Review Article

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BITE MARK ANALYSIS IN FORENSIC ODONTOLOGY

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ABSTRACT:

Human bite mark analysis is by far the most demanding and complicated part of Forensic Dentistry. Although bite marks of an individual do have uniqueness due to specific characteristics and arrangement of the teeth, when it comes to bite mark analysis, it is complicated by numerous factors, being presented as a challenge to the Forensic Odontologists. These marks are also valuable in determining the type of physical abuse and age bracket of the criminal. To deal with bite-mark evidence a Forensic dentist is called. The aim of this paper is to give a brief overview of bite mark analysis and its usefulness in forensic odontology. This review highlights the importance of bite-marks as indispensible Forensic odontological evidence.

Keywords: Bite mark, forensic, salivary DNA, dentition, suspect

INTRODUCTION:

Bite mark analysis and comparison is a complicated matter. The standard techniques for examining bite marks are based upon interpreting photographic evidence in which a bite is compared with the models of the teeth of suspects.[1] The quality and angle of the bite mark photographs and the precision of the impression of the suspect's dentition is of extreme importance to the forensic odontologist.

Rawson investigated the uniqueness of the human dentition mathematically using a precise method of measurement.[2] The uniqueness of a bite mark, however, is not such a clear-cut issue. Human skin is a very poor bite registration material.[3] Bite marks may disclose individual tooth imprints. They may appear as a double arched pattern, or even a homogeneous bruise.[4] Bite marks can be distorted by the elastic properties of the skin tissue or by the anatomic location. Also the pressure of the bite and the angle of the maxilla and mandible can change the appearance of a bite mark. The position of the body at the time the bite was inflicted may also play a part.[5]

Sorup[6] was the first to publish an analysis of bite marks. Bite marks can be found in food, flesh, cigars, pipes and musical instruments.[7] Bite marks in themselves provide a kind of dental identification. It is now realized that bite marks have come to provide detail of a kind comparable with the infinitesimal

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detail that was previously thought likely to be provided only by finger prints.[8]

The process of comparing bite marks with a suspect's dentition includes analysis and measurement of size, shape and position of the individual teeth.[9] Most comparison methods involve the fabrication of overlays.[10] There are a number of different ways to produce overlays from a suspect's dentition: handtracing from dental study casts,[11] hand-tracing from wax impressions,[12] hand-tracing from xerographic images,[13] the radiopaque wax impression method [14] and the computer-based method.[15] Sweet and Bowers [11] studied the accuracy of these bite mark overlay production methods and concluded that the computer-generated overlays provided the most accurate and reproducible exemplars.

Forensic aspect of bitemarks analysis can be applied in the following circumstances:-

Teethmarks left in the food stuffs.

1) Teethmarks on the criminal: When the victim bites the assailant in self defence.

2) Teethmarks on the victim: Found in cases of assault and murder and were usually caused during or after sexual act.

It might be due to:

a) Self infliction by the victim. b) The criminal attacking the victim usually during sexual offences like rape, and are found mostly on the breast, neck or cheek.

Collection of Bite Mark Evidence from the Bite Mark Victim:

Both in the living and deceased victims the following vital information should be recorded:

- **Demographics**-Name, age, sex, race, case number, date of examination and name of the examiners should be recorded.

- **Location of the bite mark**-Describe the anatomic location, indicate the contour of the surface (flat, curved or irregular) and state of the tissue characters. Underlying tissue-bone, cartilage, muscle or fat

- **Shape of the bite marks**- whether it is round, ovoid, crescent or irregular in shape.

- **Colour of the mark, size of the mark**- Both vertical and horizontal dimensions should be recorded in metric system. (figure 1).

- **Type of injury**- due to bite mark may be- Petechial haemorrhage, Contusion, Abrasion, Laceration, Incision, Avulsion, Artefact etc.

Steps in Examination of Victim:

The most important evidence from the bite mark victim is photography. Numerous photographs of the injury

should be taken immediately. Shots would include:

1. With and without the ABFO no.2 scale;

2. In colour and black and white;

3. On and off camera flash (oblique flashes can highlight the three dimensional nature of the same bites);

4. An overall body shot showing the location of the injury;

5. Close-ups that can easily be scaled1:1;

6. UV photography if the injury is fading;

7. If the bite is on a movable anatomic location, then several body positions should be adopted in order to assess the effect of movement.

