

**AN OBSERVATIONAL STUDY TO ANALYSE AND
COMPARE THE MORPHOLOGICAL DIFFERENCES ON
THE DORSAL SURFACE OF THE TONGUE IN THE
PEOPLE OF SOLAN**

सोलन के लोगों में जीभ की पृष्ठीय सतह पर रूपात्मक अंतर का
विश्लेषण और तुलना करने के लिए एक अवलोकन संबंधी अध्ययन

**A
Thesis**

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2024

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CERTIFICATE

It gives me immense pleasure in certifying that the thesis “**AN OBSERVATIONAL STUDY TO ANALYSE AND COMPARE THE MORPHOLOGICAL DIFFERENCES ON THE DORSAL SURFACE OF THE TONGUE IN THE PEOPLE OF SOLAN**” (सोलन के लोगों में जीभ की पृष्ठीय सतह पर रूपात्मक अंतर का विश्लेषण और तुलना करने के लिए एक अवलोकन संबंधी अध्ययन) and submitted by **HINGAD NUPUR RAJKUMAR** is based on the research work carried out under my guidance. He / she has completed the following requirements as per Ph.D. regulations of the University;

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DATE: -

HINGAD NUPUR RAJKUMAR



DEDICATED TO
MY FAMILY, FRIENDS
AND WELL-WISHERS

PREFACE

The human tongue is a unique organ of the human body. Dorsal surface of the tongue is unique from person to person as human DNA, the color, shape, and surface features are characteristic of every individual. This property makes it possible for the tongue to serve as a tool for biometric identification. Tongue print being the new biometric authentication tool is unique and cannot be forged.

This study provides valuable insights into the diversity of tongue morphology within a population, underscoring the feasibility of using these features for non-invasive identification purposes. This research contributes to the growing interest in tongue analysis for medical diagnostics and forensic applications. Further exploration and validation of these findings may pave the way for the integration of tongue biometrics in diverse fields, including healthcare and law enforcement.

tongue is definitely one of the unique structures which can add as an adjunct in forensic identification with other aids like rugoscopy, finger prints analysis and many others. One very important fact other than the uniqueness of the tongue is that it is encased in the oral cavity and is well protected and can only be protracted with consent. Tongue has many properties which are quite unique to an individual. Tongue examination is a field which is quite unexplored as compared to other forensic identification tools. It is now being considered suitable for recognition of identity. Tongue has geometrical shape information and physiological texture details which when recorded can prove to be very useful in identification. The main reason for introducing tongue prints in forensic odontology is because of its usefulness in human identification. Biometrics is a very important tool for identification and like commonly used fingerprints, facial scans, iris or voice recognition tongue scans can also be used. Our study is targeted to present the morphological differences proving the evident uniqueness of the tongue. Unlike other forensic identification tools forging of tongue prints is almost impossible. No two tongues as we are aware are similar or are completely unique to each, it is protected inside the oral cavity and highly stable. Hence this study which analysis the morphological differences on the dorsal surface of the tongue in the people of Solan was done to find out and compare if the fact that the tongue is unique actually holds true. Preservation of antemortem tongue

impressions and photographs for forensic identification has great scope and can prove to be of great help. Studies like ours which are used to collect information which can be used as a reference for further studies should be encouraged to collect more proof on the fact that tongue is a unique tool.

In our study the Digital photographs of the tongue were captured. The study sample included 316 participants. The geometrical shape, colour and surface texture details were observed and analyzed. Differences based on gender and age were studied and analyzed.

The results we got suggested that shape of the tongue, surface texture of the tongue, apex of the tongue, color of the tongue differs based on gender but surface texture, shape of the tongue, apex of the tongue, median septum does not differ based on age groups, color of the tongue differs based on age group.

To conclude the individual lingual shape is consistent and the physiological texture is invariable. In addition to rugoscopy and cheiloscopy, the study of lingual morphology may be one of the secure methods for identification in forensic dentistry. Hence the present study is to analyze the various lingual morphological aspects like shape, color, apex, median septum and other characteristics which can aid in the identification

This observational study provides valuable insights into the morphological differences present on the dorsal surface of the tongue among the people of Solan. The findings contribute to our understanding of regional variations in tongue anatomy and may have implications for oral health practices, diagnosis of systemic conditions, and the development of targeted healthcare interventions in this specific population. Further research is warranted to explore the underlying factors influencing these morphological differences and their potential clinical significance.

The observed morphological differences on the dorsal surface of the tongue in the population of Solan not only enrich our comprehension of regional variations but also hold potential implications for various aspects of healthcare. The findings of this study can be instrumental in shaping oral health practices tailored to the specific characteristics of this population. Understanding the unique morphological features

may aid in the development of region-specific oral hygiene recommendations, preventive strategies, and educational initiatives to promote better overall oral health.

Moreover, the identified variations in tongue anatomy could have diagnostic significance in the detection of systemic conditions. The tongue is recognized as a mirror reflecting the overall health of an individual, and deviations from normal morphology may serve as indicators of underlying health issues. Clinicians in Solan and similar regions can leverage this knowledge to enhance their diagnostic capabilities, potentially leading to earlier detection and intervention for systemic diseases.

The potential clinical significance of these morphological differences also opens avenues for targeted healthcare interventions. Tailoring medical approaches to the specific characteristics of the population in Solan may improve the efficacy of treatments and interventions, ultimately enhancing healthcare outcomes. This knowledge could be integrated into medical education curricula and clinical practice guidelines to better equip healthcare professionals in the region.

Despite the valuable insights gained from this study, it is acknowledged that further research is essential. Exploring the underlying factors influencing these morphological differences would provide a more comprehensive understanding. Additionally, investigating the long-term health implications and establishing associations between tongue morphology and specific health outcomes would contribute to the development of evidence-based healthcare strategies in Solan and potentially inform broader healthcare practices globally. This study lays the groundwork for continued research endeavours aimed at unravelling the intricate relationship between tongue morphology and health in specific populations.

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CHAPTER – I

INTRODUCTION



AN OBSERVATIONAL STUDY TO ANALYSE AND COMPARE THE MORPHOLOGICAL DIFFERENCES ON THE DORSAL SURFACE OF THE TONGUE IN THE PEOPLE OF SOLAN

INTRODUCTION

- Basic Background
- Rationale
- The Objectives of the Study
- Consequences of studying and analyzing Dorsal Tongue Morphology
- Possible scope and Limitations

The dorsal surface of the tongue exhibits unique morphological characteristics that have the capacity or potential to be used as a biometric identifier for medical applications and forensic identification.

Tongue analysis has gained increasing popularity and interest in recent years due to its non-invasive nature, contactless examination, and the distinctive features present on its surface. This observational study aims to analyse and compare the morphological differences on the dorsal surface of the tongue in a diverse population.

1. Basic Background: Traditional medicine systems, such as Traditional Chinese Medicine (TCM) and Ayurveda, have long utilized tongue examination as a diagnostic tool to assess an individual's health status and identify underlying imbalances or diseases.

In these systems, the tongue's appearance, colour, texture, and coating are considered reflections of the body's internal health and provide valuable diagnostic information.

2. Rationale: The growing interest in biometric identification methods and the need for non-invasive techniques in forensic science and medical diagnostics have led to exploring the potential of the tongue as a unique biometric identifier.

Unlike traditional biometrics like fingerprints and iris scans, tongue analysis offers a non-contact, hygienic, and easily accessible means of identification.

3. Objectives of the Study: The main objectives of this observational study are as follows:

- a. To find out or analyse and list or document the structural features present on the dorsal surface of the tongue.

- b. To figure out and identify any significant variations in tongue morphology among individuals of different gender or age.
 - c. To analyse the probability of morphological differences in tongue analysis as a biometric identifier for human identification.
 - d. To document and discuss the inferences of tongue analysis in forensic studies and medical researches and diagnostics.
4. Consequences of studying and analysing -Dorsal Tongue Morphology: Tongue analysis has the probability to match the existing biometric identification methods, contributing an additional layer of identification and verification.

The structural variations observed on the dorsal surface of the tongue can give a unique and individual-specific pattern, making it a valuable tool for forensic investigations, postmortem identifications, and access control systems.

5. Possible scope and Limitations: The scope of this study is limited to the morphological examination of the dorsal surface of the tongue. This study does not involve invasive procedures and subjects with underlying medical conditions are not included.

Human identification is a very demanding, challenging and difficult area. Forensic odontologists are able to identify human beings if only there are some unique features associated with that individual's oral cavity and associated organs.

Forensic odontology demands the contribution of dentists especially in criminal and legal cases. This is because they provide dental records, photographs and radiographs which are quite useful in human identification. The basic need for studying various structures useful in forensics is that a thorough understanding can be created and a data base can be updated and stored for comparative analysis.

Teeth are not always present and are liable to changes but in the absence of teeth tongue can be easily accessed.

Tongue can prove to be very useful in both forensic identification and in biometrics. From the above documented facts its quite clear that our tongue is definitely one of the unique structures which can add as an adjunct in forensic identification with other aids like rugoscopy, finger prints analysis and many others.

One very important fact other than the uniqueness of the tongue is that it is encased in the oral cavity and is well protected and can only be protracted with consent.

Tongue has many properties which are quite unique to an individual. Tongue examination is a field which is quite unexplored as compared to other forensic tools. It is now being considered suitable for recognition of identity.

Tongue has geometrical shape information and physiological texture details which when recorded can prove to be very useful in identification.

The main reason for introducing tongue prints in forensic odontology is because of its usefulness in human identification.

Biometrics is a very important tool for identification and like commonly used fingerprints, facial scans, iris or voice recognition tongue scans can also be used.

Our study is targeted to presents the morphological differences proving the evident uniqueness of the tongue. Unlike other forensic identification tools forging of tongue prints is almost impossible. No two tongues as we are aware are similar or are completely unique to each, it is protected inside the oral cavity and highly stable.

Hence this study which analysis the morphological differences on the dorsal surface of the tongue in the people of Solan was done to find out and compare if the fact that the tongue is unique actually holds true.

Preservation of antemortem tongue impressions and photographs for forensic identification has great scope and can prove to be of great help. Studies like our which are used to collect information which can be used as a reference for further studies should be encourage to collect more proof on the fact that tongue is a unique tool.

CHAPTER – II

REVIEW OF LITERATURE



- 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 and 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 court¹.
Thampan N et al 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 methods².
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 results³. 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 criminals⁴.

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 forensic⁵.

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 cases⁶.

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 tragedies⁷.

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 recognition⁸.

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 Odontology⁹.

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

<i>Biometric identification systems</i>
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 therapies and dietary modifications are made by TCM practitioners 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 it is 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 tongue 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.

CHAPTER – III

TONGUE AS A BIOMETRIC IDENTIFIER



- Uniqueness of Tongue Characteristics
- Tongue Surface Analysis for Human Identification
- Ethical Concerns in tongue analysis.

The Uniqueness of Tongue Characteristics

The tongue has very unique characteristics, especially its dorsal surface. Which proves to be a very important key when we consider tongue to be a potential tool in human identification or as a biometric identifier for human forensic identification. Here we will review the literature to understand the evidence or proof to support the uniqueness of the tongue, its morphology and its surface details.

Multiple studies have been done to investigate the unique nature of the tongue in comparison to other biometric identifiers. Fingerprints and iris which are other biometric tools can undergo minor changes over time due to multiple external factors but tongue morphology is considered to be more consistent and stable relatively.

Gaganpreet K and Dheerendra S. 2015 have stated that Tongue print is a unique biometric tool that cannot be forged easily. Advantages of tongue prints over other biometric systems are genetic independence as no two tongues are similar, physical protection as it is encased inside the mouth and its stability over time.¹⁵

A study by Diwakar and Maharshi, 2013 reported the tongue as a reliable member of the biometrics family.¹⁶ Application of the tongue biometrics system in a public use system such as the banking system has been proved by Naaz et al. in 2011.¹⁷ There has been significant research in biometrics over the last two decades. No biometric has yet been developed that is perfectly reliable or secure. For example, fingerprints and palm prints are usually frayed. Signatures, Voice, hand shapes, and iris images are easily forged. Face recognition can be made difficult by occlusions or face lifts, and biometrics such as fingerprints, iris, and face recognition are susceptible to spoofing attacks.¹⁸

Traditional biometrics like face, iris, fingerprint, palm print, and voice have been used in biometric authentication but has an inherent limitation in that they are easily forged. Research on the tongue print recognition system was first proposed by Liu et al. in 2007.¹⁹

Numerous advantages exist in using tongue print because lingual morphological aspects are difficult to forge and display stability over time. The use of photographs as

forensic identification remains unexplored in the field of dentistry. The geometric shape of the tongue is usually constant, and surface texture varies due to pathological changes of the body.^{20, 21}

Studies on tongue surface features and their uniqueness for human identification have been conducted and the researchers the results demonstrated that tongue features showed a remarkable level of individual distinctiveness, even among identical twins.

Other studies have explored the potential of combining tongue analysis with other biometric modalities for multimodal biometrics. For instance, Zhang et al. (2018) investigated the fusion of tongue and facial recognition for enhanced human identification. Their research found that the fusion of tongue and facial biometrics resulted in improved accuracy and reduced false acceptance rates compared to using either modality alone.¹⁸

While the existing literature shows promising evidence of the uniqueness and stability of tongue characteristics, it is essential to acknowledge potential limitations. The sample sizes in some studies may be relatively small, and further research with larger and more diverse populations would strengthen the findings. Additionally, the accuracy of tongue-based identification may be affected by certain factors, such as tongue positioning during imaging or variations in imaging devices.

In conclusion, the reviewed literature provides enough evidence suggesting the uniqueness of tongue characteristics for human identification. The dorsal surface of the tongue exhibits distinct features that are consistent among individuals and remain stable over time. With further research and advancements in imaging technologies, the tongue holds great potential as a reliable and robust biometric identifier, contributing to the field of forensic science and beyond.

Tongue Surface Analysis for Human Identification

Tongue surface analysis for human identification is an emerging field that holds promising potential as a reliable biometric identifier. This section will review relevant literature to explore the use of tongue surface features for individual identification and its applications in forensic science and security.

The uniqueness of the tongue print is that no two tongues are the same, and studies have found that the tongue of identical twins also does not resemble each other.²²

Database creation is mandatory to explore the use of tongue prints in forensic dentistry. Dentists can play an important role by collecting images of the tongue and prepare a cast routinely for the patients along with their other dental records. This would serve as a database and a guide for identification purposes. To conclude, tongue print being a unique record and one that cannot be forged is a better biometric authentication tool than others, and since it is personalized and constant, it can be used for forensic identification purposes too.²⁰

Sivakumar et al in 2018 stated that the tongue can be considered a good biometric system since it fulfils all the parameters, particularly the one regarding circumvention which is a problem with existing biometrics such as fingerprints. The tongue is less susceptible to forgery due to its well protected nature and consent is needed for its inspection, which might not be the case for other biometrics such as fingerprints. One of the main questions regarding this novel mode of identification is how to analyze it for such purposes. A group of researchers has reported a 97.05% accuracy rate in identifying people via their tongue by acquiring images of the patterns on the tongue and comparing pixel intensities of those images²³

The reviewed literature provides valuable insights into the use of tongue surface analysis for human identification. Studies have demonstrated the uniqueness and stability of tongue surface features, supporting its potential as a reliable biometric identifier. The development of tongue-based identification systems and the exploration of multimodal approaches show promise in enhancing identification accuracy and security. As research in this area continues to expand, tongue surface analysis may contribute significantly to the field of forensic science and other security applications.

Ahmed Shallal Obaid et al. 2023 discussed about the uniqueness of the tongue and mentioned that it is well protected hence difficult to forge. They pointed out various aspects in their paper like how traditional biometrics cause obstacles and challenges in investigations and can be easily forged and are very expensive. New more secure less expensive and reliable systems should be used in today's modern world, ditching the traditional methods. This will increase security measures.²⁴

Poojya R. 2023 in a paper discussed Tongue print or lingual impression is a new biometric authentication method used in forensics. That recent advances have been made using uniqueness of the tongue as a valid fact. She documented that algorithms

for tongue image analysis have been prepared. lingual moulded impressions, Digital photographs, rugoscopy, cheiloscopy, ultrasound, histological analysis are some ways of tongue print collection. She stated that there is an urgent need for more secure authenticated forensic tools like the tongue prints. This should be considered and used.²⁵

Bansal et al. 2021 stated that tongue prints can be used as an adjunct to other biometric systems. Hence creation of a good database is very important. He also state the advantages of tongue prints.²⁶

Latif H. 2020 stated that the term biometrics is taken from two ancient Greek words 'bios' and 'metron,' which mean 'life' and 'measure' respectively. It involves the identification of humans based on intrinsic physical or behavioural traits that are unique to individuals.²⁷

Physical characteristics most used as modes of identification include fingerprints, dental records, the iris, and facial recognition amongst others whereas behavioural characteristics used for identification purposes include voice recognition, handwriting, keystroke patterns. Although identification by biometrics is never 100%.

Pradkhshana et al . 2019 formulated a Working classification system of tongue pattern after conducting a study on 30 individuals (15 male and 15 females) where they used digital images to record information.²⁸

Working classification formulated by Pradkhshana et al. 2019 ²⁸

1	Size of tongue	Small and	Large				
2	Shape of tongue	Long and Broad	long and narrow	short and broad	short and narrow		
3	Colour of tongue	Pale	Pink	Reddish	Whitish	Brown	Pigmented
4	Texture of tongue	Smooth	Rough	Ulcerated	Hairy,	Edematous	Nodular
5	Pattern on tongue surface	1. Fissured: V shaped, Coated	2.Branched: -Horizontal -Vertical	Pattern less	Cleft	Geographic pattern	Hairy tongue

		tongue					
6	Margins of tongue:	Smooth	Scalloped	Ulcerated	Nodular		
7	Tip of tongue:	Pointed (V shaped)	Blunt (U shaped)				

Sivakumar et al. 2018 discussed the modes of identification and analysis mentioning how a group of researchers reported 97.05% accuracy rate in human identification by their tongue. This was done by taking images of the tongue patterns and comparing pixel intensities of those pictures. They further converted these images into 3 D plots of pixels of the image giving the researchers unique plots for each image.²³ They also documented about the researchers suggesting that the tongue exhibits sexual dimorphism which again can aid in human identification. Our study also has significant data proving sexual dimorphism. These researchers used alginate impressions to match the tongue getting 90% matching rate.

Abraham Johnson et al. 2018 conducted a study on 225 people (male and female) of age group 20 to 50 and concluded that⁸

GEOGRAPHIC TONGUE	FEMALE MORE THAN MALE Also correlated with Stefansu et al
PLAQUED TONGUE	MORE IN ELDERLY MALES
GEOGRAPHIC TONGUE > SCROTAL TONGUE	Abraham Johnson et al
SCROTAL TONGUE > GEOGRAPHIC TONGUE	Stefansu et al

Reddy MV et al. 2017, Suggested that the unique characteristics of the tongue are impossible to be reverse engineered. Tongue prints have way superior quality than other biometric systems used traditionally. He stated the use of lingual templates or tongue templates with two lateral views (left and right) and one profile views.²⁹

Reddy MV et al also discussed that when comparing tongue scanning to other biometric techniques Tongue due to its uniqueness and anatomy has many advantages²⁹ like

Characteristic features	Unique shape and texture in each individual
Projected when required	It's an internal organ but can be struck out for inspection
Unaffected by environment	As it is protected and encased in the oral cavity it is not affected by the external environment
Inspected with Permission of the individual	only with the consent of the individual can the tongue be examined hence chances of forgery are less

Zang B and Zang H ,2015 Suggested that a cast can be used to transfer the unique features of the tongue and later used for studies. Digital software for colour and hue corrections of the tongue are used to match with the digital databases. The mentioned that algorithms are being used for image analysis of the tongue.³⁰

Many authors on the basis of features observed on the dorsal surface of the tongue made classifications for the ease of other researchers. Like Stefanescu CL et al. 2014.³¹

CLASSIFICATION OF FEATURES ON THE DORSAL SURFACE OF THE TONGUE		
TEXTURAL VARIATIONS IN TONGUE	SHAPES OF TONGUE	TONGUE GEOMETRY FEATURES
TONGUE FISSURES OF TONGUE CRACKS	ELLIPTICAL	LENGTH
SMOOTH TONGUE	HAMMER	WIDTH
	RECTANGULAR	THICKNESS
	ACUTE TRIANGULAR	
	OBTUSE TRIANGULAR	
	SQUARE	
	ROUND	

CLASSIFICATION OF TONGUE FEATURES by Stefanescu CL et al.			
TONGUE TEXTURE	SHAPES OF TONGUE	LONGITUDINAL GROOVES	LINGUAL APEX
PHYSIOLOGICAL	OVOID	PERCEPTIBLE/ IMPERCEPTIBLE	SHARP
SCROTAL	ELLIPSOID	RECTILINEAR/TWISTY	SEPTATE
GEOGRAPHICAL	RECTANGULAR	SUPERFICIAL /DEEP	
	PENTAGONAL		
	TRAPEZOIDAL TO ASYMETRICAL		

Menard L et al. 2012 developed an ultrasound technique using an ultrasound transducer. The process involved placing it in the sublingual area to analyse the tongue function.³²

Bhattacharyya D et al. 2009 stated that tongue is a very good biometric tool as the other tools like finger prints, voice, skin colour, retinal scans all prove to have some shortcomings affecting their reliability and stability.³³ He also documented the disadvantages of various biometric systems:

Disadvantages of various biometric systems: Bhattacharyya D et al. 2009	
FINGER PRINTS	CHANGED BECAUSE OF WORK, ERODED, ALTERED DUE TO SURGERY, CHANGE CAUSED BY BURNS, INJURIES HENCE NOT STABLE
VOICE	ALTERED BY SICKNESS, COLD AND COUGH, EMOTIONAL PROBLEMS
SKIN COLOUR	CHANGES DUE TO AGE, DISEASES BURNS, ADVERSE EFFECTS OF TOPICAL CREAMS OR MEDICATIONS.
RETINAL SCAN	DISEASES LIKE ASTIGMATISM, CATARACT OR BRIGHT LIGHT.

