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**ABSTRACT**

Forensic odontology or forensic dentistry is the branch connecting dentistry with law. With an increasing number of criminal cases in the Indian subcontinent being solved with the aid of forensic odontology by the very few certified forensic dentists available, the demand of professionals in this field has risen. Also, there is a need for educating the dentist professionals as well as the dental academicians regarding their roles and duties towards the forensic aspects of dentistry. This comprehensive review is an attempt to invoke interest of the readers as well as to educate them regarding the field of forensic odontology.

**KEYWORDS:** Forensic odontology, Forensic dentistry, Age estimation, Bite marks

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**INTRODUCTION:**

Forensic (from the Latin word forum) means 'court of law'. Odontology refers to study of teeth.<sup>1</sup> Federation Dentaire Internationale (FDI) thus defines Forensic Odontology as 'that branch of dentistry which, in the interest of justice, deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings' (by Keiser-Neilson).<sup>15</sup> According to the American Society of Forensic Odontology, forensic odontology is the application of dental science to the law.<sup>2,6</sup>

**HISTORY OF FORENSIC ODONTOLOGY**

Forensic odontology has been with us since the beginning when, according to the Old Testament, Adam was convinced by Eve to put a 'bite mark' in apple.<sup>2,7</sup> The great Indian age Vatsayana depicted, in detail the human bite marks and its classification of skin pertaining to love making for the first time in Indian literature.<sup>1</sup> In 1776, the first dental identification was done by dentist patriot Paul Revere, who identified his friend and patient Dr. Joseph Warren. Warren was killed in the battle of Bunker Hill and interred in an unmarked grave. The exhumed body was identified by a prosthesis recognized by Revere.<sup>1</sup> However, forensic odontology, as science, did not appear before 1897 when Dr. Oscar Amoedo (considered as Father of Forensic Odontology) [Figure 1] wrote his doctoral thesis entitled "L'Art Dentaire en Medecine Legale" describing the utility of dentistry in forensic medicine with particular emphasis on

identification.<sup>1, 5, 7, 8</sup> After the end of World War II, rumours were rampant that Adolf Hitler had escaped with his wife, Eva Braun. Finally, pieces of Hitler's jaw were found that showed remnants of a bridge, as well as unusual forms of reconstruction, and evidence of periodontal disease. Hitler's identity was confirmed when the dental work matched the records kept by Hitler's dentist, Hogo Blaschke.<sup>9</sup>



**Figure 1: Dr. Oscar Amoedo and his doctoral thesis**

**IMPORTANCE OF FORENSIC ODONTOLOGY**

Natural teeth are the most durable organs in the body.<sup>5</sup> The diversity of dental characteristics is wide, making each dentition unique. The dental enamel is the hardest tissue in the body, and would thus withstand peri and post mortem damages, and so would dental materials adjoined to teeth.<sup>5, 8, 10</sup> Being diverse and resistant to environmental challenges, teeth are considered excellent post mortem material for identification with enough

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concordant points to make a meaningful comparison.<sup>5,8</sup>

### ROLES OF FORENSIC ODONTOLOGIST/FORENSIC DENTIST

The major fields of activity of forensic odontology can be divided into civil, criminal and research (Avon).<sup>1,11</sup> The civil sector includes malpractice and other aspects of fraud and neglect in which compensation is sought. Identification of dead and living persons also comes under this category. Criminal sector includes identification which is done by teeth and from bite marks that may be present on the victim, assailant or on some inanimate objects like food items. Research field encompasses academic courses for undergraduate and postgraduate training, teaching forensic odontology to police and new research work.<sup>1</sup>

However, so many evidences are available with the aid of forensic odontology like:

1. Identification of tooth as well as person
2. Dental age determination
3. Identification in mass disaster
4. Dental radiographic comparison between antemortem and postmortem data
5. Bite mark evaluation and evaluation
6. Trauma and abuse cases
7. Dental malpractice and negligence
8. Reconstruction of face
9. Anthropological study and research<sup>12</sup>