Photographic documentation of the bite site:

All the photographs should be taken with the camera at 90º (perpendicular) to the injury. It should be emphasized to forensic photographers that it is not possible to have too many photographs of an injury. It has been recommended that bite marks are photographed at regular 24 hour intervals on both deceased and living victim as their appearance can improve. The lighting should be arranged at an angle to shadow indentations which will appear more definite on the positive print, but precautions should be taken to prevent excessive heat from the photographic lamps causing distortion of the material and filters may be used to mask or enhance various shades of coloration that are associated with the marks. Photographs of the bite marks must be of highest standard if the forensic significance of the injury is to be maximized.[16] In general, photography provides the safest means of obtaining a permanent record of marks. Use of stereoscopic photography is advocated by some authorities to produce greater definition of details, but this method has many inherent problems. Ultra-violet and Infra-red illumination may be necessary under some circumstances to bring out some details that may not be obvious in the normal positive print. [17]

It is possible for a bitemark with high forensic value to be poorly photographed and thus lost as a valuable piece of physical evidence.

Saliva swabs of bite site:

The next step is salivary swabbing. Saliva would have been deposited on the skin during biting or sucking and this should be collected and analyzed, the aim being solely the collection of cells for DNA.

The amount of saliva deposited with a bite mark is about 0.3ml and distributed over a wide area of 20 cm. Swabs should be taken as soon as possible after the bite is inflicted and before the area is cleaned or washed. If it can be determined that the bite was inflicted through clothing, attempts should be made to seize the clothing for DNA analysis. The following technique will maximize the amount of DNA recovered.

Double swab technique

First, a cotton swab moistened with distilled water is employed to wash the surface that was contacted by the tongue and lips using light pressure and circular motions to wash the dried saliva from the surface over a period of 7 to 10 seconds. Then, a second swab that is dry is used to collect the remaining moisture that is left on the skin by the first swab. Both swabs are thoroughly air-dried at room temperature for atleast 45 minutes before they are released to police authorities for testing.

The two swabs must be kept cool and dry to reduce the degradation of salivary DNA evidence and growth of bacteria that may contaminate. After drying swabs are packed and sent to the laboratory. A control sample is prepared using same method but without swabbing the saliva.

- Saliva obtained from swabbing is used to determine the blood group antigens using absorption-elution or absorption-inhibition group testing. Identification of saliva is done by demonstrating its amylase activity in hydrolysing a starch substrate.[18]

- In case of sexual assault, oral swabs should also be taken for semen. Mouth washes (with water) can be used to obtain test samples for spermatozoa.[19], [20], [18]

Impressions of bite site:

If the bite marks have penetrated the skin, an impression of the marks should be made. [20] Ordinary plaster of Paris or dental stone was used initially for the purpose, but it was seen that the water soluble substances in the material would leach out and delicate surface lesions would be destroyed. Therefore less damaging materials like rubber-base and silicone-base impression compounds are preferred now-a-days. [21] There are two methods for making impressions:

Method I: Pour the material covering the bite area. Place wire gauze and inject additional material over it.

Method II: A special tray is constructed using cold cure confining to the shape of bite mark and impression is made. Master casts must be poured with type-IV stone and duplicate casts should also be made. Either visible light cure or epoxy resin clear material may be used to make stable rigid model.

Bite print recording:

Bite print recording is similar to the method used to lift finger prints from crime scenes, finger print lifting tape can be used to lift the ―non-perforating‖ bite marks after brushing the bite mark with finger print lifting powder. In case of dead victims with bite marks, bite marks can be excised along with the underlying tissues after fixing an acrylic stent around the bite mark to avoid shrinkage of the tissue. The specimen is then stored in 4% formalin. [20] One interesting development in the collection of bite mark evidence from the bite mark

victims is the acquisition of 3D images of the bite mark. This is performed using specialist software, such as that produced by Lumin IQ and enables by assessment of grey scale levels, a three dimensional rendition of standardized images shown in (Figure 2). They may offer a means of demonstrating the depth of an injury without the problematic use of skin impressions.[16]

Collection of Bite Mark Evidence from the Suspect:

The collection of evidence from the bite suspect must commence only after proper consent has been acquired. [22] The consent has to be written, signed by the suspect as well as a witness.[21] A detailed history of the individual including history of dental treatments (after and just before the bite marks) has to be noted. [20] Evidence collection again begins with copious photography. Shots that should be taken include:

- Overall facial shot;
- Close-up photograph of the teeth in normal occlusion & biting edge-to-edge;
- Photograph of the individual opening mouth as wide as possible;
- Lateral view. [22]

After the photographs, a thorough intraoral and extraoral examination of the individual should be carried out. The next stage is to take two high quality impressions of both the upper and lower arches. If the individual wears a dental prosthesis, impressions should be taken with this being worn and also without.[22] One set of models is used as direct evidence and the other set for the purpose of comparison.[21]

The author recommends the use of poly-vinyl siloxane (PVS) impression material(Figure 3a &b), to be combined with plastic stock trays (Figure 4). This enables the material to be poured and cast at a later time. The use of alginate materials is acceptable but they must usually be poured within 1−2 hours of the impression to prevent contraction. A further benefit of PVS materials is that they can often be poured multiple times should there be an error, for example an air blow, in a cast. An example of a set of dental casts is shown in (Figure 5), which demonstrates the importance of multiple impressions if a suspect wears a removable prosthesis. A sheet of softened wax should be used to obtain an indication of how the individual bites together, providing an occlusal record (Figure 6).

The next stage is to take registrations in the dental wax in centric occlusion, edge-to edge bite and in protrusive and lateral excursions of the jaws. These positions are again duplicated and the one set of wax bite registrations can be used to set the study models on a dental articulator and the other set of wax bite registrations used for comparison of the imprints with those of the bite marks.[21]If indicated, a buccal swab

should be taken of the suspect in order to obtain a DNA sample.[22]

Bite Mark Analysis, Comparison and Evaluation:

The preceding sections have described the impact of a variety of factors upon the forensic significance of bitemarks. Only a bitemark that exhibits at least class characteristics of the biter should be analysed. This does not render the less significant bitemark worthless within an investigation. For example, if sufficient detail exists to identify the injury as a probable bitemark, this can be of assistance to investigators, especially in cases of child abuse where there may be several injuries that are ambiguous, ie may be accidental or non-accidental.

The American Board of Forensic Odontology provides a range of conclusions to describe whether or not an injury is a bite mark. These are:

a) **Exclusion** – The injury is not a bite mark.

b) **Possible bite mark** – An injury showing a pattern that may or may not be caused by teeth could be caused by other factors but biting cannot be ruled out.

c) **Probable bite mark** – The pattern strongly suggests or supports origin from teeth but could conceivably be caused by something else.

d) **Definite bite mark** – There is no reasonable doubt that teeth created the pattern.

The first stage of analysis is to determine if the injury is a bite mark, and then to provide a statement on the forensic significance. [22] While evaluating the bite mark firstly the cause of the mark has to be determined, since bite marks may be caused by nonhumans or humans.[20]

1. Size, shape and arrangement of teeth:

Human incisor teeth produce rectangular marks whereas canine teeth produce triangular marks in the cross-section. Animal bites (dogs, cats) usually puncture the skin and the cross-sectional size of the tooth is small and circular. Number of incisor teeth and the distance between individual teeth may be greater with animal bites.

2. Size of Dental Arch:

Width of adult arches from canine to canine is 2.5-4cm. Children arches are smaller than the adults whereas “dogs and cats” arches are smaller than children.

3. Evaluation of the bite mark photographs:

Attempts should be made to thoroughly analyse the bite marks in vivo and in vitro rather than mere superimposition of marks in the photographs over the models.

4. Evaluation of the arches:

Shape of the arch should be noted. Central lines of upper and lower arches should be established

5. Suction marks:

The presence of suction marks in the centre of the arch marks is a sign of bite marks of human origin. But now it is considered that suction marks are caused due to injury to the blood vessels when compressed between the jaws of the biter.

6. Characteristics in the mark:

Ascertain the characteristics of individual marks within the arch. Areas of injuries may indicate occlusal level of particular tooth or sharp cusp. Tooth numbers should be identified. Placement of tooth marks in the arch and missing teeth should be noted.

BITE MARK ANALYSIS AND SCORING

An essential component of the determination of the Validity of bite mark analysis is that the techniques used in the physical comparison between suspect dentition and physical injury have been assessed and found valid. One of the fundamental problems with this task is the wide variety of techniques that have been described in the literature. Techniques using confocal, reflex and scanning electron microscopes, complex computer systems, typing of oral bacteria, special light sources, fingerprint dusting powder and overlays have all been reported. It is a widely held belief that while methods that are more esoteric exist, the dominant technique for comparison of exemplars is transparent overlays.