Yan Z et al. 2009 discussed that as tongue is a non-rigid organ images can be extracted in study by the help of capturing a video. He mentioned another method which is sublingual vein analysis method used for diagnosis of tongue.³⁴

Multiple techniques have been employed to evaluate tongue prints and one such mention was made by **Liu Z et al**, that a polytechnic university in Hong Kong developed a tongue image database which captured both surface textures and geometric shape of the tongue (3-dimensional analysis of the tongue) This could prove as a very important base for information in assessments, comparisons and evaluations of tongue patterns.

Liu et al. 2007 stated that the tongue is an internal organ which is well encased and protected in the oral cavity, which makes it less prone to being reverse engineered. The pattern of the ridges on the tongue along with the shape of the tongue and its texture are quite unique to every individual. Most importantly these tongue characteristics are thought to remain unchanging over time. All these features of the tongue make it a fine biometric tool.³⁵

Jain et al. 2005 mentioned different parameters that need to be fulfilled for a trait to be considered a biometric tool

A	UNIVERSALITY	EVERY PERSON SHOULD POSSESS THE TRAIT.
B	DISTINCTIVENESS	EACH PERSON SHOULD BE UNIQUE FOR THE TRAIT.
C	PERMANENCE	THE TRAIT SHOULD REMAIN RELATIVELY STABLE OVER TIME
D	COLLECTABILITY	THE TRAIT SHOULD BE EASILY MEASURABLE.
E	CIRCUMVENTION	THE TRAIT SHOULD NOT BE DISPOSED TO EASY IMITATION, REVERSE ENGINEERING OR FORGERY.

The tongue proves to be a good model as a biometric since it fulfils all these constraints, especially the one regarding circumvention which is a problem with existing biometrics such as fingerprints. Also, the tongue is less prone to forgery due to its well protected nature also consent is needed for its inspection, which might not be the case for other biometrics such as fingerprints.³⁶

(OECDiLibrary 2004) This article discussed that biometric based systems operate in similar manner which involves Biometric Sample captured, digitalizing it, perform

feature extraction or data set creation then tune the sample ultimately match the input sample with known samples in database.³⁷

Ethical Concerns in tongue analysis.

Any form of data required for forensic or biometric identification has many ethical and legal concerns which need to be dealt with and handled with a lot of sensitivity. The data we are handling during the study of tongue analysis or other forensic investigations involves a lot of data which is private and sensitive. Hence documented below are some points to be kept in mind:

1. Consent to be always informed. Any form of study using data from individuals requires a prior informed consent. It is of paramount importance to protect the privacy of the subject. Every individual should be completely be aware about the reason, risks and benefits of the examination or data collection for the study. We should make sure that the rights of every individual should be protected.
2. Protection of data: Biometric data or data collected for the study of tongue needs to be stored very carefully so that there is no access without permission. Data protection regulations should be followed religiously.

CHAPTER – IV

METHODOLOGY



- Research Gaps identified in the proposed field of investigation
- Objectives
- Research Methodology
- Tongue Image Attainment Techniques
- Data Collection and sampling
 - sample size calculation
 - inclusion criteria
 - exclusion criteria
- Data Investigation and Interpretation

RESEARCH GAPS IDENTIFIED IN THE PROPOSED FIELD OF INVESTIGATION

The human tongue has the potential to deliver a high level of uniqueness in geometrical shape, physiological texture which cannot be changed and is suitable for the use in forensic identification.

Tongue Prints, as an upcoming and new biometric authentication technique has been found advantageous for identification although in India this identification system is still at a very basic or grass-root level and definitely needs more amount of investigation, examination, research and planning to implement and dental practitioners can play a significantly important role in making Tongue Prints as a widely available and acceptable tool. Despite the fact that tongue is an important organ, it has not been given equal share in the detailed anatomical studies allotted to other organs in the body.

As we all know that tongue is encased and well protected in the oral cavity, it is very difficult to forge. Details of tongue can be evaluated by visual inspection, digital photography and lingual impressions techniques. Additional methods like biometrics validation can be used which promises to convey an intensity of distinctiveness to recognition applications, that uses tongue print, fingerprint, facial scans, iris or voice to recognize users. Tongue print is a distinctive biometric tool which cannot be forged easily. Advantages of tongue prints over other biometric systems are genetic independence (no two tongues are similar), physical protection (well encased in the oral cavity) and its stability over time.⁸

OBJECTIVES OF THE PROPOSED STUDY

- To observe and analyze the various lingual morphological characteristics like tongue shape, dorsal surface texture details, apex and visibility of medial septum which can prove the uniqueness of the tongue, aid in forensic identification and forms a part of the existing Data base.⁸
- To analyze with respect to: various morphological characteristics on the dorsal surface of the tongue.
- To analyze prevalence of: various aspects of tongue morphology with respect to gender of the study group.⁸
- This study motivates to fulfill the need of more alike studies, based on morphological aspects and biometric analysis, for educational and forensic purpose.⁸

RESEARCH METHODOLOGY

Null Hypothesis (HO): There is no difference in various aspects of tongue morphology with respect to age and sex.⁸

Alternative Hypothesis (AH): There is a difference in various aspects of tongue morphology with respect to age and sex.⁸

Sources of information: Journals, papers, Internet, etc.

Tongue Image Attainment Techniques

Tools and Techniques of Research:

1. The pictures will be taken under the same environmental and lighting conditions and from a predetermined distance using a professional camera (Nikon D5200) placed on a tripod. This will enhance the picture quality and stability of the camera.



Nikon D5200



2. Before the clinical examination of the tongue, the patients will be asked to thoroughly rinse their mouth with water in order to remove any surface debris or food particles.
3. Additionally, the subjects will be asked not to suddenly extend their tongue up to maximum protraction, but in a more relaxed position which would prevent a marked contraction of the striated lingual muscles, which would alter the characteristic aspects, as well as the shape of the tongue.

4. The purpose of the direct examination of the tongue is to analyse and record various parameters such as tongue shape, (dorsal surface details) like surface texture, median septum, lingual apex type.
5. Photographs will be taken after clinical examination.

Data Collection and Sampling Method

The study is conducted after the approval from the **ethical committee** of the institute. The signed copy of which will be attached.

1. It is an observational study with random sampling.
2. Data will be collected from the patients in the outpatient department of the dental college after briefing the patient about the study, giving him instructions documented earlier and most importantly taking an informed consent to use the data for this study.
3. The pictures of the dorsal surface of the tongue will be taken from OPD patients in the college following all the guidelines for successful data collection.
4. All the data will be recorded on a Google form by me for the convenience of the patient which will include some of the details of the patient as well as details of the surface of the tongue (morphological characteristics) along with some demographic variables.
5. Photograph of the dorsal surface of the tongue will be attached by me as an attachment in the google form for systematic data collection.
6. Link of the google form
https://docs.google.com/forms/d/e/1FAIpQLSdYF43FfnfJ9HhwspRRtEzCaXbqgc8ykiaFzd1DVx5OT4jDhw/viewform?usp=sf_link
attached copy of the google form.



M.N. D.A.V. DENTAL COLLEGE & HOSPITAL

Tatul, P.O. Oachghat (Solan) H.P. - 173223

(UNDER THE AUSPICES OF THE COLLEGE MANAGING COMMITTEE, NEW DELHI)

RECOGNIZED BY GOVT. OF INDIA/DENTAL COUNCIL OF INDIA

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Ref. No. DAV/DCH/

425

Date 04/08/2022

Name	Position/ department	Contribution
Dr. Nupur Hingad	Professor and H.O.D Oral and Maxillofacial Pathology and Microbiology	Principal investigator

From: Committee of Research Ethics, MNDAV Dental College, Solan, Himachal Pradesh

Research title: AN OBSERVATIONAL STUDY TO ANALYSE AND COMPARE THE MORPHOLOGICAL DIFFERENCES ON THE DORSAL SURFACE OF THE TONGUE IN THE PEOPLE OF SOLAN

Study Setting: MN DAV Dental College, Solan, Himachal Pradesh

This is to inform you that the Committee of Research Ethics had approved your research proposal.

Upon receiving this approval, you may commence your field work at your convenience.

- You should responsible for upholding the confidentiality of participant's data.
- If any work conducted outside this College, a written approval should be obtained from the concerned authority.
- Kindly, update us on your project advancement every 6 months. On completion of your project, kindly send to us a summary of the project final report.
- Finally, be aware that this approval embraces no financial, or any other, obligations or responsibilities on Qassim University.
- Note: Any corrections and/or alterations of this certificate will make it invalid

Gauri Keemal
Principal
M.N.D.A.V. Dental College
Tatul Solan (H.P.) 173223

GOOGLE FORM DETAILS:

<p>Email *</p> <p>Your email</p>
<p>Name *</p> <p>Your answer</p>
<p>Age *</p> <p>Your answer</p>
<p>Gender *</p> <p><input type="radio"/> Female</p> <p><input type="radio"/> Male</p> <p><input type="radio"/> Prefer not to say</p> <p><input type="radio"/> Other</p>
<p>Address</p> <p>Your answer</p>

Habits *

- ☐ Smoking
- ☐ Zarda
- ☐ Alcohol
- ☐ Other
- ☐ none
- ☐ Other: _____

Shape of Tongue *

- ☐ U Shape
- ☐ V Shape
- ☐ Acute Triangular
- ☐ Obtuse Triangular
- ☐ W Shape
- ☐ Ovoid
- ☐ Ellipsoid
- ☐ Rectangular
- ☐ Asymmetrical
- ☐ Other: _____

Surface Texture of Tongue *

- ☐ Tongue fissures / cracks
- ☐ Smooth Tongue
- ☐ Scrotal tongue
- ☐ Geographic
- ☐ Cleft
- ☐ Plaqued
- ☐ Ankyloglossia
- ☐ Bifid tongue
- ☐ Macroglossia
- ☐ Microglossia

Median Septum *

- ☐ Visible
- ☐ Not Visible

Apex *

- ☐ Rounded
- ☐ Pointed
- ☐ Septate

Colour *

Your answer

Image *

[Add file](#)

A copy of your responses will be emailed to the address you provided.

Submit

Clear form

SAMPLE SIZE CALCULATION:

$$n = Z^2 p (1 - p) / d^2$$

n = sample size, z = level of confidence 95% = 1.96, p = expected highest prevalence 71%, d= Precision (5% = 0.05)

sample size was estimated to be 316 subjects.

The subjects were carefully selected for the study so that errors in evaluation do not occur. After a lot of study and evaluation of previously done researches a criterion for inclusion and exclusion were selected. Age lot of importance was given to the age group in order to come to an age-related conclusion.

As this study was selected amidst the COVID PERIOD a lot of care was taken to simplify the study in terms of patient selection. The Data collection was done after the second wave of COVID.

INCLUSION CRITERIA:

- Patients both male and female of age group 20 – 60 was decided to be included in the study till the total number of patients (316) details are recorded.
- Data collection will be random as the patients report to the OPD and age and gender will not be given preference.
- Those patients who are willing to sign the consent form and agreeing to photography will be a part of this study in order to conduct the study ethically.

EXCLUSION CRITERIA:

Patients with Smoking habits and history of systemic illness.

Patients suffering from

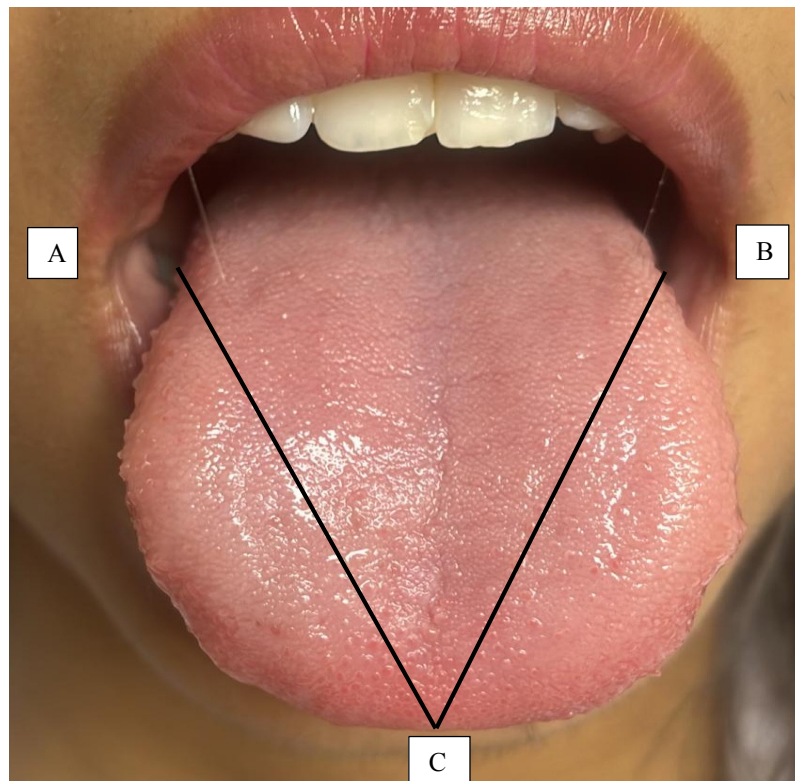
hyperthyroidism, gigantism, dwarfism, ⁸

contagious diseases, syphilis ⁸

Down syndrome

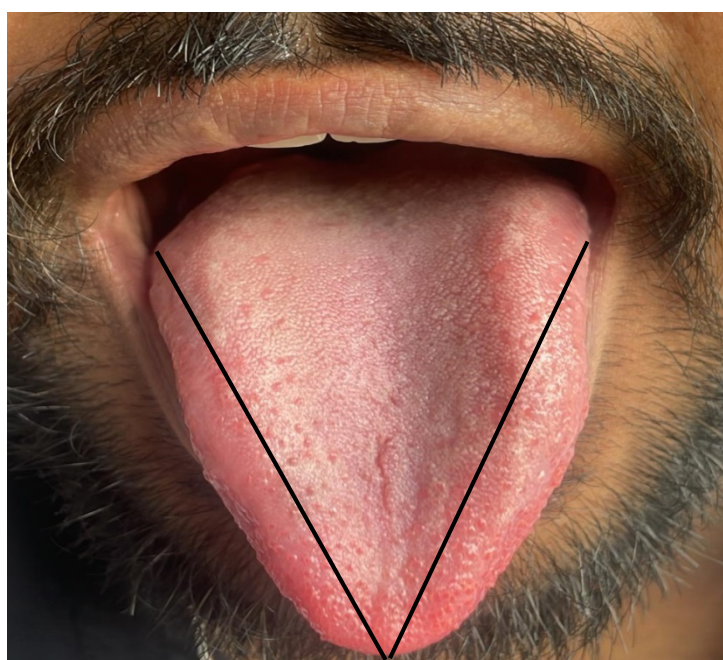
tongue deformity cases were excluded.⁸

TECHNIQUE TO BE USED FOR RECORDING SHAPE OF TONGUE DURING DATA COLLECTION:



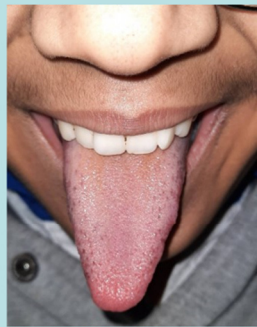
Reference points for the determination of shape of the tongue in contact with the commissures (A, B) of the lips and Tip of the tongue (C) showing a 'U' SHAPED TONGUE

Showing a 'V' SHAPED TONGUE





1

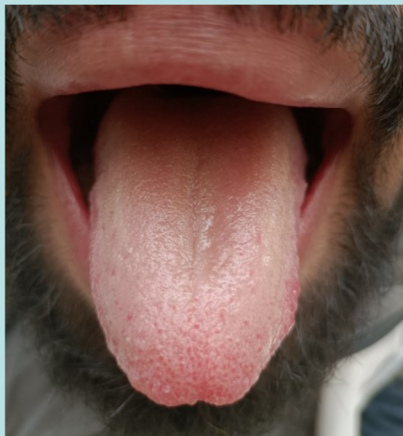


2

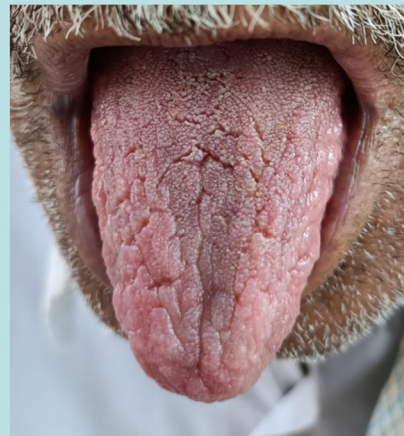


3

The clinical photographs of the tongue showing morphological characteristics like 'U' (1), 'V' (2) and 'W' (3) shapes