### HUMAN IDENTIFICATION (Comparative Identification)

This branch has been utilized for many years for the identification of victims and suspects in mass disaster, abuse and organized crimes. Dental identification has played a very important role in natural as well as manmade disasters.<sup>3</sup> The common reasons for identification of found human remains are categorized as criminal, marriage, monetary, burial, social and closure.<sup>13,14</sup>

Identification is based on comparison between known characteristics of a missing individual (termed ante-mortem data) with recovered characteristics from an unknown body (termed post-mortem data). A forensic dentist records the postmortem records completely by charting down

the dental findings and taking photographs and radiographs. An antemortem dental record will contain written notes, charts, diagrams, dental and medical histories, radiographs, clinical photographs, study models, results of specific tests, prescriptions, and referral letters and other information.

**ANTEMORTEM DENTAL RECORD**

NAME: FROST, JACK, R. SON: 333-33-3333 RACE: LT, USN  
 SEX: M RACE: C AGE: 31 XRAY TYPE & DATE: DLV 1/12/84  
 EXAMINERS: A.D. SMITH, CAPT, 2nd, USAF DATE RECONSTRUCTED: 12 DEC 77  
P.T. BRATE, C.M., D.C., USAF RECORD SUPPLIED BY: NOEL ROSENBERG, FL

**RESTORATIONS & MISSING TEETH**

**DESCRIPTION/COMPUTER CODES**

1. U	18. MODL - C
2. OL - AM, F - AM	19. MOD - AM
3. MO - AM, DO - AM	20. Mo - AM
4. PN	21. DO - AM
5. O.O - AM	22. ML - CO
6. F - CO	23. PN
7. M - CO	24. CT - RF
8. L - IR, RF	25. PN
9. CV	26. PN
10. MI - CO	27. PN
11. D - AM	28. DoFL - GI
12. PN	29. RP - X
13. FP - CV, RF - AP	30. RP - X
14. FP - X	31. RP - Y
15. FP - CF	32. HAPFL - GI
16. X	
17. U	

**LEGEND:**

AK AHALGAM	CF CROWN FULL
GE GOLD INLAY	CP CROWN PARTIAL
GF GOLD FOIL	CV CROWN VENEER
SS ANY OTHER METAL REST	FP FIXED PARTIAL
CO COMPOSITE RESIN	RP REMOVABLE PARTIAL
JN JAW FRAGMENT MISSING	CD COMPLETE DENTURE
TA TRAUMATIC AVULSION	M SERIAL
FX FRACTURED CROWN	D DISTAL
RT ROOT TIP	O OCCLUSAL
PN PRESENT NOT RESTORED	I INCISAL
RD ROTATED	F FACIAL
RF ROOT CANAL FILLING	L LINGUAL
AP APICOECTOMY	C CARIES
SE INTERMEDIATE REST	U UNRUPTED
CT CROWN TEMPORARY	X EXTRACTED

REMARKS: BILATERAL MANDIBULAR TONI

**Figure 2: Antemortem dental record format**

[Figure 2] Their accuracy and availability have a huge impact on the speed and efficacy of identification. Problems are encountered when the dental records are incomplete, irregular, lost or damaged and have poor quality radiographs. Good quality dental records are an essential part of patient care, a medico-legal requirement, and are necessary for dental identification. On completion a comparison between the two is carried out, similarities and discrepancies are noted on the comparison and a result is established. The American Board of Forensic Odontology recommends that these be limited to the following four conclusions:

- Positive identification: The antemortem and

postmortem data match in sufficient detail, with no unexplainable discrepancies, to establish that they are from the same individual.