The lack of direction from the forensic dental organizations, both European and American, complicates this matter. The American Board of Forensic Odontology (ABFO) has reported advise and guidance on many aspects of bite marks and yet one of the most pivotal questions, i.e. what is the best comparison technique to use, has not been addressed.

Transparent overlays utilize materials found in any dental office. The vast majority of forensic dentists use techniques that utilize materials that are inexpensive and easily obtainable, hence the popularity of overlays (Fig 7). There are numerous techniques for the fabrication of transparent overlays. Of all the techniques, an examination of case reports and experiments reveals that the xerographic and radiographic techniques are the most popular.

The computer technique represents the most accurate fabrication method with respect to representation of rotation and area of the biting edge. Various authors have concluded that the fabrication methods that utilized the subjective process of hand tracing should not be used in favour of techniques that are more objective. The use of computer generated techniques was advised over any other method.

In order to accomplish and achieve the goals of tooth and bite mark analysis the following techniques are used:

Overlay

The overlays of the chewing surfaces of teeth can be obtained by:

i Tracing these surfaces on a sheet of transparent acetate:

ii. A glass of photocopier machine and duplicating on transparencies or special paper:

iii. Utilizing the computer, scanner, Adobe Photoshop, etc

iv. Radiographic technique using metal fillings painted into test bite indentations created in plaster, wax wafers, etc: and

v. Inking the incisal edges of anterior teeth on stone models of suspect's teeth and imprinting the inked edges on various materials.

The protocol for bite mark comparision is made up of two broad categories

1. The measurement of specific features of the bite mark and suspect's dentition, called metric analysis
2. Matching the pattern of injury to the configuration of teeth on suspect's dental cast, called "pattern association".

Metric Analysis

The following features captured in the bite mark should be measured and recorded:

- The length, width, and depth of the tooth.
- Overall size of the mark.
- Intercanine distance.
- Spacing between tooth marks.
- Rotation from normal arch form.

A similar procedure is employed with the suspect's casts. The measurements thus obtained are compared to one another. Simple instruments such as a vernier caliper may be used for obtaining the measurements. More recently, computer based analysis such as Adobe photoshop has also been used. Metric analysis however, should not be used alone, but rather in conjugation with pattern association

Pattern Association

Pattern association involves direct methods and indirect methods of comparison. Direct method is where the suspect's models are placed directly over the photograph of the bite mark or the bite mark itself i.e in situ. Bite registration obtained from the suspect may also be compared with the actual bitemark .

Indirect method uses the following:

1. Superimposing transparent overlays of the suspect's bite edges and the bite mark photograph

2. Computer software programmes such as Adobe Photoshop.

3. CAT scans.

The newer trends are moving towards the use of computer software programs suggested by Johansen and bowers. A 3-D/CAD supported photogrammetry approach developed by Thali and coworkers hold promise for the future.

Based upon the 3D detailed representation of the cast with the 3D topographic characteristics of the teeth,interaction with the 3D documented skin can be visualized and analyzed on the computer screen. It is possible to demonstrate the progression of the biting action and the development of the subsequent injury pattern.

Bite mark identification is based on the individuality of the dentition, which is used to match a bite mark to a suspected perpetrator. This matching is based on a tooth by tooth and arch to arch comparison utilizing parameters of size shape and alignment. The most common method used to analyze bite mark is carried out in 2D space. That means that the 3D information is preserved only two dimensionally with distortions.

Biological Techniques for bite mark comparisions

The biological basis of bite mark analysis has centered on the recovery of salivary DNA and Sweet has pioneered much of his work. While such techniques offer an objective, scientifically validated method of bite mark, analysis by the systems employed are expensive and require extensive laboratory equipment and expertise.

A new technique that has attracted attention is the genotyping of oral bacteria, mostly oral streptococci. While over 2000 species in an individual's mouth it is possible to develop a bacterial 'finger print' due to the diversity of such populations.

COMPARISION TECHNIQUES:

Bite mark comparision protocol include measurement and analysis of the pattern, size and shape of the teeth against similar characteristics observed in an injury on skin or a mark on an object.

The comparision involves not only the use of superimposition techniques but also more importantly; the collection of all the evidence including the physical features as well as the dynamics of the bite and the compatibility of the features of suspect's teeth.