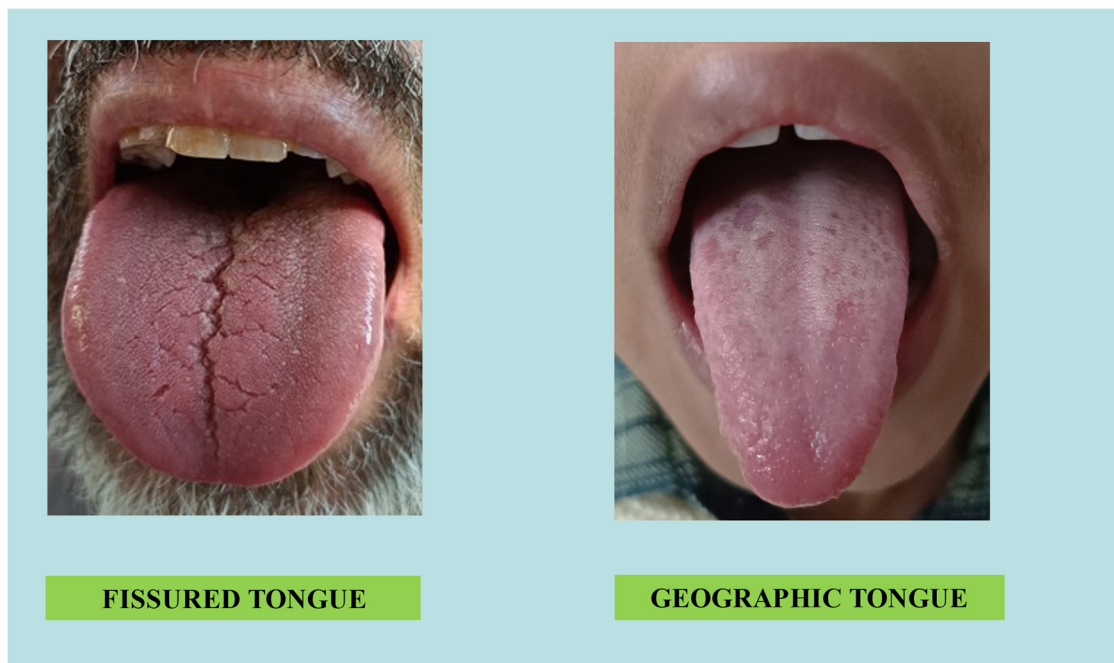
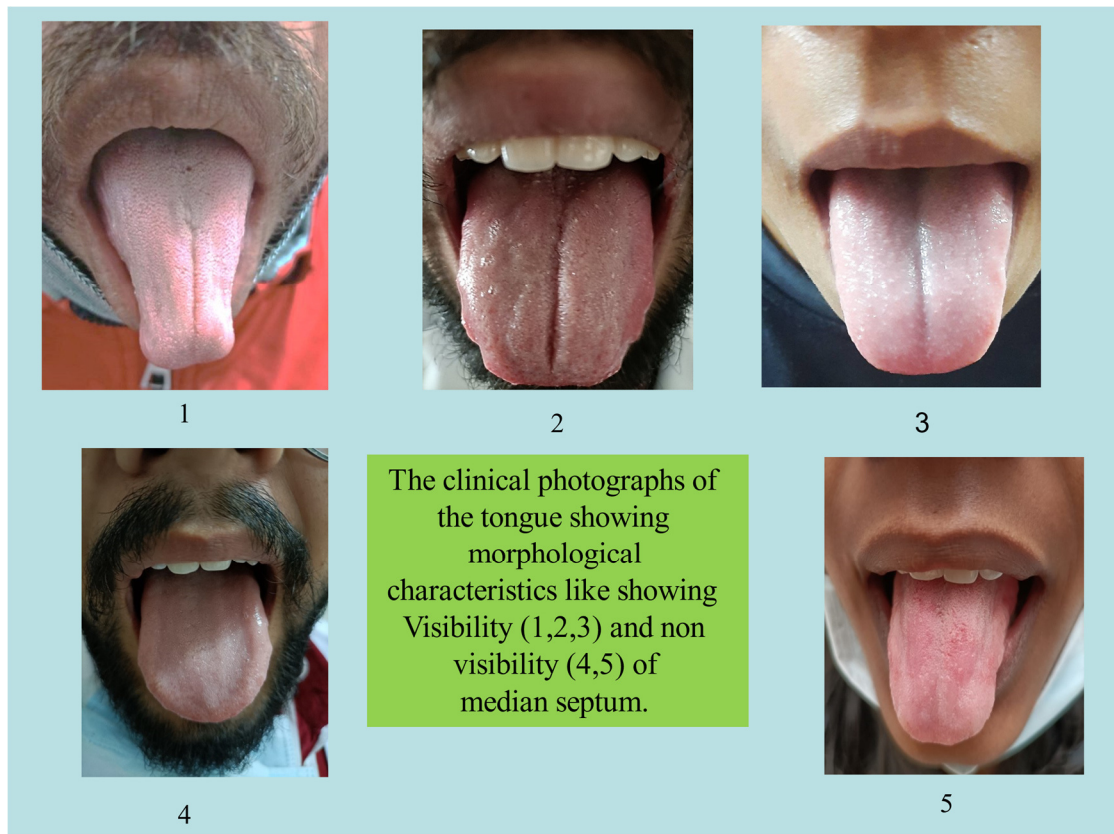


(a)



(b)

The clinical photographs of the tongue showing morphological characteristics like showing 'Smooth' (a) and 'Rough' (b) texture



Data Investigation and Interpretation**DATA ANALYSIS:**

- The observed data will be tabulated and descriptive analysis would be done using *Microsoft Excel and SPSS software*.
- Cross tabulation of various aspects of dorsal surface of the tongue with respect to age dummies and sex will be studied.
- Statistical analysis will be carried out using *Chi – Square test* to analyse prevalence of various aspects of tongue morphology with respect to age and sex of the study group.⁸

CHAPTER – V

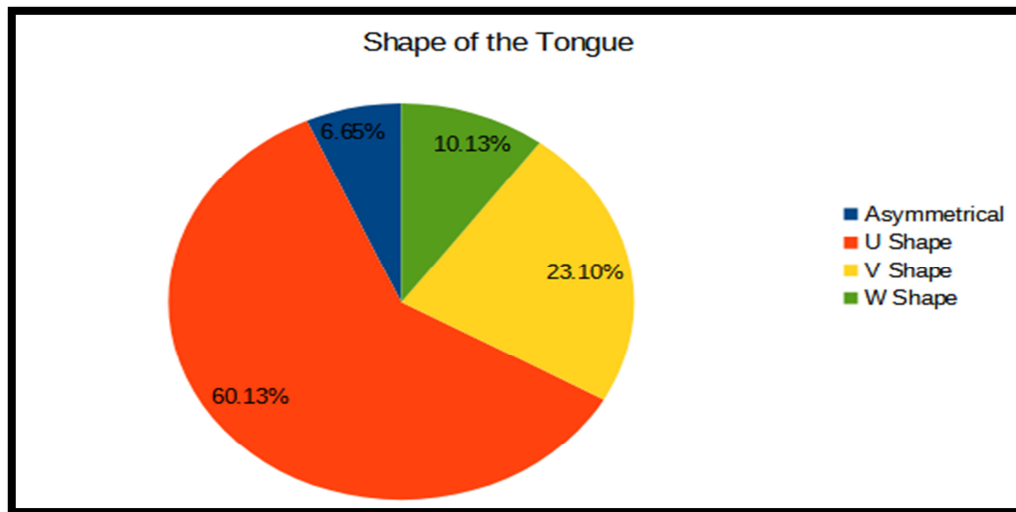
STATISTICAL ANALYSIS AND RESULTS



STATISTICAL ANALYSIS AND RESULTS

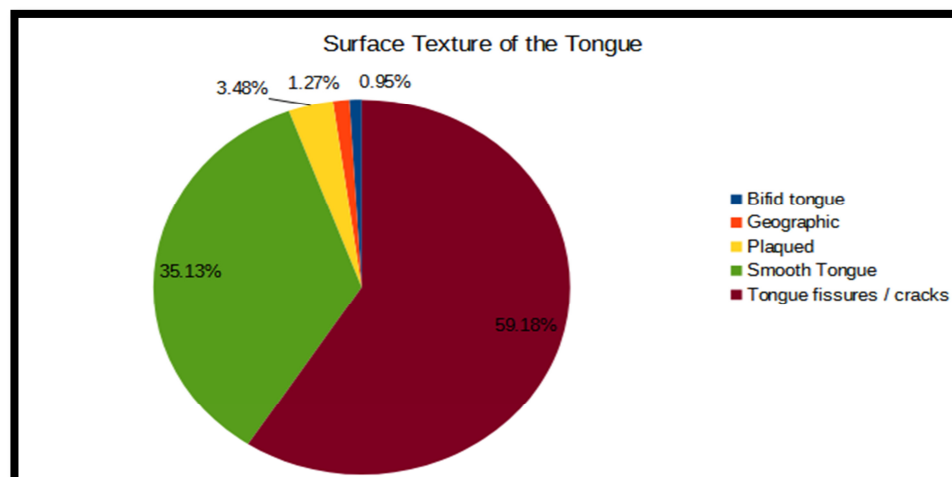
Shape of the Tongue:

The original data collected for the shape of the Tongue comprised of: acute triangular, asymmetrical, ellipsoid, obtuse triangular. Ovoid, rectangular, U shape, V shape and W shape. However, the data was merged into four categories: Asymmetrical, U shape, V shape and W shape. Fig 1 presents the distribution of the respondents on the basis of these shapes of the tongue. It can be seen that about 60% of the respondents have U shape tongue, about 23% of them have V shape tongue, about 10% have W shape and about 7% have asymmetrical shape of the tongue.



Surface Texture of the Tongue:

Fig 2 presenting the distribution of the respondents on the basis of the surface texture of the tongue shows that “Tongue fissures/cracks” (59% app) and “Smooth Tongue” are the two prominent surface textures amongst all the respondents. “Plaquet” (3%), “Geographic” (1%) and “Bifid” (1%) surface textures of the tongue are found in very less respondents.



Median Septum of the Tongue:

Fig 3 presenting the distribution of the respondents on the basis of the median septum of the tongue shows that in about 69% of the respondents, median septum is not visible in the tongue while in remaining 31% of the respondents, median septum is visible in the tongue.

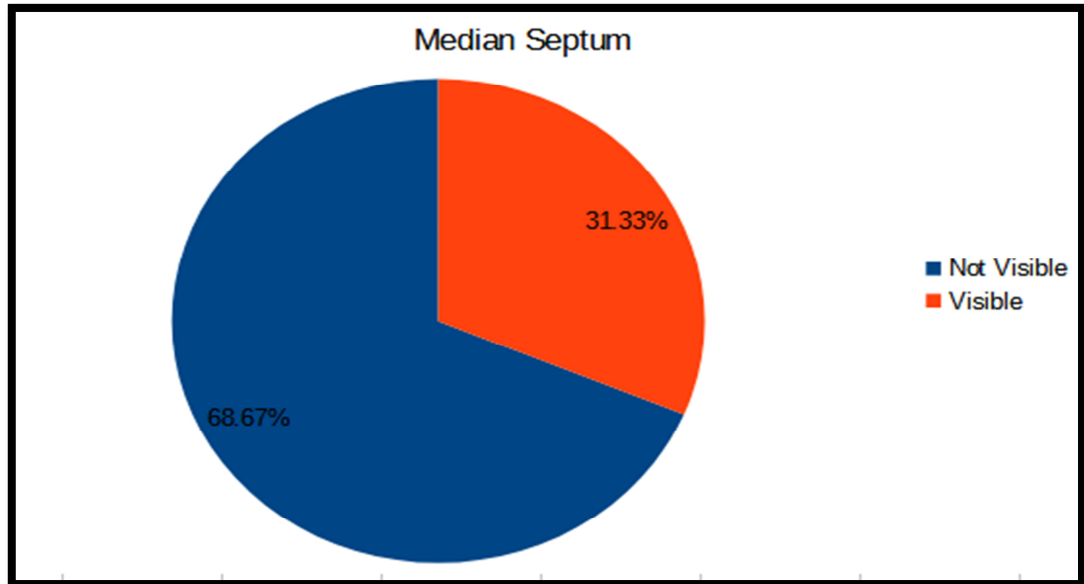
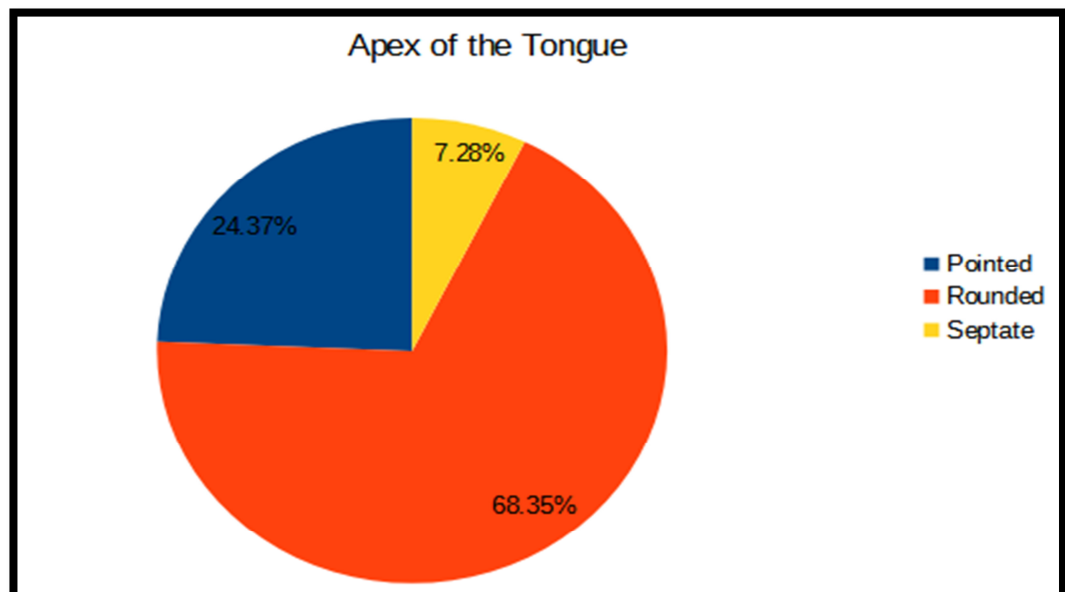
**Apex of the Tongue**

Fig 4 presenting the distribution of the respondents on the basis of the apex of the tongue shows that in about 68% of the respondents, the apex is rounded. In another 24% of the respondents, the apex is pointed while in remaining 7% of the respondents, the apex is septate.



Color of the Tongue:

The original data collected for the color of the Tongue comprised of: baby pink, pale pink, pink, pinkish purple, pinkish red, pinkish white, purple, purplish pink, red, reddish pink and whitish pink. However, the data was merged into three categories: pale pink, pink and pinkish purple. Fig 5 presents the distribution of the respondents on the basis of these colours of the tongue. It can be seen that about 72% of the respondents have pink colour tongue, about 24% of them have pale pink tongue and remaining about 4% have pinkish purple tongue.

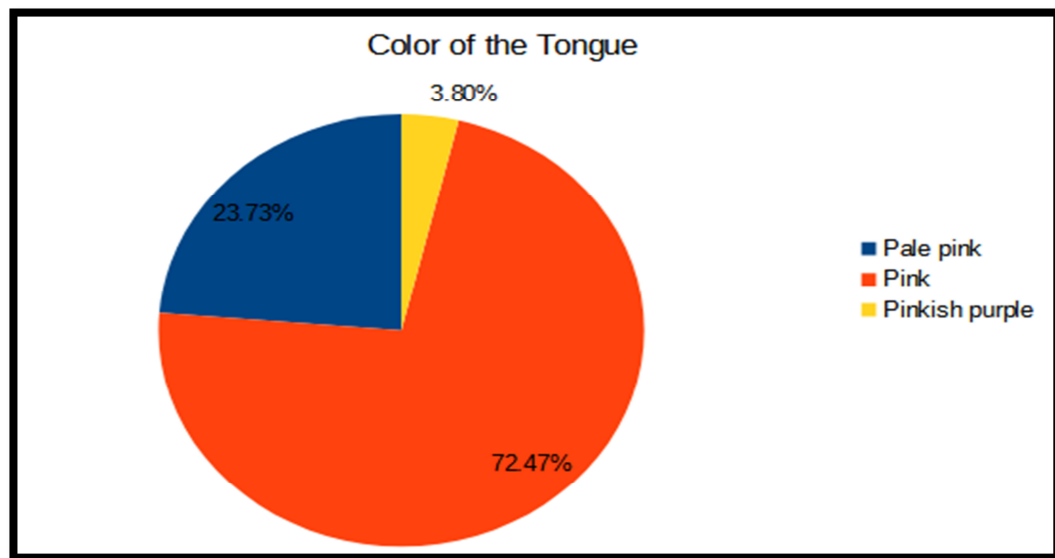
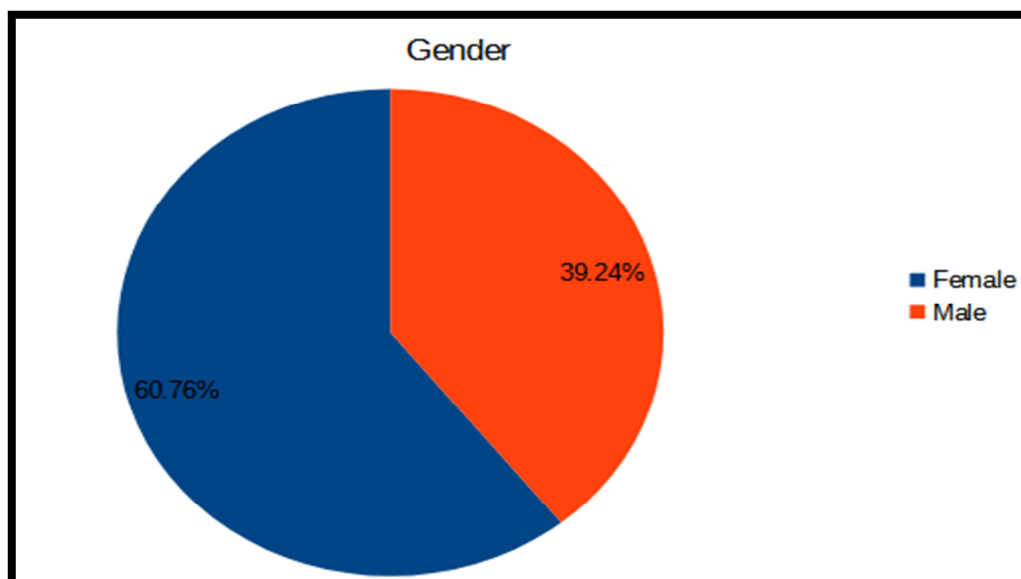
**Gender:**

Fig 6 presenting the pie chart on the basis of the gender shows that about 61% of the respondents are female while in remaining 39% of the respondents are male.



Age Groups:

The data for age was categorized into binary variable using less than equal to 30 years and greater than 30 years age groups. Fig 7 presenting the pie chart for age groups shows that about 79% of the respondents are less than equal to 30 years while remaining 21% of the respondents are more than 30 years.

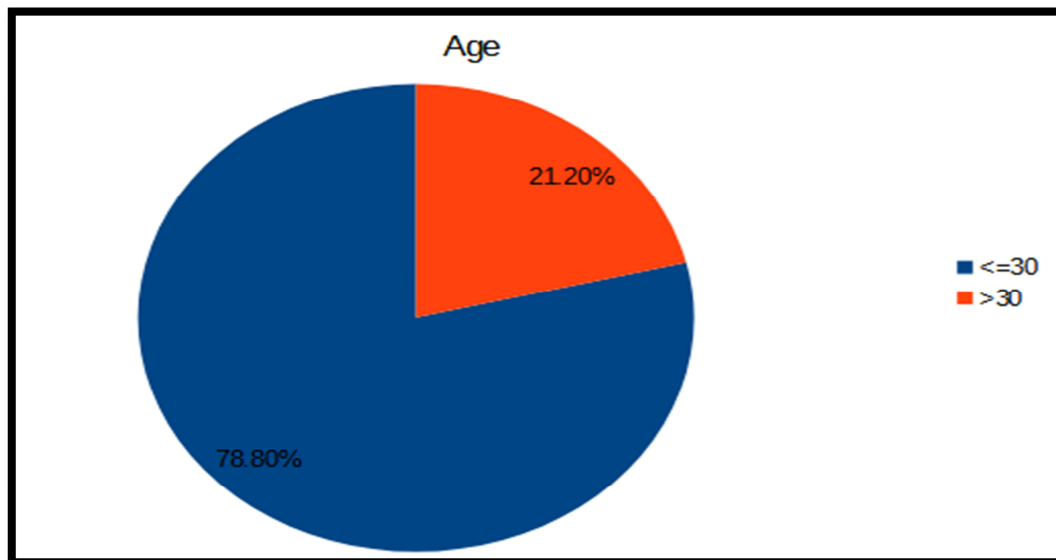
**Shape of the Tongue by Gender:**

Fig 8 presenting the column chart for shape of the tongue by gender shows that of the female respondents, about 5% respondents have asymmetrical shape, 61% have U shape, 27% have V shape and 7% have W shape. While amongst the male respondents, about 9% respondents have asymmetrical shape, 59% have U shape, 17% have V shape and 15% have W shape. Table 1 shows that p-value of Chi-square test is 0.016 which concludes that the shape of the tongue differs based on gender.