- Possible identification: the antemortem and postmortem data have consistent features but, because of the quality of either the postmortem remains or the antemortem evidence, it is not possible to establish identity positively.
- Insufficient evidence: The available information is insufficient to form the basis for a conclusion.
- Exclusion: the antemortem and postmortem data are clearly inconsistent.<sup>3</sup>

There are a certain limitations to various methods employed in forensic odontology. In our country, antemortem records are scant and if available are either incomplete or improper.<sup>15</sup> The production, retention and release of clear and accurate patient records are hence an essential part of a dentist's professional responsibility.<sup>16, 17</sup> There can be changes after obtaining antemortem records which can mislead the investigators. Inherent poor image quality is one of the most anticipated drawbacks. There are difficulties in matching the viewing angles, exposure and similar magnification in postmortem radiographs to those taken antemortem. Photographs also have considerable inherent limitations and stringent requirements are needed for accurate reproduction. The basic difficulty arises when three dimensional objects are replicated as two dimensional photographs, which can create distortion and colour change. Photographs are sometimes associated with parallax errors. Photographs without a scale or any circular reference devices may be inherently inaccurate.<sup>15</sup>

### DENTAL PROFILING (Reconstructive Identification)

In cases where ante-mortem dental records are not available, forensic odontology can still contribute to establishing the identity by creating a profile of how the deceased person was during life. This includes any unusual oral habits, type of diet, socio-economic status, but most importantly the age of the person at the time of death.<sup>8</sup>

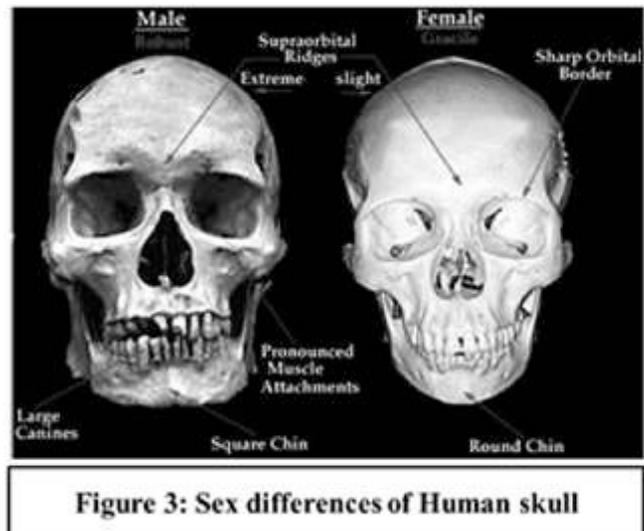
### Race

Dentists with the help of a forensic anthropologist can determine the sex and ancestry from skull shape

and form. A forensic dentist can determine race within the three major groups: Caucasoid, Mongoloid and Negroid based on the skull appearance. Additional characteristics, such as cusps of Carabelli, shovel shaped incisors and multi-cusped premolars, can also assist in determination of ancestry.

### Sex

Sex determination is usually based on cranial appearance, as no sex differences are apparent in the morphology of teeth.



**Figure 3: Sex differences of Human skull**

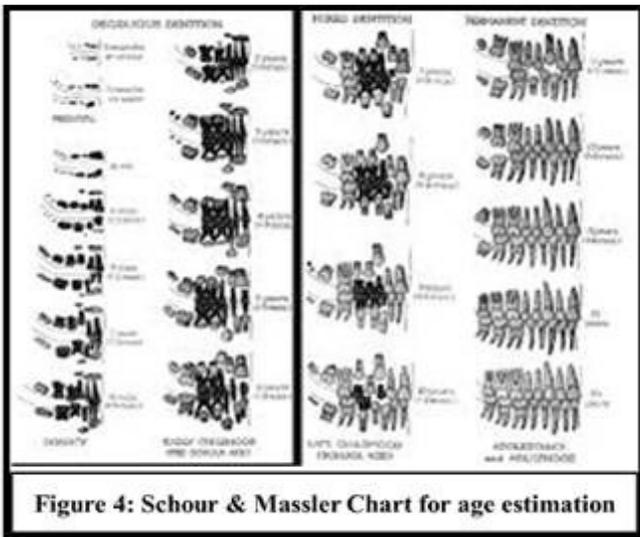
[Figure 3] Discriminant function analysis, a statistical method used for determination of sex based on tooth measurements showed a success rate of 92.5%. Minute quantities of DNA even from very old tooth specimens are helpful in determining the sex. Ameloblasts of the enamel secrete amelogenin (AMEL gene) which is present in the X and Y chromosomes of humans, females have two identical AMEL genes (XX) and males have two non-identical AMEL genes (XY). Discrimination of male and female is based on the length of the base pairs of the gene which is 106 and 112 for X and Y gene respectively.<sup>3</sup>

### Age

The age estimation should be as accurate as possible since it narrows down the search within the missing persons files and enables a more efficient and time saving approach.