The comparision techniques have been divided into two categories life size and assisted comparisions. Comparisions are made between life size 1:1 photographs and a variety of tracings and overlays or reproduction of the biting's surfaces of the suspect's teeth. Assisted comparisions involves the use of microscopes of varying types, electronic, histological, radiographic and specialized techniques including the use of experimental bite marks

LIFE SIZE COMPARISION

Life size comparision is the most common type undertaken by the odontologist using the life size 1:1 photographs with the models of the teeth

In direct method, model from the suspect can be directly placed over the photograph of the bite mark to demonstrate concordant points (figure 8). Videotape can be used to show slippage of teeth producing distorted images and to study dynamics of the bite marks. The videotape documentation demonstrated the three dimensionally of the bite in motion.

Indirect method involves preparation of transparent overlay of occlusal or incisal surfaces of teeth which are then placed over the scaled 1:1 photographs of the bite injuries and a comparison is undertaken.

This process is highly subjective .If overlay analyses are restricted to those bitemarks displaying unique characteristics, the process, in the hands of an experienced odontologist, can be highly accurate.

There are a number of methods for producing bitemark overlays and, again, these methods have been the subject of numerous research projects. Two studies are described. The first assessed the five main methods of bitemark overlay production:

- Computer-based;
- Two types of radiographs
- Xerographic; and
- Hand-Traced.

The advantages of using computerized system are accurate measure of physical parameters of the evidence, less photographic distortion, eliminates any examiner subjectivity, good image visualization, standardization of comparison procedures and reproducibility of results. [23]

Xeroradiography and contrast enhanced radiography can add valuable information and should be considered as an adjunct to standard photographic procedures.In case of the xeroradiographic technique a layer of the radiographic contrast material is used and radiographs of the mark are taken. Xeroradiography is only applicable when indentations are present.

Transillumination utilizes the changed hemorrhagic structures of the tissue which is viewed under a light source that enhances the areas of varying hemorrhagic density. Both these techniques require the removal of bitten tissue

For many years, **hand-traced overlays** were the method of choice. According to Sweet & Bowers, computer-generated overlays were by far the most accurate in terms of both tooth area and rotation. Results demonstrated that both the main techniques were reliable, and the choice of method was down to personal preference. [11]

Odontometric triangle method: In this objective method, a triangle is made on the tracing of bite marks and teeth models by marking three points, two on the outermost convex points of canines and one in the centre of the upper central incisors. Three angles of the triangles are measured and compared. (Fig. 9)

ASSISTED COMPARISION

Other special methods in bite mark analysis:

- **Vectron – sutsumi and Furukawa** described the use of a measuring instrument called a **Vectron**, which is similar to a dental surveyor and measure distances between fixed points, angles and radii.
- **Stereometric graphic analysis** – This can be used to produce contour map of the suspect‘s dentition.
- **Experimental Marks** –may be produced on pig skin, baker‘s dough or rubber for analysis.
- **Scanning Electron Microscopic(SEM)** analysis of bite mark wounds. [20],[24-26]
- **Image perception technology.** A new method of comparing and analysing photographs of bite marks with overlays of a suspected biter’s dentition using image perception software.
- However, while the overlay production method has been shown to be reliable, the application of these to the bite mark photographs and the assessment of degree of match has not much scientific support. Again, a range of conclusions is available to odontologists to describe the results of a bite mark comparison:
- **Excluded**- Discrepancies in bite marks and suspect‘s dentition.
- **Inconclusive**- Insufficient forensic detail or evidence to draw any conclusion on the link between the two.
- **Possible biter**- Teeth like the suspect‘s could be expected to create a mask like the one examined but so could other dentitions.
- **Probable biter**- Suspect most likely made the bite; most people in the population would not leave such a bite.
- **Reasonable medical certainty**- Suspect is identified for all practical and reasonable purposes by the bite mark.

CONCLUSION:

The science of bite mark analysis is relatively new and potentially valuable. This analysis has been instrumental in criminal investigations of homicide, sexual assault and abuse cases. Human dentition is influenced by genetic factors and environmental factors that determine the position of teeth in the

arch. The dentist in practice observes the individuality of human dentition commonly but there is no database to express quantitatively this uniqueness of human dentition. The serious nature of the crimes in which bites are found often dictates that the highest level of Forensic standards should be applied and need for individuals trained and experienced in the recognition, collection and analysis of this type of evidence is increasing. Analysis of such injuries should only be undertaken if unique or, in certain circumstances where class characteristics exist. With recent advances in research, more objective methods of bite mark analysis like salivary DNA recovery and bacterial genotyping have become the main stay of investigation in such crimes.