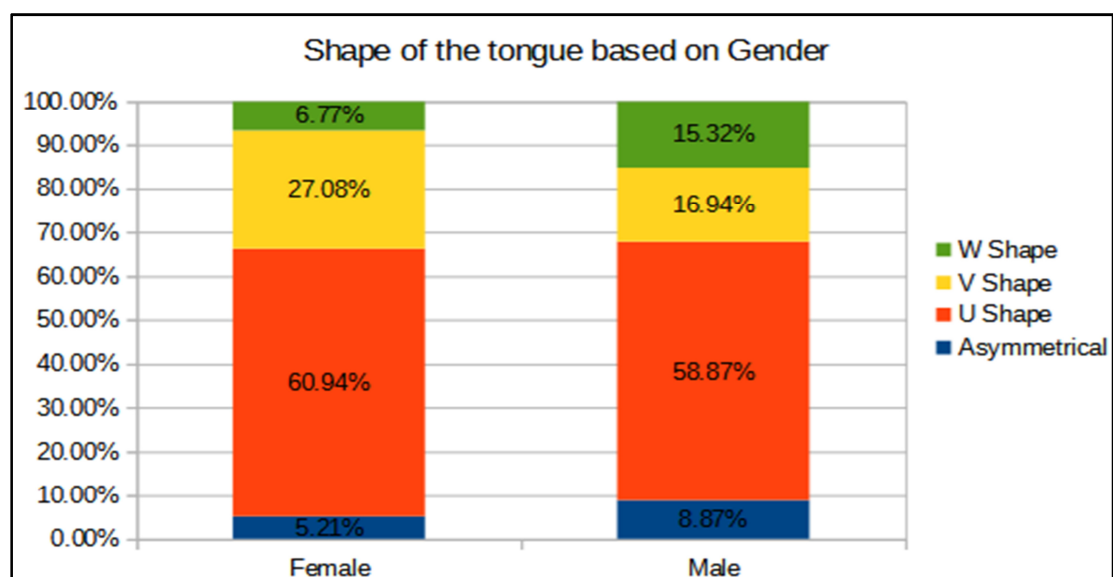
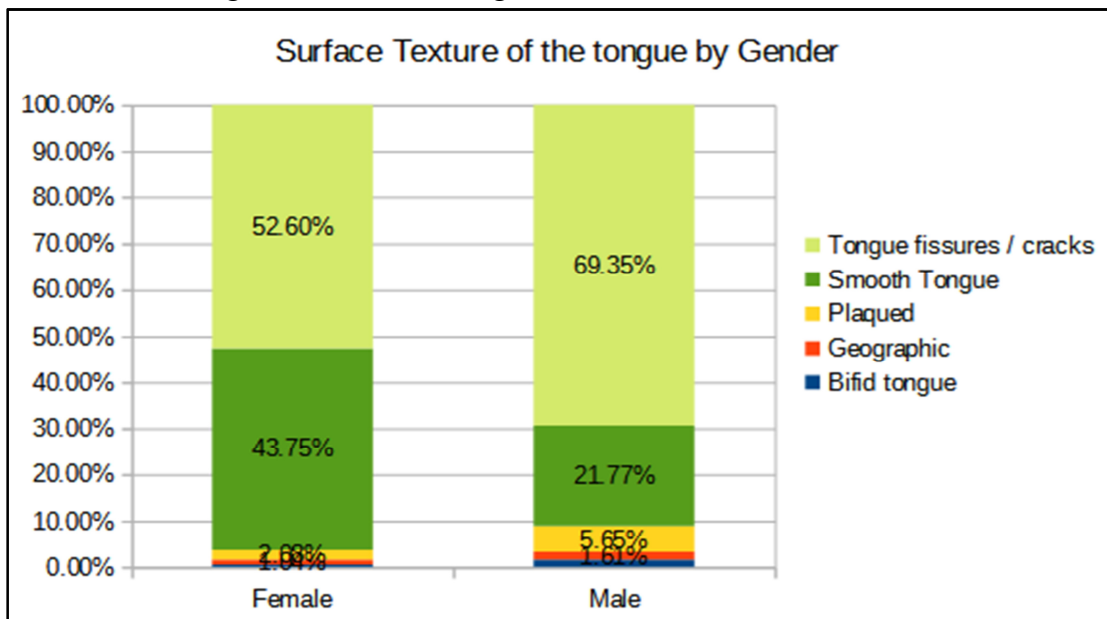


Table 1: Shape of the Tongue by Gender

	Asymmetrical	U Shape	V Shape	W Shape	Total	Sig
Female	10	117	52	13	192	0.016
Male	11	73	21	19	124	
Total	21	190	73	32	316	

Surface Texture of the Tongue by Gender:

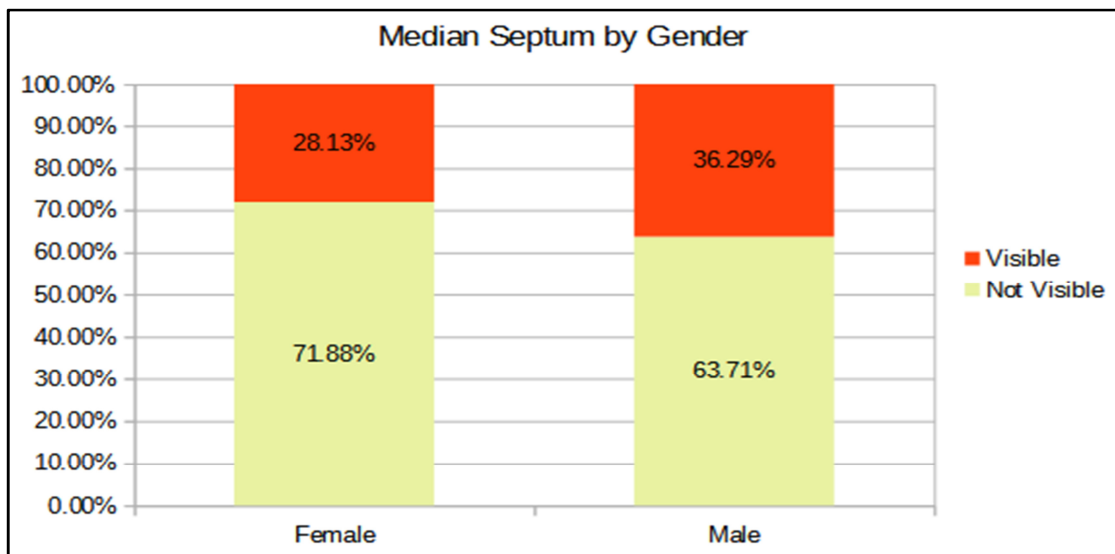
Fig 9 presenting the column chart for surface texture of the tongue by gender shows that of the female respondents, about 53% respondents have tongue fissures / cracks, 44% have smooth tongue, and only 3% of the remaining female respondents have plaqued, geographic or bifid tongue. While amongst the male respondents, about 69% respondents have tongue fissures / cracks, 22% have smooth tongue, and about 9% of the remaining male respondents have plaqued, geographic or bifid tongue. Table 2 shows that the p-value of Chi-square test is 0.001 which concludes that the surface texture of the tongue differs based on gender.

**Table 2: Surface Texture by Gender**

	Bifid tongue	Geographic	Plaqued	Smooth Tongue	Tongue fissures / cracks	Total	Sig
Female	1	2	4	84	101	192	0.001 (HS)
Male	2	2	7	27	86	124	
Total	3	4	11	111	187	316	

Median Septum by Gender:

Fig 10 presenting the column chart for median septum by gender shows that of the female respondents, for about 28% respondents median septum is visible while for remaining 72% female respondents median septum is not visible. The percentage is higher for male respondents where for about 36% respondents median septum is visible and for remaining 64% male respondents median septum is not visible. Table 3 shows that the p-value of Chi-square test is 0.137 which concludes that the median septum does not differ based on gender.

**Table 3: Median Septum by Gender**

	Not Visible	Visible	Total	
Female	138	54	192	0.137 (NS)
Male	79	45	124	
Total	217	99	316	

Apex of the Tongue by Gender:

Fig 11 presenting the column chart for apex of the tongue by gender shows that of the female respondents, about 69% respondents have rounded apex, 26% have pointed apex, and only 5% of the remaining female respondents have septate apex of the tongue. While amongst the male respondents, about 67% respondents have rounded apex, 22% have pointed apex, and only 11% of the remaining male respondents have septate apex of the tongue. Table 4 shows that the p-value of Chi-square test is 0.077 which concludes that the apex of the tongue differs based on gender.

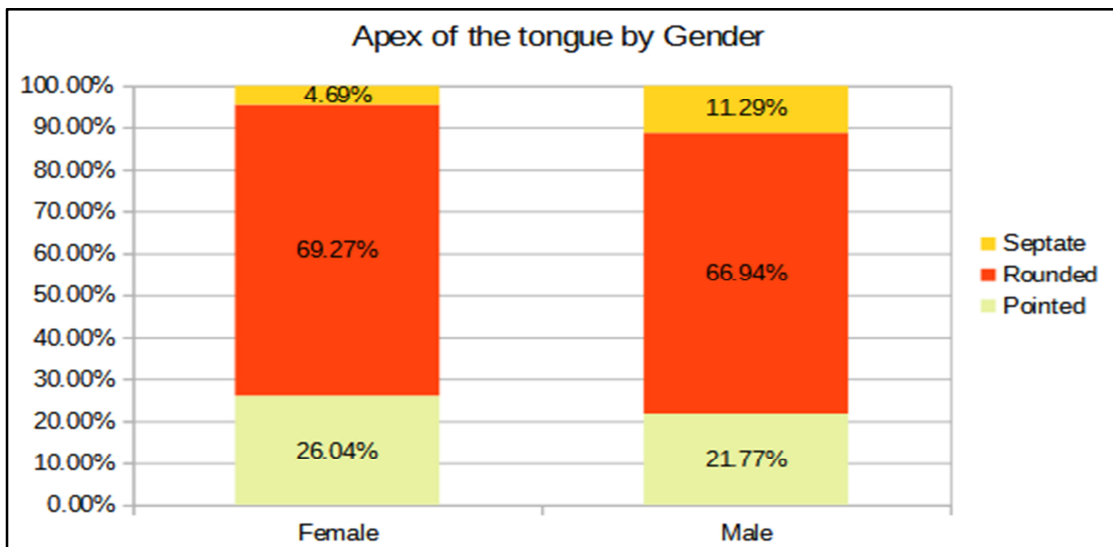


Table 4 : Apex of the tongue by Gender

	Pointed	Rounded	Septate	Total	Sig
Female	50	133	9	192	0.077 (NS)
Male	27	83	14	124	
Total	77	216	23	316	

Color of the Tongue by Gender:

Fig 12 presenting the column chart for color of the tongue by gender shows that of the female respondents, about 75% respondents have pink, 21% have pale pink, and only 4% of the remaining female respondents have pinkish purple. While amongst the male respondents, about 69% respondents have pink, 27% have pale pink, and only 4% of the remaining male respondents have pinkish purple. Table 5 shows that the p-value of Chi-square test is 0.443 which concludes that the color of the tongue differs based on gender.

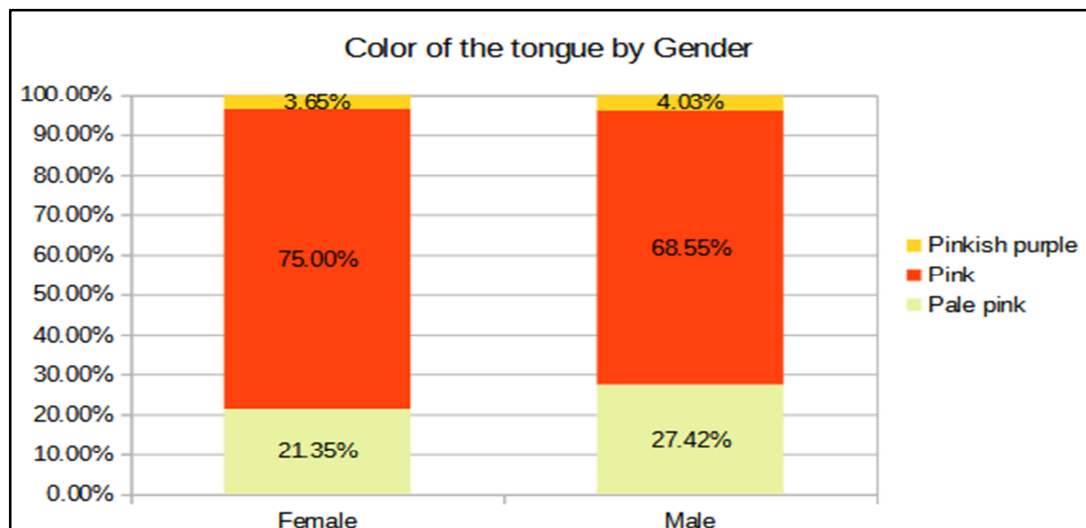
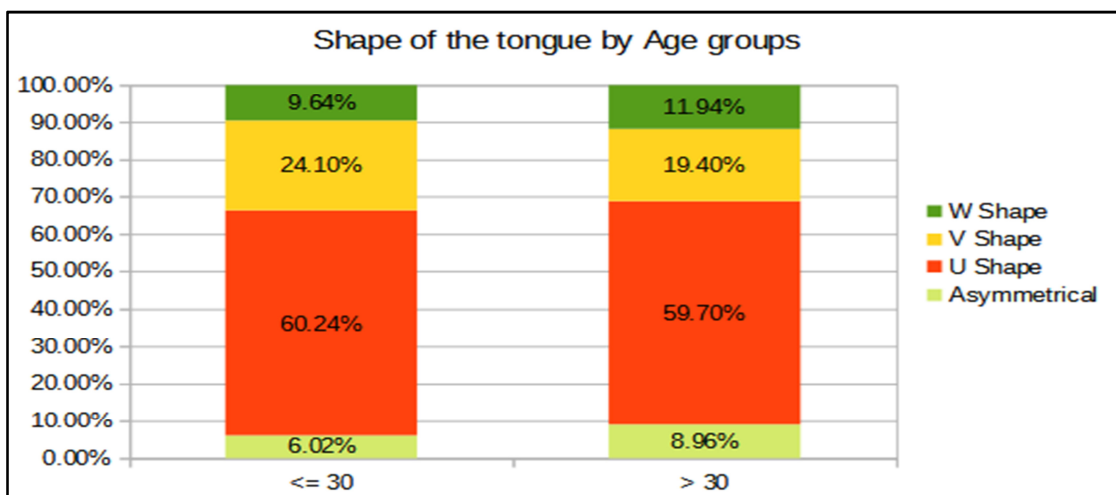


Table 5: Colour of the tongue by Gender

	Pale pink	Pink	Pinkish purple	Total	Sig
Female	41	144	7	192	0.443 (NS)
Male	34	85	5	124	
Total	75	229	12	316	

Shape of the Tongue by Age groups:

Fig 13 presenting the column chart for shape of the tongue by age groups shows that of the younger respondents, about 6% respondents have asymmetrical shape, 60% have U shape, 24% have V shape and 10% have W shape. While amongst the middle age respondents, about 9% respondents have asymmetrical shape, 60% have U shape, 19% have V shape and 12% have W shape. Table 6 shows that the p-value of Chi-square test is 0.69 which concludes that the shape of the tongue does not differ based on age groups.

**Table 6: Shape of the tongue by age groups**

	Asymmetrical	U Shape	V Shape	W Shape	Total	Sig
<= 30	15	150	60	24	249	0.69 (NS)
> 30	6	40	13	8	67	
Total	21	190	73	32	316	

Surface Texture of the Tongue by Age groups:

Fig 14 presenting the column chart for surface texture of the tongue by age groups show that of the younger respondents, about 59% respondents have tongue fissures / cracks, 37% have smooth tongue, and only 4% of the remaining younger respondents have plaqued, geographic or bifid tongue. While amongst the middle aged

respondents, about 61% respondents have tongue fissures / cracks, 30% have smooth tongue, and about 9% of the remaining male respondents have plaqued, geographic or bifid tongue. Table 7 shows that the p-value of Chi-square test is 0.283 which concludes that the surface texture of the tongue does not differ based on age groups.

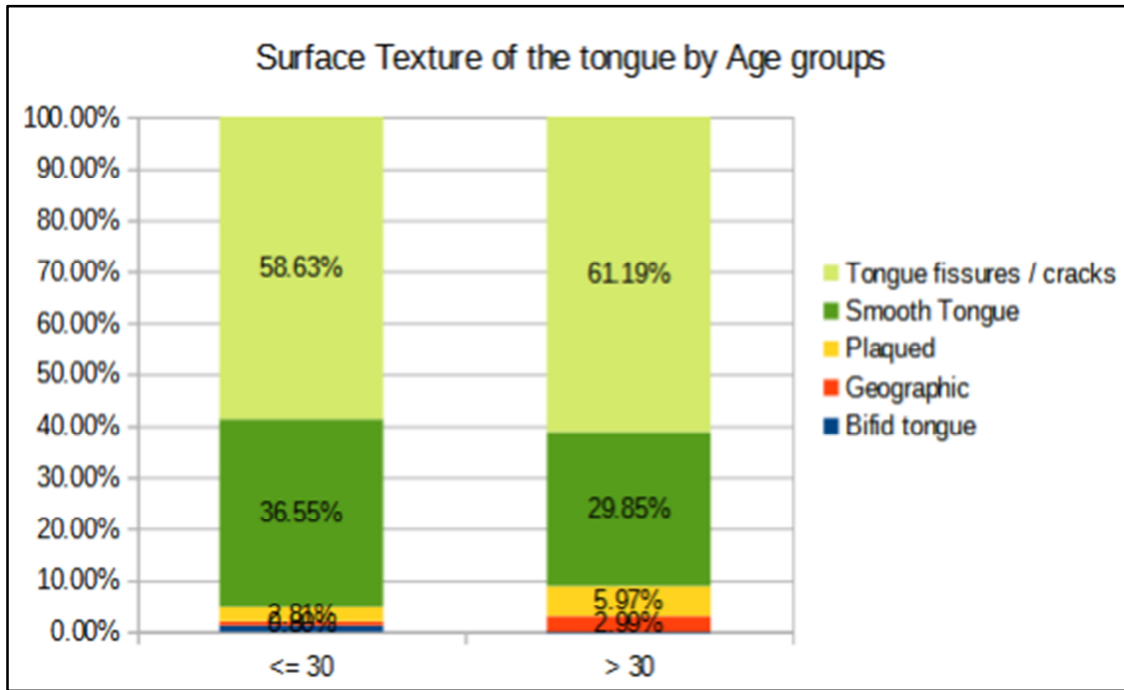


Table 7: Surface Texture of the tongue by age groups

	Bifid tongue	Geographic	Plaqued	Smooth Tongue	Tongue fissures / cracks	Total	Sig
≤ 30	3	2	7	91	146	249	
> 30	0	2	4	20	41	67	0.283(NS)
Total	3	4	11	111	187	316	

Median Septum by Age groups:

Fig 15 presenting the column chart for median septum by age groups show that of the younger respondents, for about 33% respondents median septum is visible while for remaining 67% younger respondent's median septum is not visible. The percentage is lower for middle aged respondents where for about 27% respondent's median septum is visible and for remaining 73% middle aged respondents median septum is not visible. Table 8 shows that the p-value of Chi-square test is 0.375 which concludes that the median septum does not differ based on age groups.

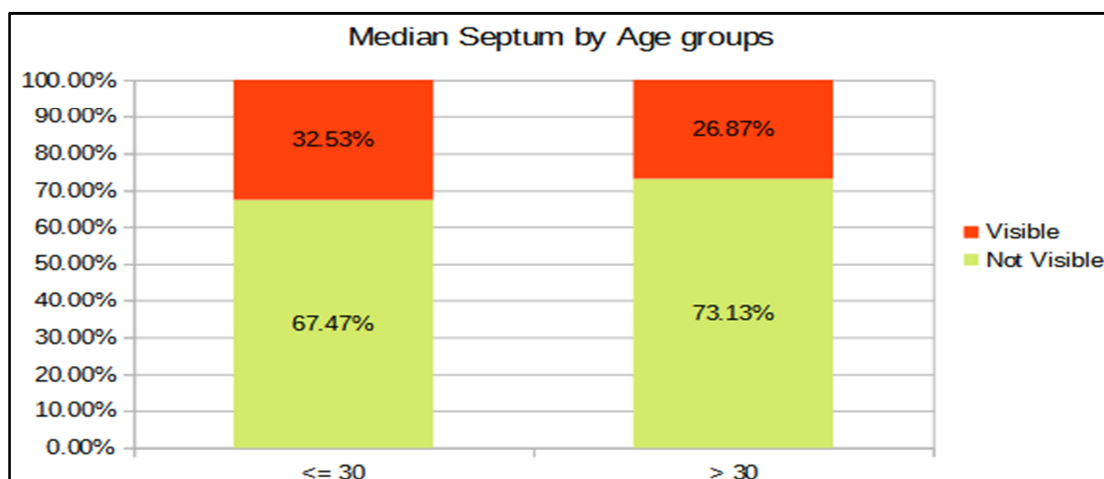


Table 8: Median Septum by age groups

	Not Visible	Visible	Total	Sig
<= 30	168	81	249	
> 30	49	18	67	0.375 (NS)
Total	217	99	316	

Apex of the Tongue by Age groups:

Fig 16 presenting the column chart for apex of the tongue by age groups show that of the younger respondents, about 68% respondents have rounded apex, 26% have pointed apex, and only 6% of the remaining younger respondents have septate apex of the tongue. While amongst the middle aged respondents, about 69% respondents have rounded apex, 19% have pointed apex, and only 12% of the remaining middle aged respondents have septate apex of the tongue. Table 9 shows that the p-value of Chi-square test is 0.183 which concludes that the apex of the tongue does not differ based on age groups.