The age estimation in children and adolescents can be done by Atlas approach where the morphologically distinct stages of mineralization that all teeth share are observed. The Tables of

Schour & Massler have become a classic example of an atlas approach.



[Figure 4] The neonatal line formation and incremental lines of Retzius are other methods. Moorrees et al divided dental maturation of the permanent dentition into 14 different stages ranging from “initial cusp formation” up to “apical closure complete” and designed different tables for males and females.<sup>18</sup> Among many proposed methods, the Demirjian method (1973) of age assessment has been widely accepted. The classification of stages proposed by Demirjian appears to be best suited for forensic purpose, since stages are defined by changes in form and development of teeth and these stages are independent of possibly complicated length measurements.<sup>19</sup>

The age estimation in adults are the morphological and radiological techniques such as Gustafson, Bang and Ramm, Solheim, Kvaal and Solheim & Kvaal methods.<sup>19</sup> Amongst the morphological methods, an early age estimation technique was published by Gustafson. It is based on the measurement of regressive changes in teeth such as the amount of occlusal attrition, the amount of coronal secondary dentine formation, the loss of periodontal attachment, the apposition of cementum at the root apex, the amount of apical resorption and the transparency of the root. For each of these parameters, Gustafson assigned different scores on a scale from 0 to 3 and by adding these, an overall score was obtained which was linearly related to an estimated age. Amongst the radiological techniques, Kvaal et al developed a method from measurements of the size of the pulp

observed on periapical radiographs from six types of teeth: maxillary central and lateral incisor and second bicuspid and mandibular lateral incisor, canine and bicuspid. The age estimation is based on gender and the calculation of several length and width ratios in order to compensate for magnification and angulation of the original tooth image on the radiograph.<sup>18</sup>

## DNA

Teeth present as an excellent source as DNA material and its sources are pulp, dentine, cementum and periodontal ligament fibers. DNA from teeth and bone are preserved for many years even after putrefaction of remains. The other sources include saliva and mucosal swabs. Saliva may also be isolated from various sources in the crime scene, for example, postage stamps and envelopes, glasses, cigarettes, straws, food and chewing gum, toothbrushes and dental floss, and dental impressions. Use of DNA for human identification is proved to be very effective and has been documented.<sup>3</sup> The human identification methodology relies upon three important steps: DNA isolation or extraction, amplification of specific DNA regions using PCR techniques and molecular profiles analysis.<sup>20,21</sup> The amplified DNA is then compared with antemortem samples such as stored blood, hairbrush, clothing, cervical smear, biopsy specimens.<sup>3</sup>

