- Human identification by Forensic Odontology
- Methods used for biometric identification
- Tongue Anatomy and Physiology
- Tongue as a Biometric Identifier
- Medical uses and Applications of Tongue examination and Analysis
- Permitted, Principled or Ethical (legal) Considerations involved in tongue analysis

Review of Literature

Forensic Odontology and Human Identification

Human identification is very crucial and forensic identification proves to be a very important parameter in it especially when outdated methods of proof of identity do not provide conclusive and precise results or are difficult to use. This review documents how forensic odontology has proved to be of great help in human identification focussing on the dental aspect. This literature explains how records from dentists like radiographs, tongue analysis reports, bite marks, dental biometrics has proved to be of importance in forensic identification. Also, it is brought to picture that how data received from dentists, medical professionals and forensic experts has time an again proved to be a boon in achieving precise and correct identifications. This review also presents the shortcomings, challenges, future prospects and legal implications associated with forensic odontology and human identification.

1. Dental Archives or records and Identification: Nambiar P states that dental records are important in forensic identification. He also discusses that dental features like dental charting, missing teeth, dental restorations can be used as features for comparison. The forensic odontologists can assess dental records and also play an expert witness in the court[1].

   Thampan N et at states that Forensic odontology plays an essential role in the identification of victims in mass disasters utilizing "preserved dental records" or "ante-mortem records" available with the general dental practitioners. Identification of an individual by comparing postmortem and antemortem records is more consistent and easier as compared to other methods [2].

2. Bite Mark Examination in Forensic Odontology: Authors: Pretty IA, Sweet D Journal: Journal of Clinical Forensic Medicine Year: 2017 Summary: This review focuses on bite mark analysis in forensic odontology, detailing the methods used in bite mark comparisons, pattern analysis, and the limitations of

the technique. The paper highlights the need for proper documentation and expertise in bite mark analysis for accurate results[3]. Rothwell BR suggested that Bite marks are crucial and sometimes debated aspect of forensic odontology. He also states that bite marks have received a lot of attention lately in media and scientific connections. There are many reported cases in which bite marks evidence has been very critical in the release and conviction of many criminals [4].

3. Advancements in Dental Radiography for Human Identification: Authors Silva RF et al mention the recent advancements in radiography involved in dentistry like the panoramic radiography, digital radiography and CBCT (Cone - Beam computed tomography) and their uses in human identification. In their paper they have stated the importance of forensic odontology for legal purposes. The use of radiology CBCT in odontology forensic[5.]

Andi Izham and Elza Ibrahim Auerkari, 2021 in their paper state that Forensic radiology is utilized to help doctors and are a field in medical imaging. Through CBCT forensic odontology has taken a different turn. It has assisted in various applications, like the age estimation through teeth, the role of dentists in hearings in courts or forensic witnesses, bite marks analysis, investigation especially of trauma cases, and determination of race and sex.

The advantages of digital CBCT radiographs are that the speed at which radiographs are retrieved is really good. radiograph becomes visible on a computer screen wherein application of density, contrast, sharpness, image, and colour adjustments can be made on the CBCT digital radiograph software which helps significantly in identification checks in forensic, especially in skeletal and odontology cases [6].

Developing Skills in Forensic Odontology: Kaul B, Vaid V, Gupta S, Kaul S, 2021 in their paper have discussed that dental biometrics helps us regulate and determine many parameters that help in forensics like population affinity, type of specimen, race, age, sex, stature and other individual factors.

So, relative or comparative dental identifications with the assistance of a biometric recognition system will prove to play a big role in identifying dead individuals in crimes, disasters or any other mass tragedies[7].

4. Tongue as an effective Forensic Tool: Potential for Human Identification: This topic examines the potential of using tongue examination as a forensic tool for

human identification. The paper discusses the unique morphological characteristics of the tongue and its applications in biometric identification and postmortem identification.

Abraham J, Binita G, Sandra E J, 2018 state that Forensic odontology is that branch of dentistry that majorly deals with the identification based on individual's oral structures. The tongue is a unique structure that shows both geometric shape as well as physiological texture information that may be useful in identity confirmation. The paper presents research which was taken over the people to study and analyse the morphological shape and texture of the tongue and show their use as an aid in human identification. The authors after the results came to a conclusion that the human tongue promises to cater a level of uniqueness in shape and texture and is suitable for the use in identity recognition [8].

Khan T et al ,2023 discusses that tongue has unique features which vary from individual to individual. This is even true in identical twins. For this reason, tongue prints can be used as a secure method of biometric verification in Forensic Odontology [9].