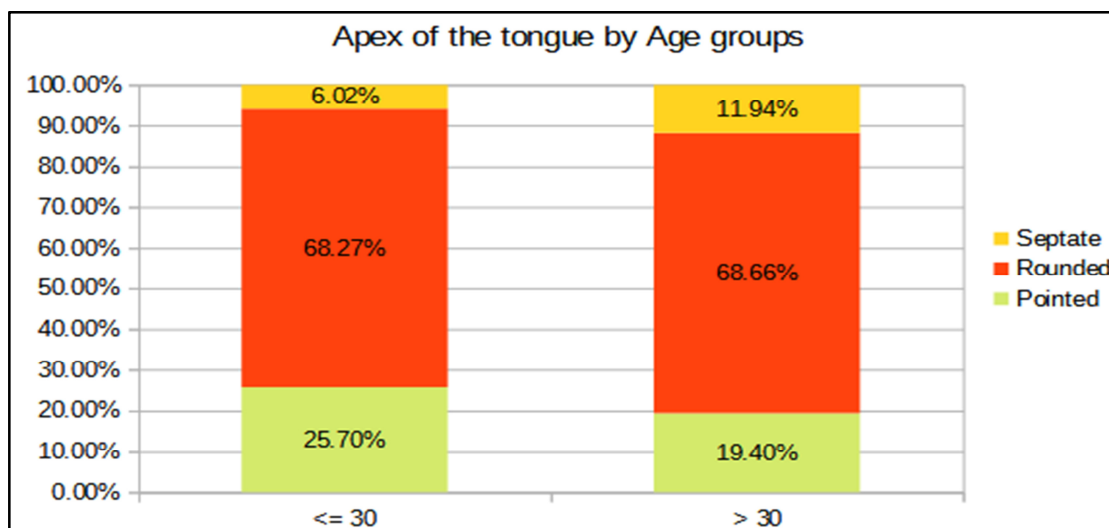
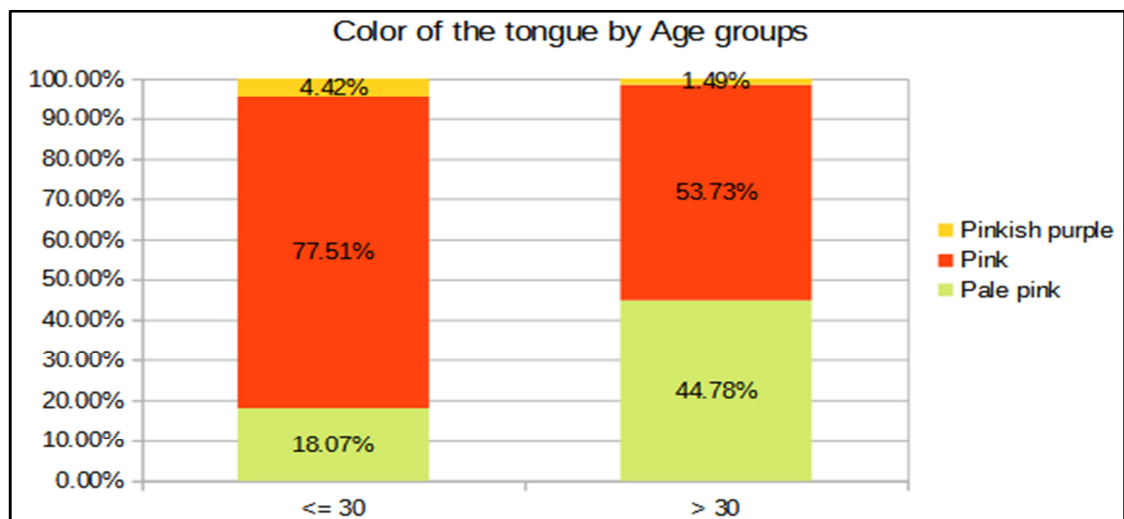


Table 9: Apex of the tongue by age groups

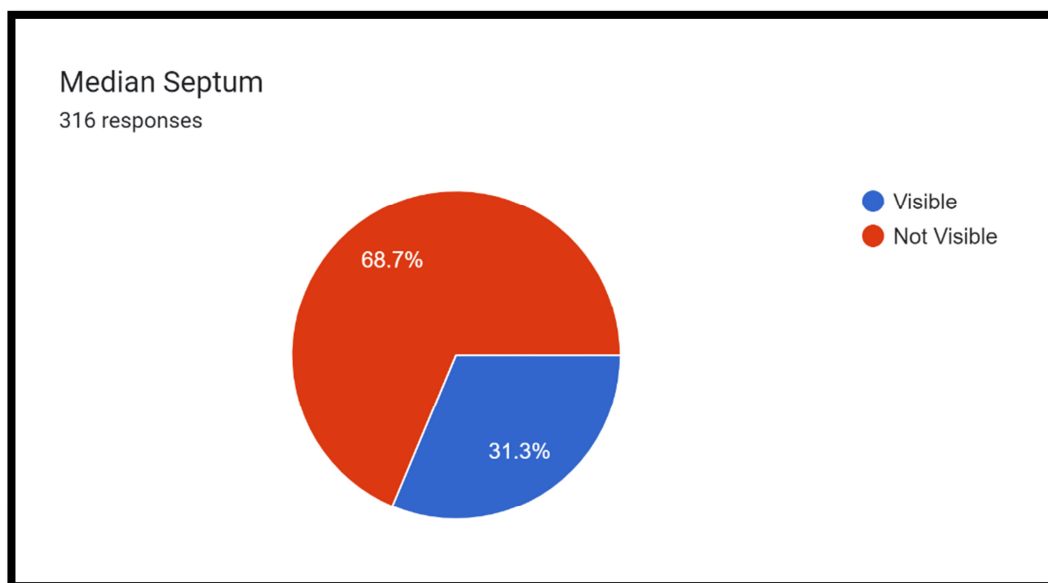
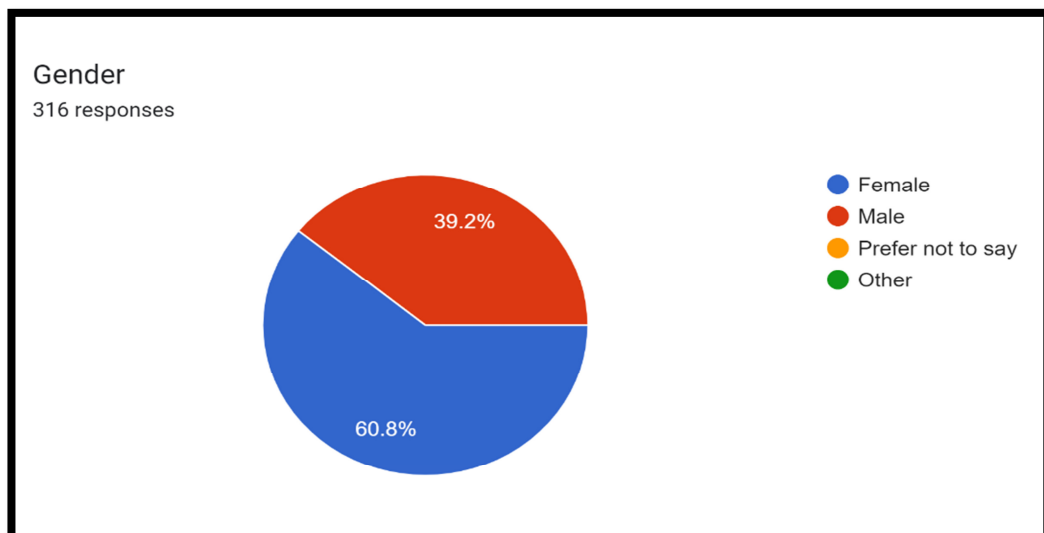
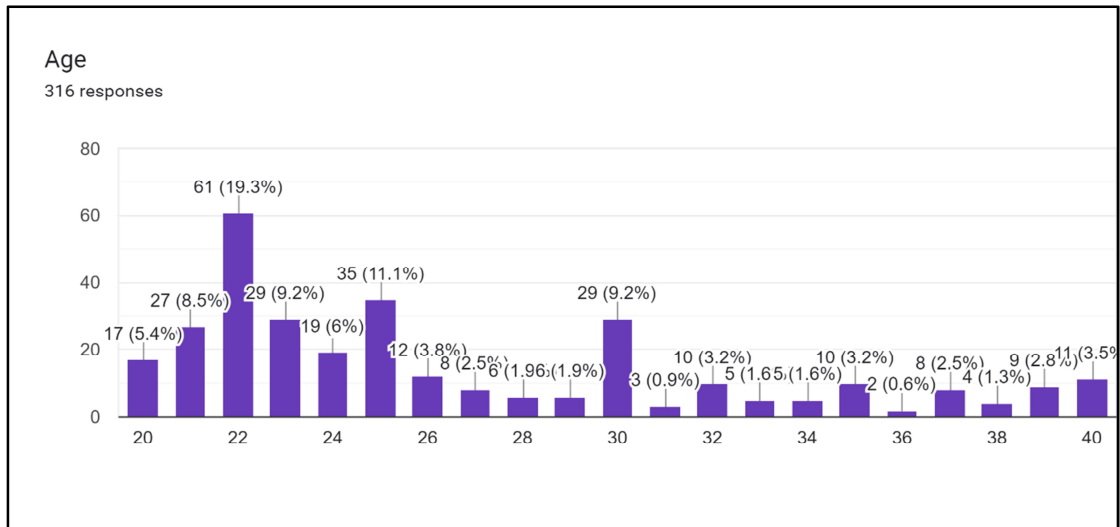
	Pointed	Rounded	Septate	Total	Sig
<= 30	64	170	15	249	
> 30	13	46	8	67	0.183 (NS)
Total	77	216	23	316	

Color of the Tongue by Age groups:

Fig 17 presenting the column chart for colour of the tongue by age groups show that of the younger respondents, about 78% respondents have pink, 18% have pale pink, and only 4% of the remaining younger respondents have pinkish purple. While amongst the middle-aged respondents, about 54% respondents have pink, 45% have pale pink, and only 2% of the remaining middle-aged respondents have pinkish purple. Table 10 shows that the p-value of Chi-square test is 0 which concludes that the colour of the tongue differs based on age groups.

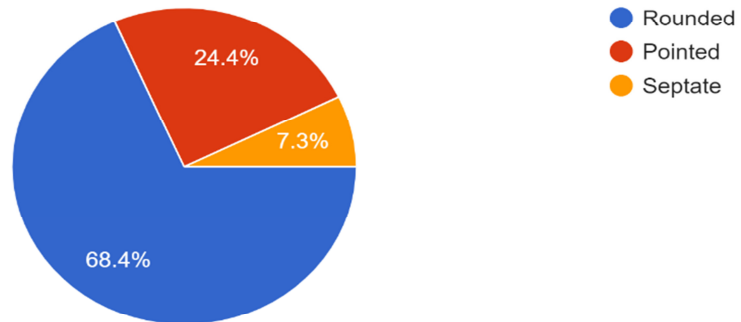
**Table 10 : Color of the tongue by age groups**

	Pale pink	Pink	Pinkish purple	Total	Sig
<= 30	45	193	11	249	
> 30	30	36	1	67	0 (HS)
Total	75	229	12	316	

DATA COLLECTED FROM GOOGLE FORMS:

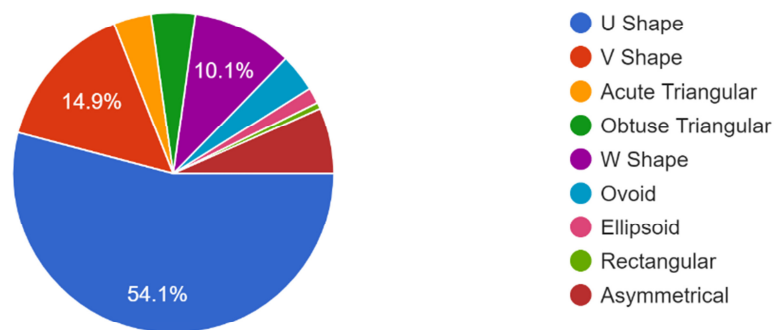
Apex

316 responses



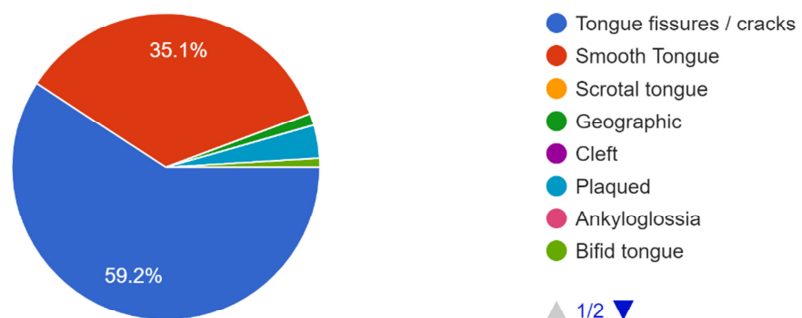
Shape of Tongue

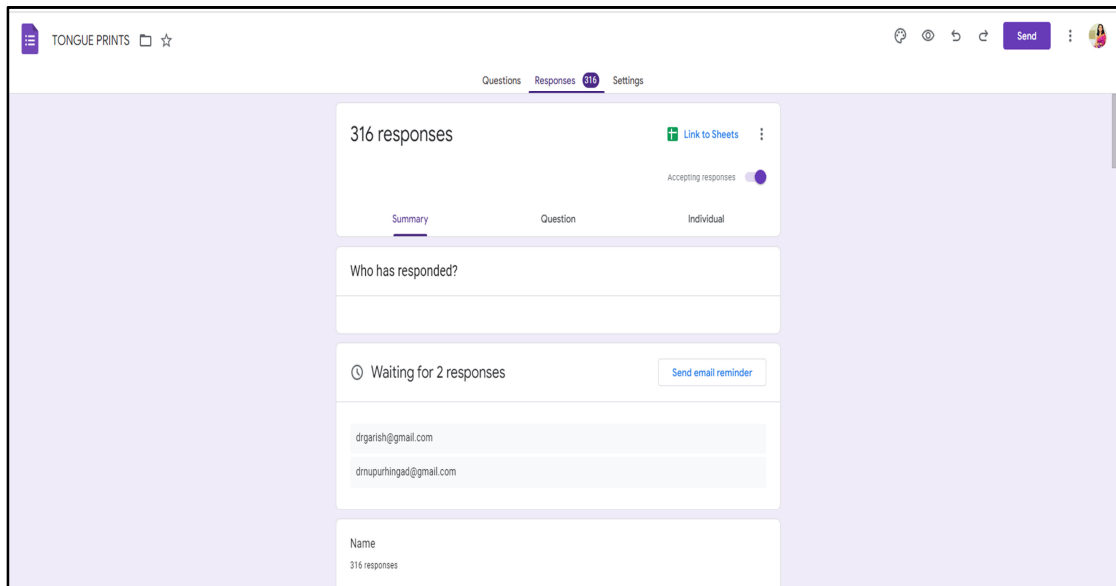
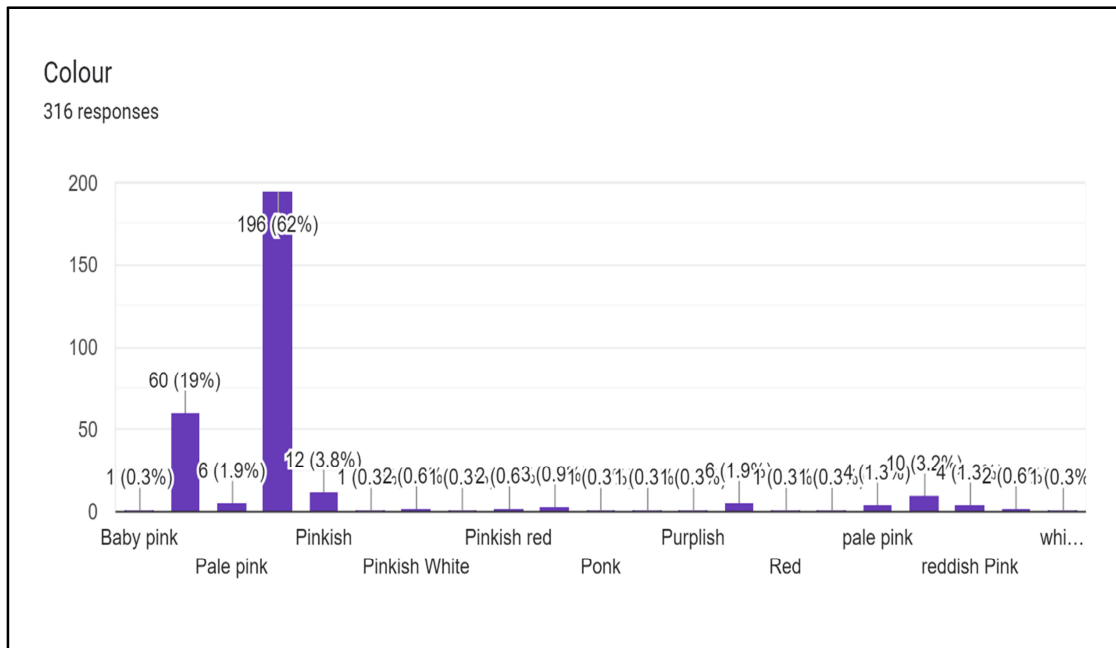
316 responses



Surface Texture of Tongue

316 responses





SUMMARY OF RESULTS AND CONCLUSION

Shape of the Tongue:

The original data comprised of: acute triangular, asymmetrical, ellipsoid, obtuse triangular. Ovoid, rectangular, U shape, V shape and W shape. The data was merged into four categories: Asymmetrical, U shape, V shape and W shape. [Figure 1a] shows that *about 60% of the respondents have U shape tongue, about 23% have V shape tongue, about 10% have W shape and about 7% have asymmetrical shape of the tongue.*

Surface Texture of the Tongue:

[Figure 1b] shows that “Tongue fissures/cracks” (59% app) and “Smooth Tongue” are the two prominent surface textures amongst all the respondents. “Plaquet” (3%), “Geographic” (1%) and “Bifid” (1%) surface textures of the tongue are found in very less respondents.

Median Septum of the Tongue:

[Figure 1c] shows that in about 69% of the respondents, median septum is not visible in the tongue while in remaining 31% of the respondents, median septum is visible in the tongue.

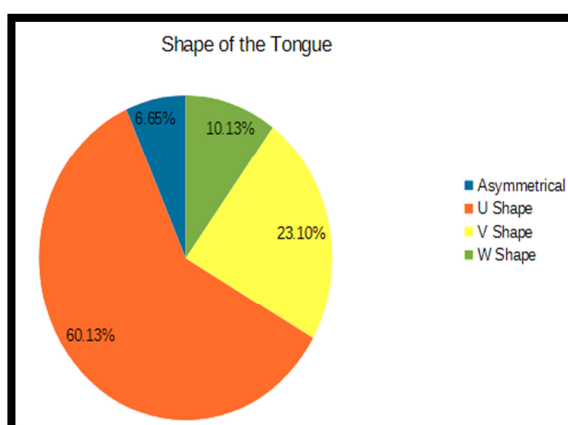
Apex of the Tongue:

[Figure 1d] shows that in about 68% of the respondents, the apex is rounded. In another 24% of the respondents, the apex is pointed while in remaining 7% of the respondents, the apex is septate.

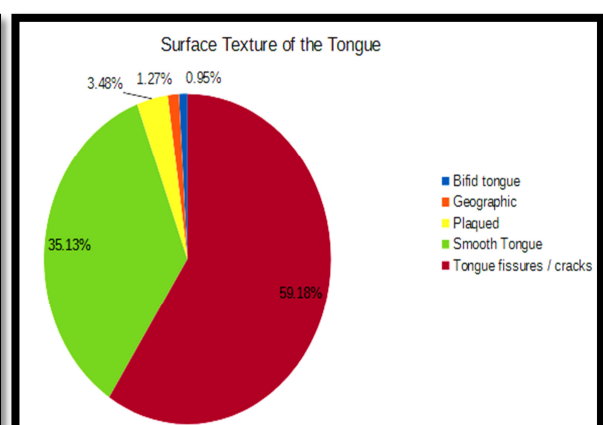
Color of the Tongue:

The original data comprised of: baby pink, pale pink, pink, pinkish purple, pinkish red, pinkish white, purple, purplish pink, red, reddish pink and whitish pink. The data was merged into three categories: pale pink, pink and pinkish purple. [Figure 1e] shows that about 72% of the respondents have pink color tongue, about 24% of them have pale pink tongue and remaining about 4% have pinkish purple tongue.