## IDENTIFICATION IN MASS DISASTERS

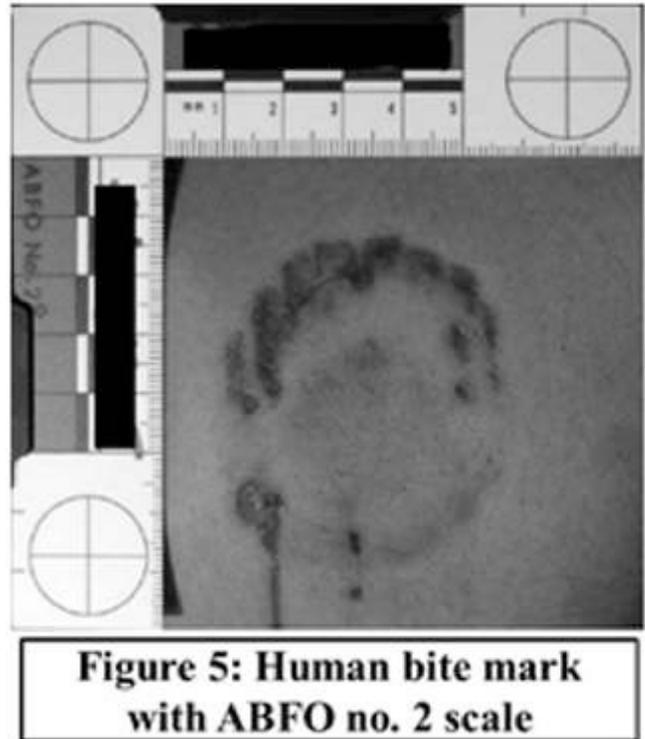
Transport accidents form the majority of cases in which dental identifications are needed, particularly aircraft accidents in which both fire and trauma are often severe. Fires in and collapse of heavily occupied buildings are another source of multiple problems of identification. Generally, the team includes a coordinator or head of the team, a pathologist and various specialists with experience related to the particular type of disaster, in addition to the forensic odontologist. In a situation involving fire or severe trauma, physical features are often destroyed. Because teeth are heavily calcified, they can resist fire as well as a great majority of traumas. Dental examination is significantly confounded when heat and flames have fragmented tooth enamel, and soot and smoke have been deposited on the teeth. Generally, teeth and restorations are resistant to heat, unless they are exposed directly to flame. Preservation is possible in most cases.<sup>22</sup>

## BITE MARK ANALYSIS

Criminal cases in which a suspect or a victim has left his or her teeth marks on another person or on an inanimate object such as a candy bar, an apple, cheese or even a beer can seem to occur more frequently. Although in a crime involving shooting it may be possible to determine that a bullet was fired by a particular weapon, it may be more difficult to relate the weapon to the assailant. When the teeth are used as weapons, they are not so easily disposed, and they can be related to the person inflicting the wound. Bite marks occur under various circumstances, usually associated with murder or rape with sexual motives. Bite marks may be identified on both the living and the dead and in the latter case may be ante mortem or post-mortem injuries.<sup>23</sup>

## BITES IN HUMAN TISSUE

The scientific examination of bite-mark evidence is interesting and tough.<sup>23</sup> Bitemarks will typically present as a semi-circular injury which comprises two separate arcs with either a central area absent of injury or with a diffuse bruise present.<sup>24, 25</sup> Human bitemarks are most often found on breast and legs in females and on arms and shoulders in males.<sup>26</sup> The force required to penetrate the skin is considerable, and bites showing laceration of the tissue are necessarily aggressive in nature.<sup>23</sup> Bite marks may have a central area of ecchymoses (contusions) caused by 2 possible phenomena: (1) positive pressure from the closing of the teeth with disruption of small vessels or (2) negative pressure caused by suction and tongue thrusting. An intercanine distance (i.e. the linear distance between the central point of the cuspid tips) measuring more than 3.0 cm is suspicious for an adult human bite. The pattern, size, contour, and color of the bite mark should be evaluated by a forensic odontologist. The photograph should be taken such that the angle of the camera lens is directly over the bite and perpendicular to the plane of the bite to avoid distortion. A special photographic scale was developed by the American Board of Forensic Odontology (ABFO) for this purpose as well as for documenting other patterned injuries and can be obtained from the vendor (ABFO No. 2 reference scale). [Figure 5] In addition to photographic evidence, every bite mark that shows indentations should have a polyvinyl



siloxane impression made immediately after swabbing the bite mark for secretions containing DNA. This impression will help provide a three-dimensional model of the bite mark. Written observations and photographs should be repeated daily for at least 3 days to document the evolution of the bite. Because each person has a characteristic bite pattern, a forensic odontologist may be able to match dental models (casts) of a suspected abuser's teeth with impressions or photographs of the bite. DNA is present in epithelial cells from the mouth and may be deposited in bites. Even if saliva and cells have dried, they should be collected by using the double-swab technique. First, a sterile cotton swab moistened with distilled water is used to wipe the area in question, dried, and placed in a specimen tube. A second sterile, dry cotton swab cleans the same area and then is dried and placed in a specimen tube.<sup>27</sup> The ABFO provide a range of conclusions to describe whether or not an injury is a bite mark. These are:

- Exclusion – The injury is not a bitemark
- Possible bitemark – 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
- Probable bitemark – The pattern strongly suggests or supports origin from teeth but could

conceivably be caused by something else

- Definite bitemark – There is no reasonable doubt that teeth created the pattern.<sup>24</sup>

### **Bites in Other Materials**

Criminals may, from time to time, leave their dental signature in bitten apples, chocolate, cheese, or other foods left at the scene of a crime. There are cases in which assailants have bound victims with adhesive tape and torn off section of the tape with their teeth, leaving identifiable bite marks on the tape. The same principles of analysis apply as in the case of tissue bites, but bites in artificial substances of foods can often yield more information because of the lack of distortion of the material and its ability to make a good impression of the biting edges of the teeth.<sup>23</sup>

### **CHILD ABUSE AND NEGLECT**

Craniofacial, head, face, and neck injuries occur in more than half of the cases of child abuse. Oral injuries may be inflicted with instruments such as eating utensils or a bottle during forced feedings; hands; fingers; or scalding liquids or caustic substances. The abuse may result in contusions, burns, or lacerations of the tongue, lips, buccal mucosa, palate (soft and hard), gingiva alveolar mucosa, or frenum; fractured, displaced, or avulsed teeth; or facial bone and jaw fractures. Unintentional or accidental injuries to the mouth are common and must be distinguished from abuse by judging whether the history, including the timing and mechanism of injury, is consistent with the characteristics of the injury and the child's developmental capabilities. Multiple injuries, injuries in different stages of healing, or a discrepant history should arouse a suspicion of abuse. Consultation with or referral to a knowledgeable dentist may be helpful.<sup>27</sup>

### **DENTAL NEGLECT**

Dental neglect is the “willful failure of parent or guardian to seek and follow through with treatment necessary to ensure a level of oral health essential for adequate function and freedom from pain and infection.” Dental caries, periodontal diseases, and other oral conditions, if left untreated, can lead to pain, infection, and loss of function. These undesirable outcomes can adversely affect learning, communication, nutrition, and other activities necessary for normal growth and development.<sup>27</sup>

### **LITIGATION TO DENTAL MALPRACTICE AND NEGLIGENCE**

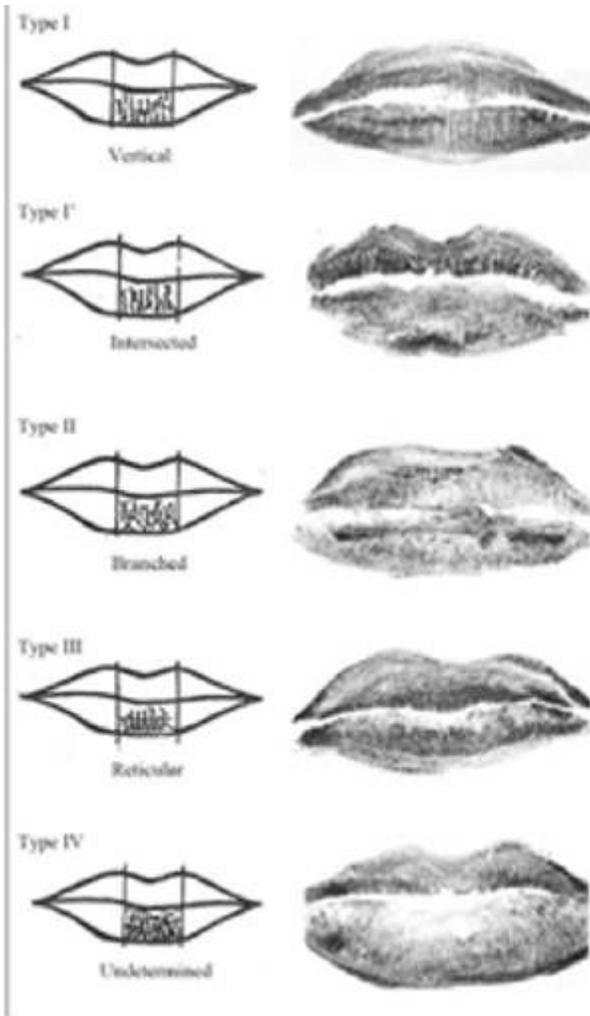
Negligence, in general, is the breach of duty caused by omission to do something which a reasonable person would do, or doing something which a prudent and a reasonable person would not do. Malpractice on the other hand is the failure to exercise knowledge, skill and care with resultant injury to the patient.<sup>28</sup> Because neither the judge nor the jury may fully understand the complexities in matters before the bar, the law allows for the use of the expert witnesses. Unlike other (fact) witnesses, an expert witness is allowed to testify or present his or her opinion. That opinion is based upon the expert's training, education and experience. An expert may conduct tests or other activities that assist him or her in reaching that opinion. However, the expert's testimony and opinion must be grounded in accepted theory and practice.<sup>9</sup>