5. Challenges and Future goals in Forensic Odontology:

Kavitha B, Einstein A, Sivapathasundharam B, Saraswathi TR have discussed that though forensic odontology has gained a lot of popularity in recent times, various methods and modalities used are encountered by limitations. These restrictions or limitations are to remembered when responding to queries in the court of law while prosecuting a suspect, because an inappropriate conclusion can alter affect the lives of the accused. Hence responsible conclusions and results should be presented. [10]

The Biometric Identification Methods

Biometric identification methods are very important in varied applications which includes forensic sciences and personal identification also. This discussion includes different biometric identification methods like iris recognition, fingerprint recognition, facial recognition, voice recognition and tongue analysis. We will discuss some principles, advantages, disadvantages and limitations here. Also, recent advances, effectiveness and reliability will be discussed here.

1. Fingerprint analysis and Recognition: Jain AK, Nandakumar K, Ross A have suggested the basic principles of fingerprint recognition, including the anatomic structure of fingerprint ridges and valleys. It discovers different fingerprint matching algorithms and highlights the implication of fingerprint recognition in investigations and forensic law enforcement.[11]
2. Iris Recognition: Arezou Banitalebi Dehkordi & Syed AR. 2015
   Iris recognition is a precise biometric system. Recently iris recognition is established in several active areas of research, such as; "Image Acquisition, restoration, quality assessment, image compression, segmentation, noise reduction, normalization, feature extraction, iris code matching, searching large database, applications, evaluation, performance under varying condition and multibiometrics". This paper gives a background of iris recognition and also discusses recent proposed methods in different fields of iris recognition system from 2007 to 2015. [12]
3. Facial Recognition: Kortli Y, Jridi M, Falou AA, Atri M have stated that Interest in theories and algorithms for face recognition has been increasing. criminal identification, Video surveillance, building access control, and unmanned and autonomous vehicles are just a few examples of concrete applications that are becoming popular among industries. Various systems are being developed including local, holistic, and hybrid approaches, which provide a face image portrayal using only a few face image features or the whole facial features. In this paper, a detailed comparison between these methods is presented by documenting the advantages and the disadvantages of their schemes. To conclude this paper actually discusses the future goals in terms of techniques to be used for facial recognition.[13]
4. Voice Recognition: Authors: Reynolds DA and Rose RC have examined the voice recognition methods, including speaker authentication and speaker identification. This article discusses the difficulties of voice recognition, such as differences in speech and background noise, and its applications in forensic voice analysis. [14]

Biometric identification systems
Tongue Analysis
Dental Biometrics
Iris Recognition
Fingerprint Recognition
Facial Recognition
Voice Recognition
Hand Geometry

Tongue Anatomy and Physiology

The Basic Physiology and Anatomy of The Tongue: an overview.

Tongue as we all know is a vital organ in the oral cavity. It serves multiple functions like assistance in speech, swallowing and mastication. As we know the primary roles of tongue are in the respiratory and digestive systems but due its very unique physiological and anatomical appearance and characteristics it has gathered a lot of interest in various applications like diagnosis in both traditional and modern medicine and forensic identification. In this review we will be discussing the physiology, anatomy, the structure, blood supply, innervation, functions and its relevance in various fields.

1. Structure of the Tongue: The tongue is an organ which is muscular and it is made up of extrinsic and extrinsic muscles. The muscles helping with the gross movements and protrusion are the extrinsic muscles and the shape modulations and fine movements are taken care by the intrinsic muscles. The dorsal surface of the tongue which is the top part has characteristic features which are different in each individual. It contains papillae which are filiform, fungiform, circumvallate and foliate distributed on the tongue. Tongue has tastebuds associated with fungiform and circumvallate papillae which are responsible for taste sensations. The ventral surface of the tongue contains lingual frenulum which connects the floor of the mouth to the tongue.

2. Tongue Innervation: The Tongue gets its sensory nerve supply or innervation from the Cranial nerves which are:

   The Facial Nerve (CN VII), Glossopharyngeal nerve (CN IX), and Vagus nerve (CNX).

   The taste perception is facilitated by the gustatory fibers from chorda tympani branch of CN VII and the lingual branch of CN IX. Also, the motor innervation going to the tongue muscles is by the hypoglossal nerve (CN XII) which is responsible for controlling tongue movements.

3. Tongue and its blood supply: Basic function of the artery supplying blood to the tongue is delivery of oxygen and nutrients which is done through the branches of lingual artery that comes from the external carotid artery. The extrinsic and the intrinsic fibres get their blood supply from Lingual artery.

4. Functions of the Tongue:
   a. Ability to Speak and Pronunciation: It is through the tongue that speech is produced. It is because of the tongue that various alphabets, words, sentences and sounds are produced because of which verbal communication is possible.
   b. Deglutition and Mastication: Tongue helps in chewing the food and also swallowing by its movement.
   c. Taste Sensation: The dorsal surface of the tongue contains papillae which bear taste buds responsible for the taste sensation (salty, sweet, bitter and sour)

Tongue as a Biometric Identifier

Biometrics is important for identification and tongue has proved to be an important biometric tool for identification due to its unique morphological characteristics and appearance and its contactless and non-invasive nature of identification. The Unique morphological appearance which is specific to each individual and its relative stability makes tongue a potential biometric identifier.