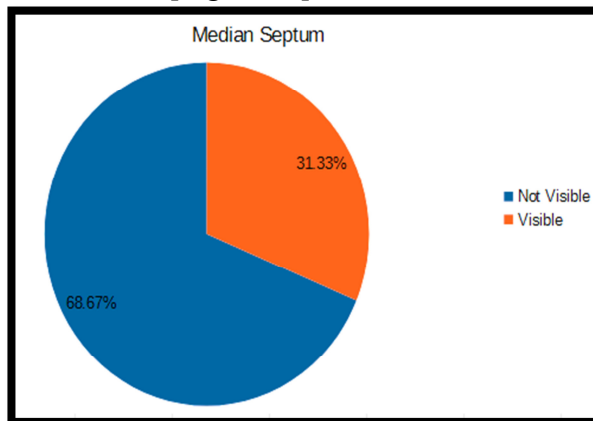
[Figure 1a]



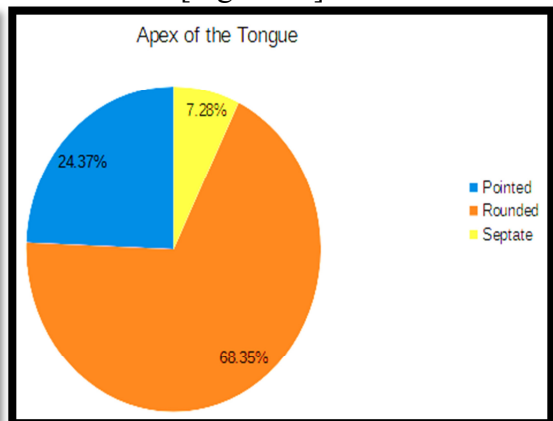
[Figure 1b]



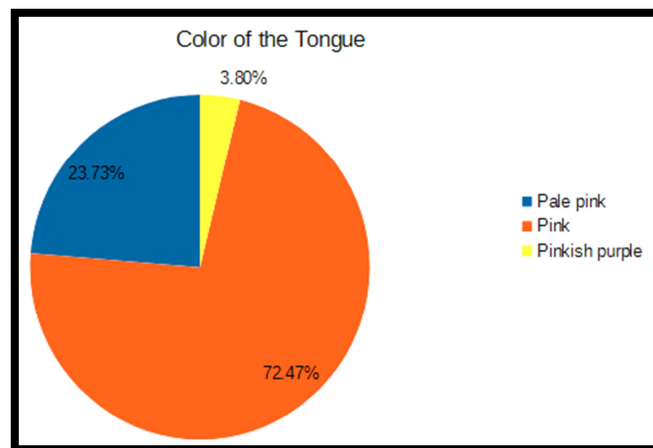
[Figure 1c]



[Figure 1d]



[Figure 1e]



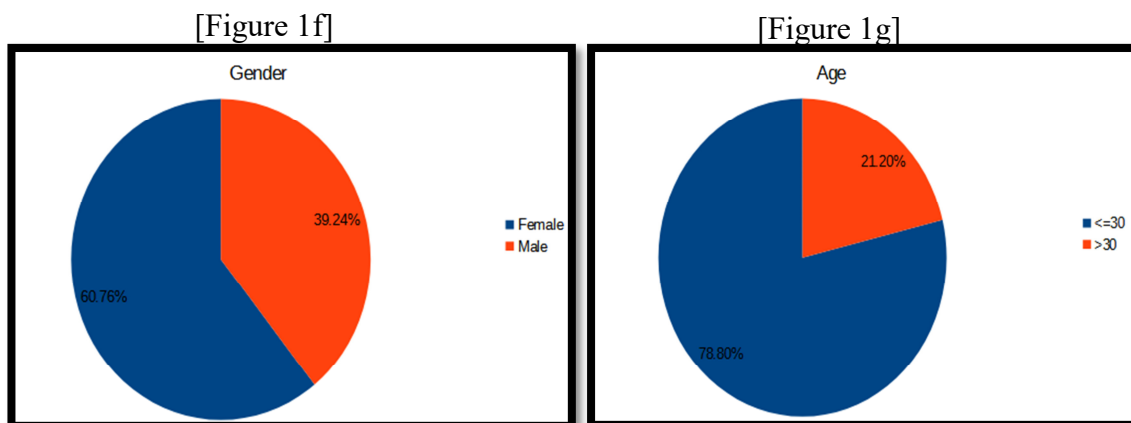
[figure 1 a – figure 1e]

Gender:

[Figure 1f] shows that about 61% of the respondents are female while in remaining 39% of the respondents are male.

Age Groups:

Age variable was categorized into binary variable using less than equal to 30 years and greater than 30 years age groups. [Figure 1g] shows that about 79% of the respondents are less than equal to 30 years while remaining 21% of the respondents are more than 30 years.



Shape of the Tongue by Gender:

Figure 2a shows that of the *female* respondents, about 5% respondents have asymmetrical shape, 61% have U shape, 27% have V shape and 7% have W shape. While amongst the *male* respondents, about 9% respondents have asymmetrical shape, 59% have U shape, 17% have V shape and 15% have W shape. Chi-square results from [Table – 1a] ($p < 0.05$) concludes that the shape of the tongue differs based on gender.

Surface Texture of the Tongue by Gender:

Figure- 2b shows that of the female respondents, about 53% respondents have tongue fissures / cracks, 44% have smooth tongue, and only 3% of the remaining female respondents have plaqued, geographic or bifid tongue. While amongst the male respondents, about 69% respondents have tongue fissures / cracks, 22% have smooth tongue, and about 9% of the remaining male respondents have plaqued, geographic or bifid tongue. Chi-square results from [Table -1b] ($p < 0.05$) concludes that the surface texture of the tongue differs based on gender.

Median Septum by Gender:

Figure 2c shows that of the female respondents, for about 28% respondents median septum is visible while for remaining 72% female respondents median septum is not visible. The percentage is higher for male respondents where for about 36% respondents median septum is visible and for remaining 64% male respondents median septum is not visible. Chi-square results from [Table - 1c] ($p > 0.05$) concludes that the median septum does not differ based on gender.

Apex of the Tongue by Gender:

Figure 2d shows that of the female respondents, about 69% respondents have rounded apex, 26% have pointed apex, and only 5% of the remaining female respondents have septate apex of the tongue. While amongst the male respondents, about 67% respondents have rounded apex, 22% have pointed apex, and only 11% of the remaining male respondents have septate apex of the tongue. Chi-square results from [Table – 1d] ($p=0.077$) concludes that the apex of the tongue differs based on gender.

Color of the Tongue by Gender:

Figure 2e shows that of the female respondents, about 75% respondents have pink, 21% have pale pink, and only 4% of the remaining female respondents have pinkish purple. While amongst the male respondents, about 69% respondents have pink, 27% have pale pink, and only 4% of the remaining male respondents have pinkish purple. Chi-square results from [Table – 1e] ($p=0.443$) concludes that the color of the tongue differs based on gender.

Shape of the Tongue by Age groups:

Figure 2f shows that of the younger respondents, about 6% respondents have asymmetrical shape, 60% have U shape, 24% have V shape and 10% have W shape. While amongst the middle age respondents, about 9% respondents have asymmetrical shape, 60% have U shape, 19% have V shape and 12% have W shape. Chi-square results from [Table - 1f] ($p=0.69$) concludes that the shape of the tongue does not differ based on age groups.

Surface Texture of the Tongue by Age groups:

Figure 2g shows that of the younger respondents, about 59% respondents have tongue fissures / cracks, 37% have smooth tongue, and only 4% of the remaining younger respondents have plaqued, geographic or bifid tongue. While amongst the middle aged respondents, about 61% respondents have tongue fissures / cracks, 30% have smooth tongue, and about 9% of the remaining male respondents have plaqued, geographic or bifid tongue. Chi-square results from [Table - 1g] ($p=0.283$) concludes that the surface texture of the tongue does not differ based on age groups.

Median Septum by Age groups:

Figure 2h shows that of the younger respondents, for about 33% respondents median septum is visible while for remaining 67% younger respondent's median septum is not visible. The percentage is lower for middle aged respondents where for about 27%

respondent's median septum is visible and for remaining 73% middle aged respondent's median septum is not visible. Chi-square results from [Table-1h] ($p=0.375$) concludes that the median septum does not differ based on age groups.

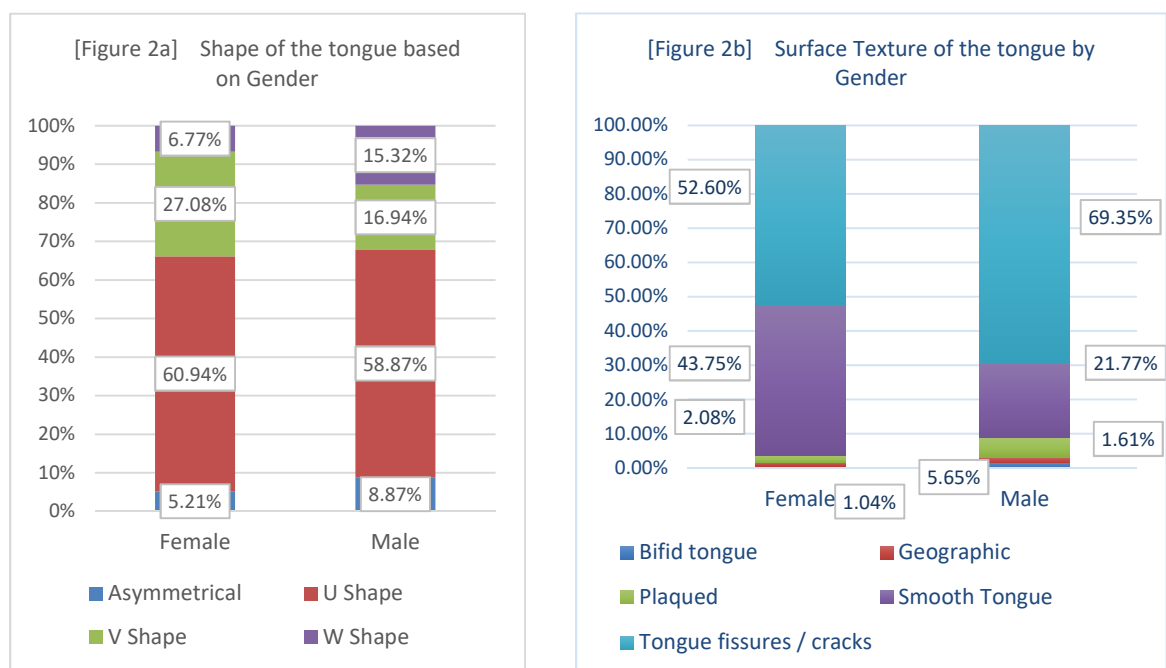
Apex of the Tongue by Age groups:

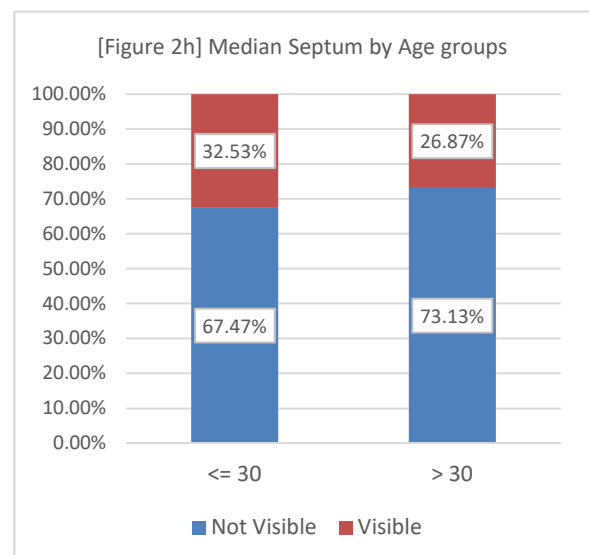
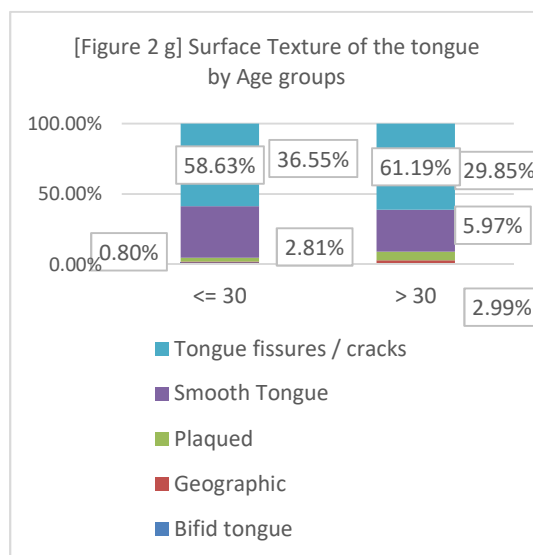
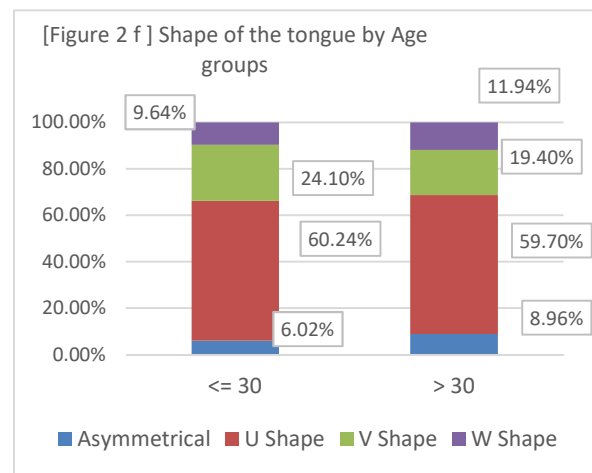
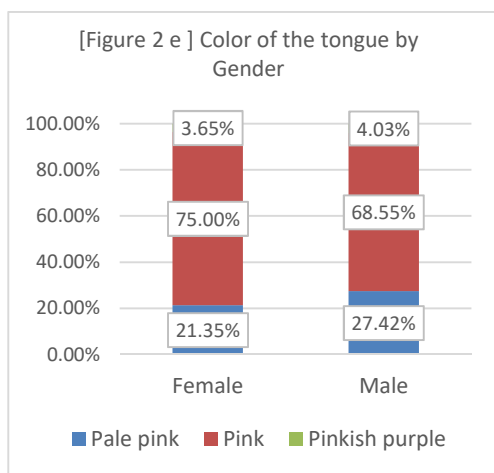
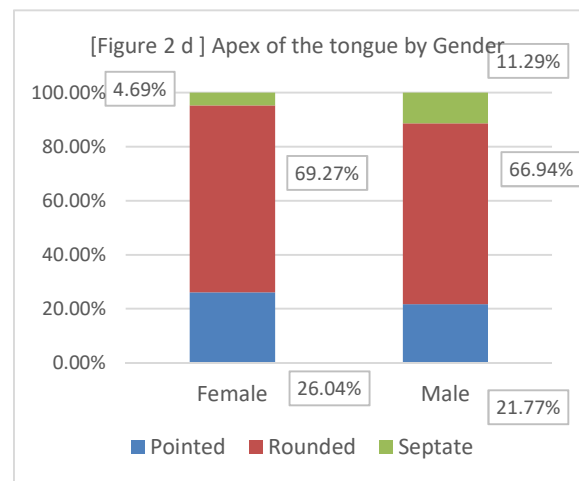
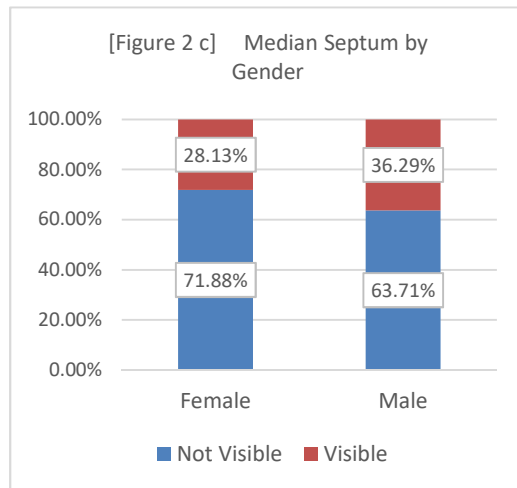
Figure 2i shows that of the younger respondents, about 68% respondents have rounded apex, 26% have pointed apex, and only 6% of the remaining younger respondents have septate apex of the tongue. While amongst the middle-aged respondents, about 69% respondents have rounded apex, 19% have pointed apex, and only 12% of the remaining middle-aged respondents have septate apex of the tongue. Chi-square results from [Table - 1i] ($p=0.183$) concludes that the apex of the tongue does not differ based on age groups.

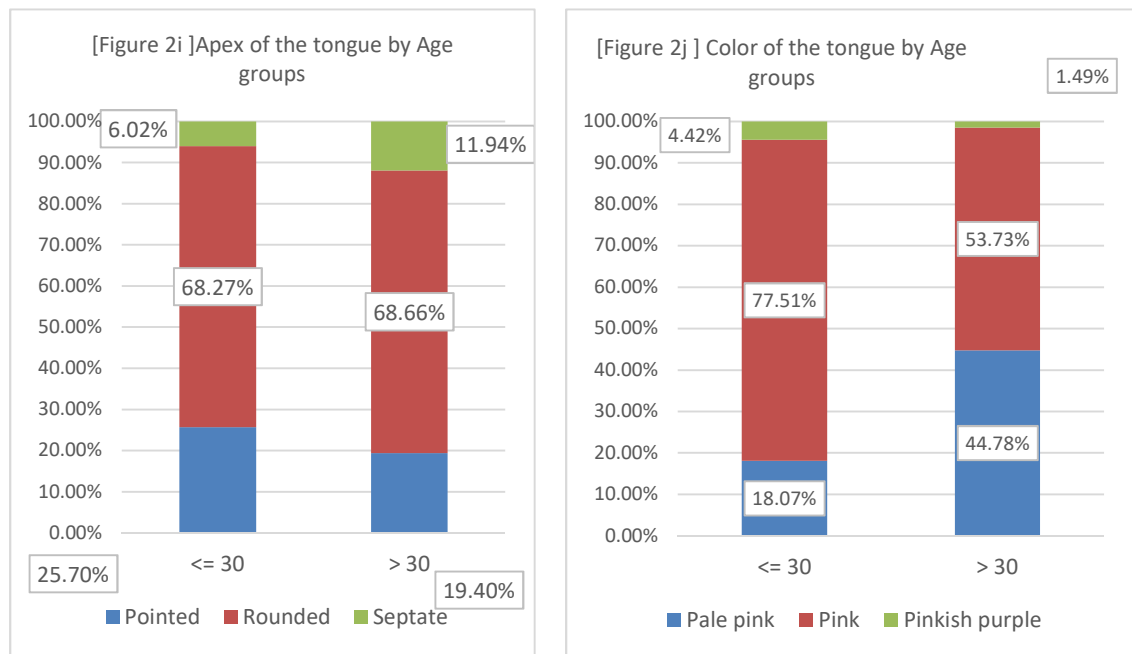
Color of the Tongue by Age groups:

Figure 2j shows that of the younger respondents, about 78% respondents have pink, 18% have pale pink, and only 4% of the remaining younger respondents have pinkish purple. While amongst the middle-aged respondents, about 54% respondents have pink, 45% have pale pink, and only 2% of the remaining middle-aged respondents have pinkish purple. Chi-square results from [Table - 1j] ($p<0.05$) concludes that the color of the tongue differs based on age groups.