### **CHEILOSCOPY**

Lip prints are normal lines and fissures in the form of wrinkles and grooves present in the zone of transition of human lip, between the inner labial mucosa and outer skin, examination of which is known as cheiloscropy. Lip prints are unique for individuals like the finger prints. Lip print recording is helpful in forensic investigation that deals with identification of humans, based on lip traces. A lip print may be revealed as a surface with visible elements of lines representing the furrows. This characteristic pattern helps to identify the individuals since it is unique for individuals.<sup>5</sup>

Lip prints have to be obtained within 24 hours of time of death to prevent erroneous data that would result from post mortem alterations of lip. Lip print pattern depends on whether mouth is opened or closed. In closed mouth position, lip exhibits well defined grooves, where as in open position the grooves are relatively ill defined and difficult to interpret.

Suzuki and Tsuchihashi (1970) have proposed a classification of lip prints also known as Tsuchihashis classification, [Figure 6] these are most widely used classification in literature. They classified the natural lip marks/fissures in four types as:



**Figure 6: Suzuki & Tsuchihashi classification of Lip prints**

- Type I – Vertical
- Type I' – Partial length across the lip grooves of Type I
- Type II – Branched grooves
- Type III – Intersecting grooves
- Type IV – Reticular grooves

● Type V – Other patterns<sup>29</sup>

One common problem that is encountered during the cheiloscopy studies is that of smudging or spoiling of lip prints leading to unidentifiable marks. When the lines are not clear (only the shape of lines is printed), individual identification of human being based on this trace is extremely difficult, unless the trace contains more individual characteristics like scars, clefts etc, and often identification ends with group identification.<sup>5</sup> A lip print at the scene of a crime can be a basis for conclusions as to the character of the event, the number of the people involved, sexes, cosmetics used, habits, occupational traits, and the pathological changes of lips themselves.<sup>29</sup>

**PALATOSCOPY & RUGOSCOPY**

The study of palate in general is called as Palatoscopy and the study of the patterns of the grooves and ridges (rugae) of the palate to identify individual patterns is called as Rugoscopy. Palatal rugae comprise about three to seven ridges radiating out tangentially from the incisive papilla. The most prevalent palatal rugae shape is sinuous followed by curve, line, point and polymorphic varieties. The palatal rugae that are larger were the sinuous. [Figure 7] The pattern of these rugae is considered unique to an individual and can be used as reliable method in postmortem cases.<sup>5</sup> In addition, rugae patterns may be specific to ethnic groups facilitating population differences.<sup>30</sup> The shortcomings in applying rugoscopy as a definitive tool in forensic odontology are many. Postmortem identification is not possible without the antemortem records. To give rugoscopy such importance, previous recording, scanning and preservation through dental casts and computer records are essential. Palatal rugae are often destroyed in fire accident cases and in those cases of decomposition and thus rugoscopy does not have application after this stipulated period.<sup>5</sup>

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