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FIGURES:

Fig. 1: Measurement of bite mark

Fig 1 Measurement of a bite mark

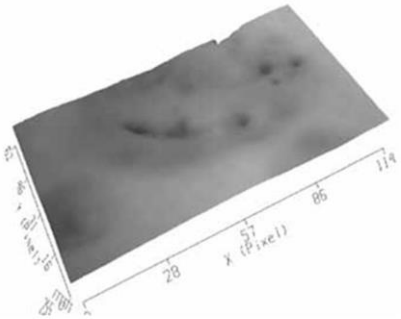

Fig 2 3D rendering of a bite mark from a stranded image

Fig 3 Impression materials used in the collection of bitemark evidence: **(a)** impression materials including two grades (light and medium body) of poly–vinyl siloxanes and one of alginate; **(b)** stock impression trays such as these are appropriate for bitemark evidence collection.

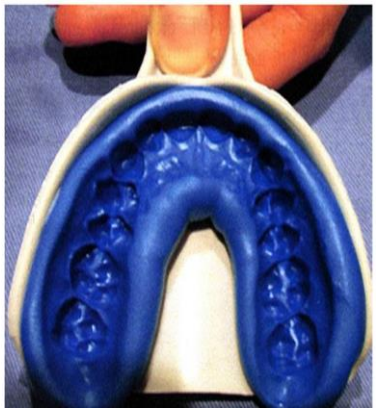

Fig 4 Impression of dentition of an individual using rubber base impression material

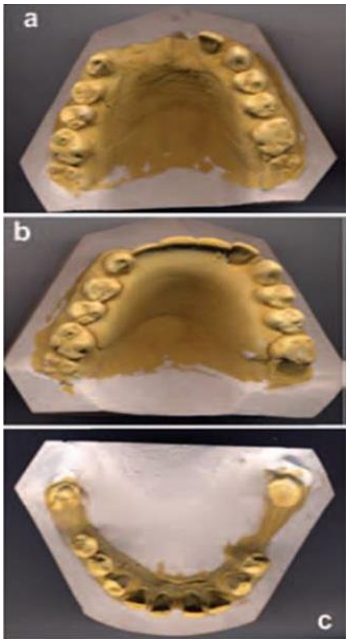

Fig 5 Example of stone casts produced from a bitemark suspect: **(a)** cast model of suspect's maxillary arch without dental prosthesis in place; **(b)** cast model of suspect's maxillary arch with partial denture in place; **(c)** cast model of suspect's mandibular arch.

Fig 6 Example of a wax bite obtained from a bitemark suspect.

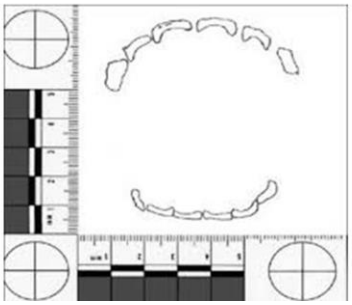

Fig 7 The overlay technique for transferring the indented bite marks from the victim or from the cast of the suspect and its subsequent comparision with those of actual left bite marks.

Fig 8 Comparison of model from the suspect with given bite mark

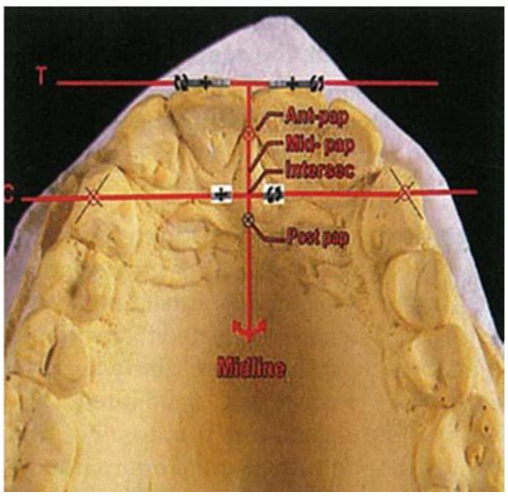

Fig 9 Odontometric triangle method