[FIGURE 2a – FIGURE 2j]







SUMMARY OF RESULTS AND CONCLUSION

[Table – 1a] : Shape of the Tongue by Gender

	Asymmetrical	U Shape	V Shape	W Shape	Total	Sig
Female	10	117	52	13	192	0.016
Male	11	73	21	19	124	
Total	21	190	73	32	316	

[Table – 1b] : Surface Texture by Gender

	Bifid tongue	Geographic	Plaqued	Smooth Tongue	Tongue fissures / cracks	Total	Sig
Female	1	2	4	84	101	192	0.001 (HS)
Male	2	2	7	27	86	124	
Total	3	4	11	111	187	316	

[Table – 1c]: Median Septum by Gender

	Not Visible	Visible	Total	Sig
Female	138	54	192	0.137 (NS)
Male	79	45	124	
Total	217	99	316	

[Table – 1d]: Apex of the tongue by Gender

	Pointed	Rounded	Septate	Total	Sig
Female	50	133	9	192	0.077 (NS)
Male	27	83	14	124	
Total	77	216	23	316	

[Table - 1e]: Color of the tongue by Gender							
	Pale pink	Pink	Pinkish purple	Total	Sig		
Female	41	144	7	192	0.443 (NS)		
Male	34	85	5	124			
Total	75	229	12	316			
[Table - 1f] : Shape of the tongue by age groups							
	Asymmetrical	U Shape	V Shape	W Shape	Total	Sig	
<= 30	15	150	60	24	249	0.69 (NS)	
> 30	6	40	13	8	67		
Total	21	190	73	32	316		
[Table - 1g]: Surface Texture of the tongue by age groups							
	Bifid tongue	Geographic	Plaquet	Smooth Tongue	Tongue fissures / cracks	Total	Sig
<= 30	3	2	7	91	146	249	0.283 (NS)
> 30	0	2	4	20	41	67	
Total	3	4	11	111	187	316	
[Table - 1h]: Median Septum by age groups							
	Not Visible	Visible	Total	Sig			
<= 30	168	81	249	0.375 (NS)			
> 30	49	18	67				
Total	217	99	316				
[Table - 1i]: Apex of the tongue by age groups							
	Pointed	Rounded	Septate	Total	Sig		
<= 30	64	170	15	249	0.183 (NS)		
> 30	13	46	8	67			
Total	77	216	23	316			
[Table - 1j]: Colour of the tongue by age groups							
	Pale pink	Pink	Pinkish purple	Total	Sig		
<= 30	45	193	11	249	0 (HS)		
> 30	30	36	1	67			
Total	75	229	12	316			
[TABLE -1]				[TABLE – 1 a – TABLE- 1j]			

CHAPTER – VI

DISCUSSION



Concluding what our study reveals is it:

- shows that *about 60% of the respondents have U shape tongue, about 23% have V shape tongue, about 10% have W shape and about 7% have asymmetrical shape of the tongue* suggesting the variability in the shape of the tongue. Although the ‘U’ shape is most common in both males and females.
- **It is very clear from our study that there is reasonable amount of difference in the geometrical shape of all the patients. The shape most common in our study in both males and female patients is u shaped which is, 190 patients out of 316**
- “Tongue fissures/cracks” (59% app) and “Smooth Tongue” are the two prominent surface textures amongst all the respondents.
- “Plaqued” (3%), “Geographic” (1%) and “Bifid” (1%) surface textures of the tongue are found in very less respondents.
- **It is noticed in our study that 187 patients out of 316 have tongue fissures and cracks on the surface and 111 patients have smooth tongue.**
- about 69% of the respondents, median septum is not visible in the tongue while in remaining 31% of the respondents, median septum is visible in the tongue.
- shows that in about 68% of the respondents, the apex is rounded. In another 24% of the respondents, the apex is pointed while in remaining 7% of the respondents, the apex is septate. **Septate being the least common type.**
- *shows that about 72% of the respondents have pink color tongue, about 24% of them have pale pink tongue and remaining about 4% have pinkish purple tongue.*

Gender

- 61% of the respondents are female while in remaining 39% of the respondents are male. Females have been more cooperative in terms of agreeing to be photographed for the study.

Age

- about 79% of the respondents are less than equal to 30 years while remaining 21% of the respondents are more than 30 years.

Statistical analysis also

- ***concludes that the shape of the tongue differs based on gender.***
- shows that of the *female* respondents, about 5% respondents have asymmetrical shape, 61% have U shape, 27% have V shape and 7% have W shape. While

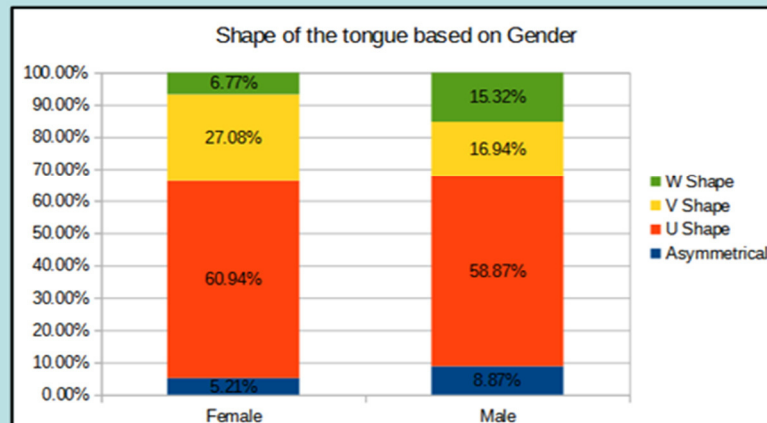
amongst the *male* respondents, about 9% respondents have asymmetrical shape, 59% have U shape, 17% have V shape and 15% have W shape. Again, stating that U shape is more common both in male and female patients.

- *concludes that the surface texture of the tongue differs based on gender.*
- *concludes that the apex of the tongue differs based on gender.*
- *concludes that the colour of the tongue differs based on gender.*
- *concludes that the median septum does not differ based on gender.*
- *concludes that the shape of the tongue does not differ based on age groups.*
- *concludes that the surface texture of the tongue does not differ based on age groups.*
- *concludes that the median septum does not differ based on age groups.*
- *concludes that the apex of the tongue does not differ based on age groups.*
- *concludes that the colour of the tongue differs based on age groups.*

- *(p<0.05) concludes that the shape of the tongue differs based on gender*
- *(p<0.05) concludes that the surface texture of the tongue differs based on gender.*
- *(p=0.077) concludes that the apex of the tongue differs based on gender.*
- *(p=0.443) concludes that the colour of the tongue differs based on gender.*
- *(p>0.05) concludes that the median septum does not differ based on gender.*

- *(p=0.69) concludes that the shape of the tongue does not differ based on age groups.*
- *(p=0.283) concludes that the surface texture of the tongue does not differ based on age groups.*
- *(p=0.375) concludes that the median septum does not differ based on age groups.*
- *(p=0.183) concludes that the apex of the tongue does not differ based on age groups.*
- *(p<0.05) concludes that the colour of the tongue differs based on age groups.*

Shape of the Tongue by Gender:



U shape most common in both males and females.

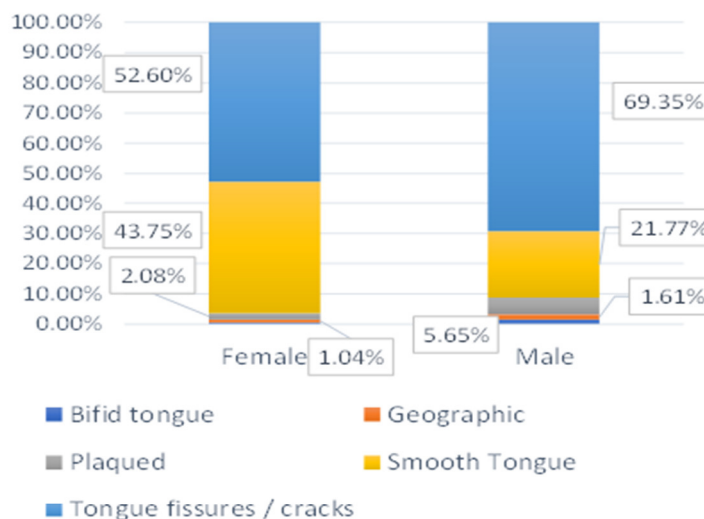
V shape Females > males

W shape Males > Females.

P value < 0.016 Statistically significant

Data from Other studies:* supporting

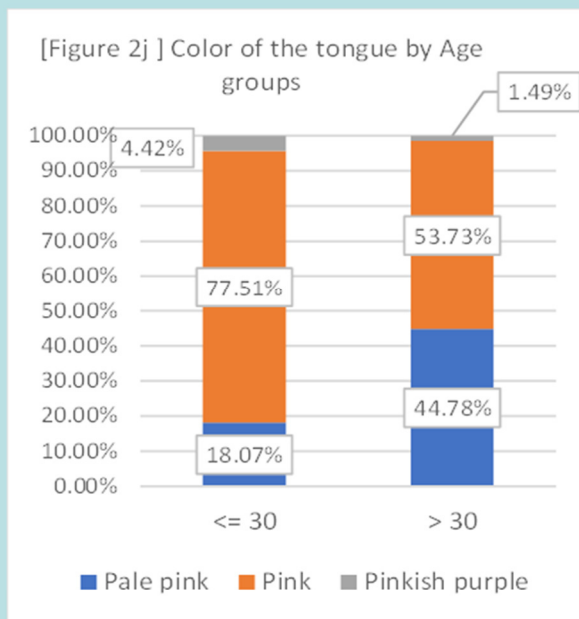
[Figure 2b] Surface Texture of the tongue by Gender



Smooth tongue Females > Males

Fissures Males > Females

P VALUE < 0.001 (HS) Which is highly significant



Colour of the Tongue

Pink colour age group (≤ 30) > Age group (> 30)

p value = 0

CHAPTER – VII

FUTURE PERSPECTIVES



FUTURE PERSPECTIVES

- Advancements in Tongue Analysis Technologies
- Standardization
- Tongue Analysis formal education and training
- Use of tongue in forensic practice.

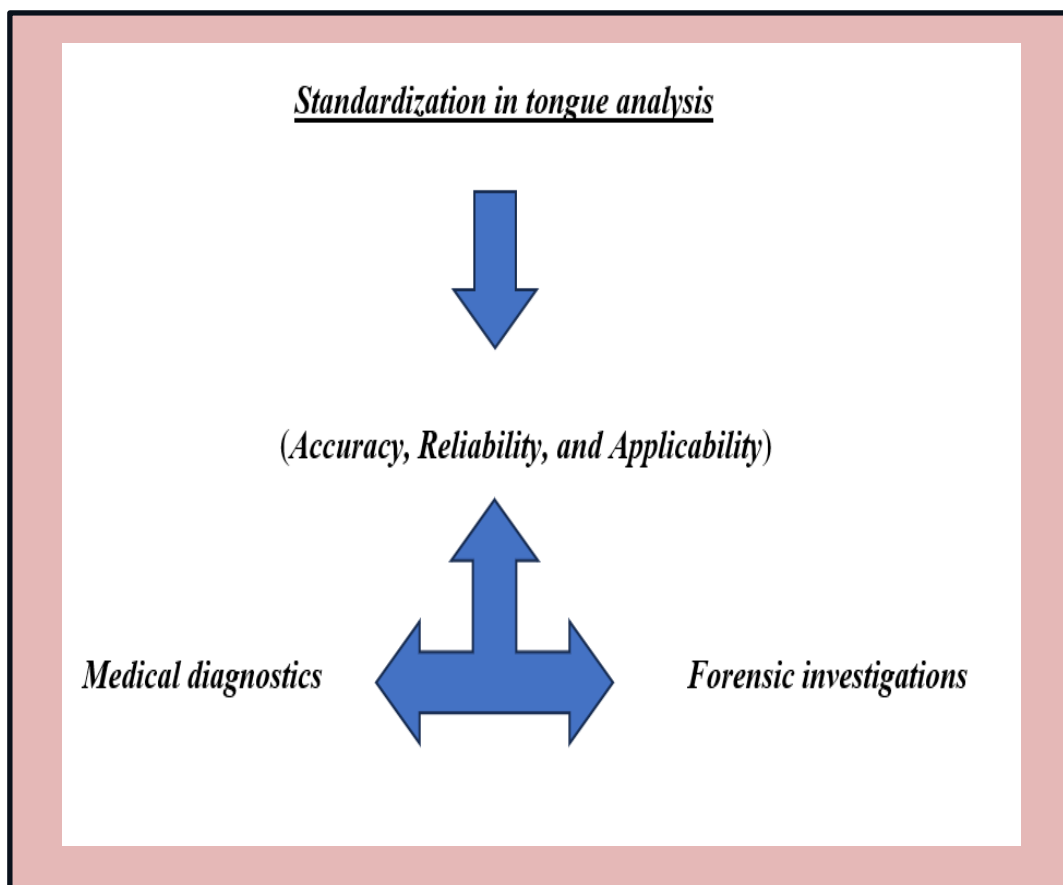
Technologies have been on the advancing front and with there has been evolution in the analysis of tongue also. This has made changes giving more accurate and reliable results in medical and biometric applications. Some known advances are:

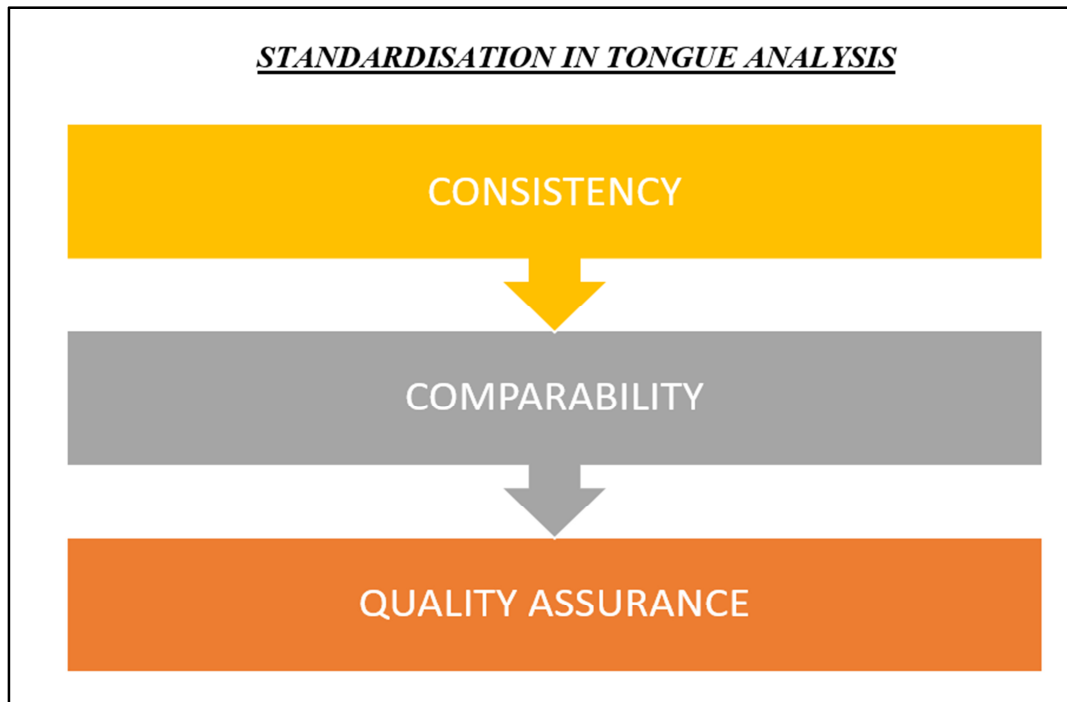
1. Artificial Intelligence (AI) and Machine Learning: Recently the use of Artificial intelligence using algorithms and machine learning has gained a lot of popularity in tongue analysis which has made automated feature extraction and the recognition of patterns possible. AI encompassed systems can really help humans in identifying the unique tongue characteristics which are required in diagnosing medical conditions and help in forensic and biometric identification.
2. Increased resolution of imaging: Intraoral cameras and Optical Coherence Tomography (OCT) give very good quality images in terms of resolution especially of the dorsal surface of the tongue. If the image is of good quality, it positively enhances the visualization and interpretation of the images giving more accurate analysis after tongue examination.
3. Computer vision techniques: We are quite aware that any form of study is prone to subjective differences and human prejudices to overcome these factors Computer vision techniques can be used. They can automatically use tongue images for analysis. These can be used for detection of abnormalities and analysing other features of the tongue.
4. Phone applications for Tongue analysis: Tongue is such a promising diagnostic and biometric tool that smartphone applications are being developed to help medical diagnosis and for individual use. Patients can just take the picture of their tongue with the smartphone and get information regarding
5. Advances in imaging techniques: traditionally images which were 2 – Dimensional were used for study and diagnosis but recent advances have made 3- Dimensional imaging possible. This gives better examination

opportunities making variations in structure and abnormalities in surface details more apparent to diagnosis.

6. Tongue as an adjunct: Greater accuracy can be attained by the use of tongue analysis in collaboration with other forensic tools. This can be explained by stating that finger print scanning can be used with tongue scans. This can give very reliable results. Better identification systems can be made on this model.
7. Other modes like Data Analytics can be used for tongue diagnosis.
8. Health tracking with wearable trackers especially for the tongue can be worked on. As literature proves the tongue be very helpful in overall health diagnosis.
9. Misuse of Data and unauthorised access should be taken care of. Privacy is paramount.
10. With technological advancement comes security and privacy issues which need to be dealt with in order to use data efficiently.

STANDARDISATION IN TONGUE ANALYSIS:





TONGUE ANALYSIS FORMAL EDUCATION AND TRAINING:

- **CURRICULUM FORMULATION : TEACHING**
Structured Education Anatomy And Physiology , Tongue, Normal Variations, Pathological Changes and Specific Tongue
- **EDUCATIONAL & ACADEMIC COURSES**
TAKEN IN :Medical Schools, Dental Schools, Traditional Medicine Programs
- **CONTINUOUS EDUCATION PROGRAMS : FOR PROFESSIONALS ALREADY PRACTICING**
- **HANDS-ON TRAINING WORKSHOPS FOR VALIDATION**
- **CERTIFICATION PROGRAMS FOR TONGUE ANALYSIS**
- **INTERDISCIPLINARY TRAINING INITIATIVES**
- **ONLINE EDUCATIONAL RESOURCES: FOR TONGUE TRAINING**
- **COLLABORATING WITH UNIVERSITIES, RESEARCH INSTITUTIONS**
- **PRACTICAL CASE STUDIES**
- **ETHICAL AND LEGAL : EXPLANATIONS AND INFORMATION ON GUIDELINES.**

In order to use the technology well we need a workforce which is skilled enough, with experience to carry out the procedures. This is only possible if there are enough

training formally acquired to carry out the process. To make this possible it is very important to pay attention to the areas responsible for the education and training.

USE OF TONGUE IN FORENSIC PRACTICE

Proof of identity in Humans	Since tongue has unique characteristics, it can be used for identification
In association with Bite Mark	Tongue prints in conjunction with bite marks can be used in forensic identification for more reliable results.
Identification in dead bodies	During postmortem when body is disfigured, tongue comes to rescue.
Forensic investigations	Tongue due to its stability and reliability acts as an excellent tool for forensic investigation
Estimation of Time Since Death	Tongue changes in colour after death can help us calculate the postmortem interval
Guilty or not Guilty in criminal cases	This can be done with the help of tongue prints.

Khan et al. 2023 stated that even though tongue due to its distinctive properties is one of the primary tools in TCM diagnosis not much has been done with the tongue in relation to disaster. Its role in manmade disaster and natural disasters should be evaluated.

They also spoke about the future scopes related to tongue prints and documented that Methods like spectrum analysis and Gabor filter are being used to analyse tongue prints. These are producing noteworthy outcomes. They state that only after the tongue prints have undergone pre- processing for form analysis and texture, they can be used for tongue print biometric verification. This requires expensive tools and specialised knowledge. If these constraints are removed in future tongue prints can really help humans.⁹

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PUBLICATIONS



Progress is Impossible without Change : Understanding 'Block-Based' Curriculum

Abstract

Curriculum is a formal document, which is framed to enable the learners to achieve the outcomes of a given course. It contains the syllabus and details of course structure, along with the teaching and assessment methods. A curriculum must also contain details of the purpose of the course, the experiences required to fulfil the course purposes and details of evaluation method.

Educational institutes are providing quality education all over the world using various approaches. Many institutes have now shifted from traditional curriculum to a blend of various innovative approaches that includes, block-based, problem-based learning, competency-based, etc. that are more student centered. Due to these different approaches there is always a dilemma to select which approach is best.

The present study gives a detailed insight into the block-based curriculum. A curriculum block is a self-contained sequence of instruction and focuses attention on having a wide variety of "bricks" from which curricula can be assembled. The study also discusses the advantages and shortcomings of block-based design and compares it with the traditional curriculum with special reference to medical and dental curriculum. This study will help us identify areas in our curriculum design that needs to be modified or changed completely.

Keywords: Integrated Curriculum, Traditional Curriculum, Problem-based Learning, Competency-based Learning, Block-based Curriculum

Introduction

Curriculum is an ideological document, reflecting the local circumstances, which frames the learners' experience to enable them to achieve a given course's outcomes. It should contain both the syllabus, which means topics of learning to be covered, and details of course structure, including the teaching supervision provided and assessment methods (Grant, 2014). A curriculum should contain details of the course's purpose, the organization of the learning program, the experiences required to fulfill the course purposes (including details of supervision provided), and details of evaluation methods. The curriculum must also give a detailed description of the training structure, including entry requirements, duration of the program,

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assessment systems, flexibilities, teaching, feedback, and supervision (GMC, 2010; Swanwick, 2013). There are many curricula formats, depending on the curriculum designers' ideological basis and the local context and purposes.

