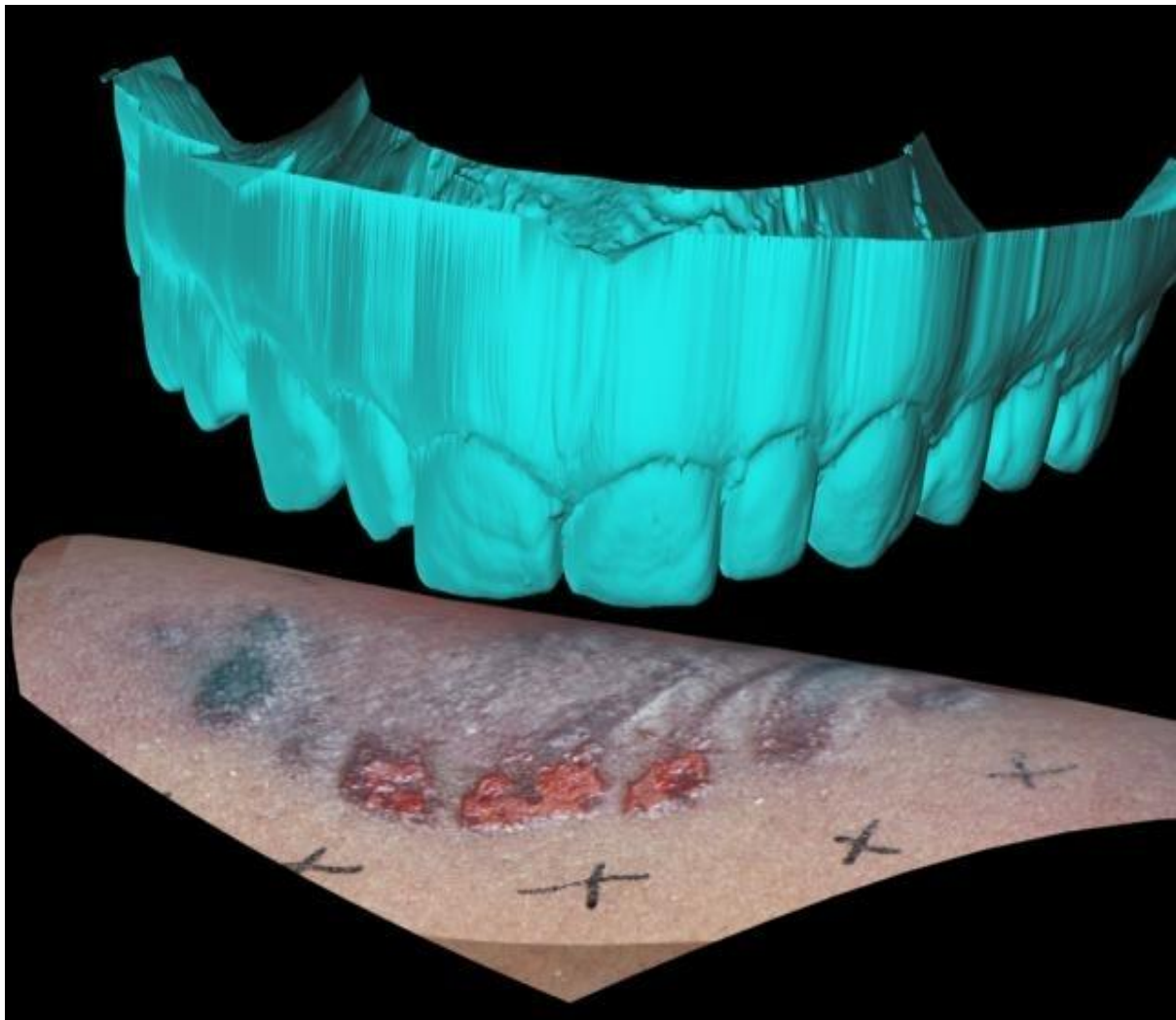


Fig.7 3D technology (www.forensicmed.co.uk)

7 Discussion

Dental technology is constantly evolving and modern technologies in diagnostics and therapeutic tools are implemented in everyday practice. Emerging new digital technologies and advancement provides easier solutions. The use of new digital techniques in bitemark analysis can enhance the reliability of bitemark analysis in court proceedings. The digital procedures have many advantages. As the procedure can be digitalised, it has the easy storage options compared to the conventional bitemark analysis. Multiple storage options to secure the evidence are another gain being digitalised. Being an automatic procedure, most of the technique like scanning avoid observer bias. This may also provide better accessibility and make it easier and uncomplicated for a third party to study the materials.

Different studies show that the flexibility to study the 3D digital dental cast from various axes has an advantage compared to the 2D image analysis. It allows the examiner to study the dentition from different angles and enables manipulation and superimposing of images much easier. Sheets et al. (13) and Bush et al. (2) reported the possibility of placing higher number of landmarks in 3D analysis. Martin-de-las-Heras et al. (3), (8) used specialized software and algorithms to study the 3D dental contours which can result in optimal bitemark analysis.

One of the disadvantage is that the 3D bitemark analysis is technique sensitive. The examiner should have sufficient knowledge and equipment to conduct the analysis. Bitemark analysis using conventional methods may be economical compared to the digital bitemark analysis. But as the digital equipments are becoming more affordable and considering the usage in judicial system, the expenditure is insignificant.

8 Conclusion

It is important to establish the bitemark analysis as a reliable and precise tool in the judiciary system. In order to minimise the errors in conventional methods, the new technologies should be introduced. The advantages of using digital techniques in bitemark analysis exceeds the disadvantages. As the injury created is three dimensional, the new methods like 3D technologies should be considered more appropriate for bitemark analysis. It is significant to expand the scientific knowledge and further research is required to evaluate the new techniques in bitemark analysis.

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