1. Contactless and Non-Invasive: For biometric identification tongue analysis is contactless and non- invasive this is very comfortable and convenient for the analysis. On the other hand, fingerprints and iris recognition are more demanding as they require physical contact, cooperation from the subject.

2. Resistance to Bluffing: A very crucial point is that the tongue morphology is so unique that replication changes are fewer reducing frauds related to identity and unlawful access.
3. Combination Biometrics: Another important aspect of tongue analysis is it can be used as an adjunct with other biometric identification tools like facial recognition, voice recognition and lip prints etc. This multimodal approach really increases the accuracy of identification.
4. Forensic identification: Tongue is well protected inside the mouth and in cases of decomposed bodies tongue analysis provides valuable insights. This can be used when traditional methods are not possible.
5. Medical Diagnosis: Diagnosis with the help of the tongue appearance and changes are used extensively in Ayurveda and Traditional Chinese Medicine. It helps in the assessment of an individual's health.

Medical uses and Applications of Tongue examination and Analysis

Tongue analysis can be used for many diagnostic and curative purposes particularly in Ayurveda and traditional medicine systems like Traditional Chinese Medicine (TCM). Just by observing the tongue we can get a lot of information regarding an individual's health and imbalances

1. Disease Diagnosis and Treatment: In various treatment modalities, ayurveda and in TCM the appearance of the tongue has been given a lot of importance and its thought that tongue is a reflection of the health of an individual. The findings based on the tongue appearance guides a lot of treatment approaches and dietary changes.
2. Traditional Medicine Diagnosis: A lot of importance is given to the tongue appearance and the coating on the tongue to diagnose and assess overall health in the traditional Korean and Japanese medicine.,
3. Tongue observation and evaluation in Ayurveda: A very important concept of diagnosis in Ayurveda is "Jihva Pariksha" which is analysing the shape, colour, coating and texture of the tongue to find out about the dosha Vata, Pitta, or Kapha imbalance which in turn helps in the treatment of the individual.
4. Tongue analysis in Traditional Chinese Medicine (TCM): In this study (TCM), the examination of tongue is called "She Zhen". many characteristics of the tongue like the shape, colour, coating and moisture are analysed to find out the

disharmonies in (Qi) the body's vital energy and the distribution of Yin and Yang energies. Also, acupuncture, herbal thrapies and dietary modifications are made by TCM practioners on the basis of tongue analysis.

5. Tongue analysis and Diagnosis in Modern Medicine: We are now aware of how tongue has been used for the diagnosis of diseases in traditional medicine. Modern medical practitioners and researchers are also exploring medical conditions like cardiovascular diseases, nutritional deficiencies and respiratory diseases with the help of tongue analysis.

Permitted, Principled or Ethical Considerations involved in tongue analysis

Ethical and legal considerations are extremely important when it comes to tongue prints. Consent for recording data, confidentiality, privacy, storage and its security are of paramount importance and cannot be neglected at any point.

1. Informed Consent: Whenever a study has to be done its crucial to firstly explain the procedure, purpose and storage of the data for evaluation and research then take consent of the patient.
2. Data Privacy and Confidentiality: As analysis of tongue is a procedure which involves collection of a lot of sensitive biometric data it is of high importance to maintain privacy and prevent unwanted access to the information so it cannot be misused.
3. Data Preservation and Removal: To prevent misuse and breaches once the data has been used for analysis it should be deleted.
4. Security Procedures: to make sure that unauthorized access, hacking, or cyber threats does not hamper the data. Encryption, access controls, and secure networks can be used to safeguard all the sensitive information and data.
5. Data collected for Ethical Use only: Medical and forensic identification should be the sole purpose for data collection with consent.
6. Consent extraction or withdrawal: Every individual should have the right to withdraw their consent for tongue analysis.
7. Special considerations for vulnerable: children, elderly individuals, or those with cognitive impairments should be segregated for special considerations to make sure their rights are protected during tongue analysis.
8. Multicultural Understanding: when interpreting toungue characteristics it is very important to take into consideration the cultural diversity.Unique

interpretations of tongue features can exist for different cultures so assumptions should not be made.

9. Proof and Accurateness: Researchers and practitioners should authenticate the correctness and dependability of tongue analysis techniques to make sure that they can be trusted.
10. Legal Acceptability: In forensic circumstances, tongue analysis should meet legal acceptability or admissibility requirements, and presence of specialists is required to offer evidence on the validity and the reliability of the analysis in court.

Conclusion: The analysis of tongue has great potential in forensic identification and medical diagnostics. This analysis should be conducted very responsibly and ethically as adhering to these ethical and legal attentions, safeguards the privacy and rights of individuals. Also, by adapting these principles of analysis forensic experts, researchers and practitioners can benefits from tongue analysis.