Medical and Dental Curriculum differs from others as it involves teaching in a clinical setting and is directly related to patient care (Bligh and Brice, 2010). Medical and Dental educational institutes are providing quality education all over the world using various approaches. Many institutes have now shifted from traditional curriculum to a blend of multiple innovative approaches that include block-based curriculum, problem-based learning, core competency-based, etc., that are more student-centered. This article describes the curriculum and elaborates integrated block-based system.

History of Dental Curriculum

The history of formal independent dental education goes back to the early 19th century when the first dental school started in the United States, and in 1909 formed the first council on dental education to monitor the standards of dental degrees (Field, 1995). Until that time, dentists got training as apprentices in medical schools (Wu et al., 2010). There are dental schools worldwide, but their missions and goals vary, and all countries have their regulatory bodies.

With modernization and the advancement of dental science and technology, the dental curriculum needs timely updates so that the graduating dental students get the best training to face the community, work in collaboration and apply their knowledge to patient care (Whitney et al., 2010). Currently, few countries still use traditional dental curriculum. In comparison, many have shifted to a block-based integrated, competency-based curriculum. Some Universities follow a blend of both known as a hybrid curriculum (Perry et al., 2017).

Block-Based Curriculum

A curriculum block is a self-contained sequence of instruction. It focuses attention on having a wide

variety of "bricks" from which curriculum can be assembled and have precise descriptions of blocks that will enable educators to make informed choices and placements in designing curricula (Curriculum Blocks, 2000). Traditional curriculum involves didactic teaching, and each subject is taught independently with initial years of preclinical work followed by clinical training. On the other hand, block-based integrated curriculum teaches basic science as theme-based; for example, the cardiac system theme will involve lectures on anatomy, physiology, and biochemistry (Perry et al., 2017).

Properties of curriculum blocks (Curriculum Blocks, 2000)

- Different curriculum blocks can have different time dimensions. If there is a block for 'Dental Education,' it might have two credit hours in the first year, but the block of 'Cell structure and function' might need five credit hours. In short, different topics can have different time dimensions (Table-1).
- A curriculum block can have any one of the several instructional formats. In addition to didactic lectures, every block needs different teaching methodologies for the particular topic/ subject the individual block covers. A single block may include a mix of teaching methodologies.
- A curriculum block can relate to one discipline or several. The blocks' content may feature a particular domain or explore other fields needed to understand a specific topic of the block completely. For example, the block for 'Head and Neck structure and function' will need to explore more than one discipline like anatomy, physiology, pathological aspect, and radiology.
- A curriculum block needs adequate description. A block description provides curriculum designers with sufficient information to enable them to make informed choices. Two chief items of information clearly describe the specific learning goals credibly targeted by the block and an indication of the degree to which the claimed results have been validated.

After finalizing the blocks according to the required targeted goals, the next step is to implement the action plan that needs operational requirements, evidence of achieved goals, and the working team. The Curriculum designing team finally selects particular blocks for a specific year that matches the particular level of education. Each University constructs its curriculum by a particular set of blocks. Different colleges could end up with varying arrays of blocks and still meet national, state, and local standards and the learning objective for a particular course. The curriculum undergoes continuous reform as a process of development. Each block has a block organizer and members associated with the discipline needed for the topic.

Example of a block: Block for Head and Neck structure and function will involve department of Anatomy, Physiology, Radiology, and Oral biology.

Assessment As a Component of Curriculum

The aim of the assessment must be clear and realistic. There must be a close link between the assessment task, the learning objectives, and the feedback. Different types of assessment measure different types of learning. Therefore, it is always advised to use a combination of assessment tool (Table-2).

Table 1: Showing the Timeline and Example of Block Distribution in Each Year

Year	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April
1 st	Block 1		Block 2					Block 3	
2 nd	Block 1			Block 2			Block 3		
3 rd	Block 1				Block 2			Block 3	
4 th	Block 1			Block 2					
5 th	Block 1								

Source : Author's Computation

Table 2: Matching the Learning Outcome to Type of Assessment.

Types of learning outcome	Assessment method eg.
Critical thinking	Essay, report, *MCQ, *SAQ, *PBL
Performing procedure	Demonstration, role play, lab report etc.
Knowledge and understanding	Written or Oral Examinations.*OSCE
Developing self	Learning journal, portfolio, group project etc.
Creativity	Designing project, presentations etc.
Managing information	Library research assignment, use of bibliography etc.
Communicating	Written or Oral presentation, discussions, debate etc.

Source : Author's Computation

*MCQ-multiple choice questions, *SAQ-Short answer questions, *PBL-prblm based learning, *OSCE-objective structured clinical examination

Assessment is the main component of all educational processes (teaching, learning, curriculum design). The ultimate goal of medical assessment is to identify a competent doctor who will provide society services (Ferris and Flynn, 2015). Assessment in medical education is unique as it needs assessment of core knowledge and clinical skills. It needs to be more systematic as it finally relates to providing a competent doctor to society. Block-based curriculum uses formative assessment throughout the block in the form of quizzes, assignments, and written examination. Summative assessment at the end of a block is in the form of a written test.

The curriculums' ignored nonacademic aspects are leadership skills, communication, social behavior, values and ethics, and professionalism. These domains are called the hidden curriculum. Although all are part of competencies that society expects from a doctor, they are difficult to assess. The curriculum is divided into semesters and an internal block system. Students are not promoted to next block unless he /she fulfill the competencies needed for the previous block.

Teaching and Learning Theories in Curriculum Design

The topics of the blocks are so variable that no one method suits all. Therefore, a combination of different teaching methods is used. Learning theories inform curriculum development and implementation by providing a framework to select teaching methods and planning strategies to assess learning. Each individual has his learning style, and therefore, it is essential to consider different learning theories while planning any curriculum design. The ideas provide a framework that helps the stakeholders select the teaching-learning methods and plan the strategies for assessing learning for successful learning outcomes. The more the learning theories are considered during curriculum design and implementation, the better the learning outcome (Mugisha and Mugimu, 2015).

The fundamental theories that should be considered during curriculum planning are the;

- **Kolb's Theory of Experiential Learning** : This theory has four interrelated elements of learner's experience, reflection, forming concepts, and application. Kolb also emphasizes the importance of feedback in developing the learning process.
- **Social Constructivism** : The concept by Vygotsky states that we learn more in collaboration than alone. Group learning stimulates cognitive skills, critical thinking essential for the retention of knowledge.
- **Community of Practice (CoP)** : Lave and Wenger discussed this concept. According to this, when learners actively participate in the learning process with similar professional communities by periodic discussions, face to face or online, it enhances learning and keeps their knowledge updated.

There are many more theories through which various learning principles can be drawn and matched, and satisfied during curriculum design. In the medical/ dental curriculum, apart from the prescribed syllabus, we use simulation, power-point presentations, small group discussions, team assignments, use OSCE to assess simulated scenarios, provide timely feedback and take timely feedback from the students. By using all these methods, the block-based curriculum almost satisfies all theories of learning.

Advantages of Block-based Curriculum: (Quintero et al., 2016)

- Integrated and multidisciplinary approach of a block-based curriculum makes learning enjoyable.
- Learning one topic from different aspects makes understanding and application more effortless and less stressful.
- Studies have found less attrition of students in block-based integrated curriculum.

The students experience learning and implementation simultaneously, which is of great importance in medical and dental education.

Limitations of Block-based Curriculum: (Quintero et al., 2016)

- Designing blocks needs expertise and a deep understanding of the facilities.
- Simultaneous interaction of different discipline leads to difficulty in communication and confusion among the teaching faculty.

Due to the fixed time allotted for each block, sometimes a particular topic has too many disciplines involved, leading to superficial information/knowledge delivery.

Comparison Between Block-based and Traditional Curriculum

A good curriculum design requires building a knowledge base for students at each level, stimulating critical thinking, suitable teaching methodologies, and motivating research work. The curriculum design should also be less stressful to the students and should help develop good student-teacher relationships. Below is the comparison of both curricula under different domains.

1. **Knowledge:** knowledge is the range of information or understanding and is essential to perform and compete. According to the literature, students found knowledge better with integrated /blocks than traditional design (While, 1994; Hussein et al., 2017).
2. **Critical Thinking:** The knowledge gained needs to be applied at the right place. These critical thinking skills are required for the medical curriculum. Critical thinking helps students to handle emergency and unavoidable situations efficiently. Jordan et al., (2011) and Akram et al., (2019), in their study, concluded that students with block-based integrated curriculum make better knowledge application than students with traditional design.
3. **Teaching Methodologies:** Traditional Curriculum primarily uses didactic lectures, which are a passive learning method. Block curriculum uses problem-based learning, case-based learning, and small group discussions and debates. All these innovative

active learning techniques make learning interesting for students and develop critical thinking. By giving them real-life experience, students understand the problems better (Chambers, 1993), are satisfied, and get good scores (Ariana et al., 2017; Collis et al., 2010). These techniques used in block-based curriculum, according to Whipp et al., (2000), help students get better knowledge, help ethical decision making, and develop habit of life-long learning.

4. **Communication Skills:** Medical and dental students need good communication skills for better teamwork and dealing with patients. Interactive learning sessions like PBL and debates used in block-based curriculum help develop students' communication skills (Jardon et al., 2011; Meo 2013).
5. **Stress:** Students' stress can have a negative effect on their performance. However, curriculum design is not the only factor to be considered in stress management. Studies show variable results. Some associate more stress with traditional curriculum design and some with block-based (Slavin et al., 2014; Quintero et al., 2016).
6. **Student-Teacher Relationship:** Student-teacher relationship is multi-factorial and may vary according to culture and geographic location. Due to active learning methods of block-based curriculum, the teachers are more approachable, making student-teacher relations better (Hussein et al., 2017).
7. **Clinical Skills:** In a block-based curriculum, clinics are integrated, and therefore, students get completely involved in treatment planning and treating one patient thoroughly. Whereas in traditional, due to rotation posting, students do only one type of treatment at a time and do not get involved in complete treatment planning of one case. Arias et al. (2016) related better clinical skills with integrated curriculum.
8. **Personality Development:** Active learning process develops analytical skills and builds confidence in students with a block-based Curriculum (Marshall et al., 2014).

9. **Assessment Methods:** Assessments in a block-based curriculum consumes less time as it assesses multiple subjects in a single day, while for traditional curriculum, each subject needs a day.
10. **Research:** In the traditional undergraduate curriculum, research is taught in the form of a subject, only theory. Actual research is compulsory only during higher education. Whereas in a block-based integrated curriculum, research is a compulsive activity for all years during undergraduate studies in addition to the theory component.

Dental graduation/education in India is for five years. The first two years teaches basic medical and dental subjects through lectures and practical. Preclinical procedures are introduced during this period for all specialties of dentistry. The third and

less attention is given to treatment planning for a patient as a whole and problem-based learning in the Indian Curriculum. This pattern is adopted in post-graduate training but also needs to be introduced in the undergraduate curriculum itself. Table-3 shows few important differences in the traditional and block-based curriculum.

Discussion

Curriculum refers to the lessons and academic content taught in a specific program (Curriculum-Glossary, 2021). Block-based designing is only the structure of the university curriculum. This framework helps the curriculum to meet the complex demands of the health system. The curriculum structure of the University under the block system integrates bio-psycho-social cultured concepts of health and illness. Apart from

Table 3: Shows the Difference between the Block and Traditional Curriculum

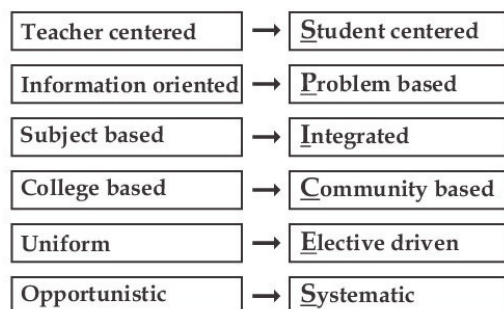
Traditional Curriculum	Block based curriculum
Teacher-centered	Student-centered
Multiple topics are taught at the same time	One system is taught at one time
Doesn't focus on real learning and gives limited scope for independent study of any subject.	Focuses on content area and gain complete understanding by creating and continuity in students' learning.
Mostly uses lectures/diadic teaching	Uses multiple methods like class presentations, group discussion, role play, simulation

Source : Author's Computation

fourth years have equal lectures and rotational clinical postings. The fifth-year is of internship. During this, the students perform all complex and straightforward clinical procedures on patients under supervision. Assessment is done only for the first four years, including a written exam, orals, and assessing technical and clinical skills. In a study by Rao et al. (2014), it was found that the main difference in the Dental Curriculum of India and other developed countries was introducing clinical experience at a later stage. Also, in another study (Elangovan et al., 2010), it was found that

the basic core knowledge of dentistry, nonacademic components like value, ethics, communication, individual development, professionalism, social behavior are also included in teaching and assessment. Independent blocks are designed for all and incorporated in all the years of graduations. This type of approach reflects the SPICES model of curriculum design (Figure-1) that includes strategies such as student-centered learning, problem-based learning, integrated teaching, community-based education, elective programs, and a systemic approach (Quintero et al., 2016).

Figure 1: SPICES Model



Source : Harden (1984)

Bligh and Brice, (2010) have also suggested a framework of quality curriculum design principles. This framework describes how medical education should be taught so that the students are trained perfectly for good medical practice. The acronym is RIFLE (Figure-2).

Figure 2: RIFLE framework for Curriculum Designing

R	Realistic	The curriculum is effective if the students can correlate its importance to patient care.
I	Integrated	Students learn better if the curriculum is planned in such a way that the students are taught a single topic by staff from different specialties so that they can relate their core knowledge with variety of disciplines.
F	Feedback	Feedback keeps the learners motivated and helps self assessment and reflection.
L	Learning	Learning process should involve interaction and must be made interesting and engaging for better outcome.
E	Evaluation	The curriculum should be regularly evaluated.

Source : Bligh J. and Brice J. (2010)

It is mentioned by Elangovan et al., (2010) that the students of India who study traditional curricula have an excellent theoretical quality as they need to refer to textbooks. The theoretical knowledge base of students was evident from the subjective exams. As traditional curriculum is subject-centered and less complicated to deliver, it is still preferred in many universities. However, aspects of critical thinking, problem-solving, and research are the strength of integrated curriculum, which is not well addressed in traditional design. Hecker et al., (2009), in their study, compared the scores of licensing exams with the formal medical curricula

and they found that curriculum designs do not have much effect on student's performance. These inconsistent findings make it difficult to decide which curriculum design creates better graduates to fulfill society's needs.

Conclusion

'How' students learn is equally important as 'What' they learn. Therefore, understanding how they learn will contribute much more in improving what they learn. Here comes the vital role of curriculum design. The medical curriculum is now emphasizing professionalism and fitness to practice, for which we need students to engage with a robust curriculum effectively. Whichever curriculum design is followed, the outcome should be to produce young doctors who are 'safe beginners'. They should be able to provide exemplary patient care. No curriculum remains

static, and continuous changes are happening according to society's requirements and developments in medical and dental science/technology. The basis for any change in curriculum is always to improve the existing curriculum design. It ranges from simply flipping a subject from one year to another to introducing a completely new course (Johnson, 2015). Curriculum change is needed to keep the knowledge and technology updated with modernization, reconstructing according to learner ability and eliminating outdated teaching methods.

As sudden change in curriculum design is very difficult and also it is a long process, we recommend that initially institutes should start using innovative teaching methods that involves active participation of students. We also recommend including teaching and assessing the hidden curriculum domains like professionalism, ethics and communication skills.

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Application of Deep Learning Tools in Rugoscopy: Exploring Digital Imaging Study

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Abstract

Background: In forensic odontology (FO), human identification is a difficult undertaking, especially in circumstances of man-made and natural calamities. Palatal rugae, such as fingerprints and dental morphology, are highly unique, stable, and consistent throughout life. Palatoscopy or rugoscopy plays a crucial role when other methods of identification, such as fingerprints and dental records, are inaccessible. **Objectives:** This study aimed to understand the efficiency of deep learning in rugoscopy for human identification using digital images. **Methods:** Deep learning models can measure phenotypic traits, behavior, and other characteristics. This study ties together recent advances in deep learning and computer vision to meet the requirement for more efficient rugae monitoring. Sensor-based monitoring of rugae can be used in deep learning models to identify exceptionally large datasets to analyze e-information. Researchers will discuss the implementation of such solutions in rugoscopy. **Results:** The scope of rugoscopy prompted us with the aim to understand its efficiency in human identification using digital images. **Conclusion:** Computer vision and deep learning advancements may provide innovative solutions to these worldwide concerns. Observations can be effectively recorded using cameras and other sensors. Automated imaging in laboratories can also capture the physical look of specimens.

Keywords: Computer vision, forensic odontology, human identification

INTRODUCTION

Forensic odontology (FO) is a branch of dentistry that focuses on determining an individual's identity by examining the distinctive characteristics of the mouth cavity.^[1] This research is mostly used in medicolegal investigations and identifying accidental remains by analyzing dental data, as well as identifying an individual based on human remains during mass disasters.^[2]

The use of palatal rugae (palatoscopy) in dentistry is an alternate way for human identification, particularly in traffic accidents, mass disasters, acts of terrorism, and other emergency situations.^[3,4] Palatal rugae are elevations or asymmetric ridges occurring on either side of the mid-palatine raphe and^[5] posterior to the incisive papilla in the front or front part of the palatal mucosa. They never cross the midline. The palatal rugae are fully developed at birth, with the characteristic shape, length, width, prominence, position, and orientation forming unique^[3,6] patterns for each individual. Digital forensics is a very advanced field that uses modern techniques for analysis,

and also, it solves problems, which involve large amounts of complex data. It is also used for the examination or comparison of large volumes of relevant evidence, such as images, audio, and videos, which is more accurate than manually, and it is a time-consuming task. This study focuses on implementing artificial intelligence (AI) and machine learning (ML) tools using rugoscopy in human identification, which can be an adjunct to the other standard human identification procedures, using a live video sequence to record palatal rugae, based on the standardized rugae classification, and assessing the average size, pattern, and shape to compare with the deceased for an outcome.

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MATERIALS AND METHODS

Study design

This study emphasized collecting and storing palatal rugae patterns in humans, which can be utilized for the purpose of human identification, and it was performed using digital forensics, which is a highly advancing field and requires modern analyzing techniques for solving complex problems through the analysis of a huge amount of data sets.

Limitations

Examination or comparison of huge volumes of possibly relevant evidence, such as images, videos, and audio, in an accurate manner, is a painstaking, time-consuming task with possible human errors due to incompetence, fatigue, or other factors. Thus, using conventional intensive and manual approaches makes it impossible to deal with issues and complications currently found in forensic science. The human expert, investigator, or practitioner can be tired, biased, prejudiced, incompetent, or emotional during the examination or investigation process. This often leads to increasing error rates or false results, which lead to failure of investigation and miscarriage of justice.^[7]

Materials used

The following study was conducted using intraoral scanners, and an intraoral camera is a digitalization instrument, which replaces a conventional impression in recording intraoral anatomical landmarks. Video display, processing unit, and intraoral camera with light source are all included in intraoral camera (IOC) systems. Intraoral cameras have a wide range of features, including macro-mode (magnification), light-emitting diode (LED) lights, and picture or video recording.^[8] Intraoral scanners, however, are a medical device that consists of a handheld camera (hardware), a computer, and software. The goal of intraoral scanner (IOS) is to precisely record the three-dimensional shape of an object. Standard Tessellation Language (STLlike) or open Standard Tessellation Language (STL) is the most extensively used digital format.

Importing the image with an image acquisition tool, analyzing and altering the image, and output, which could be a modified image or a report based on image analysis, are the three processes of image processing. Analog and digital image processing are the two types of image processing processes employed. Computer-assisted image alteration is possible thanks to digital image processing technology. All sorts of data must go through three general stages when using digital approaches: preprocessing, augmentation, and presentation, as well as information extraction.

Subjects

The challenge of classification has proven difficult for rugae researchers. To make that simple, a few are most likely used and followed when required:

1. Trobo classification (1932): Rugae are separated into two types: simple rugae (classified from A to F) and compound rugae (identified with the letter X). Composed rugae are made up of two or more simple rugae unions [Table 1].

2. Martins Dos Santos classification (1946)^[5,9]: Based on the shape and position of each palatal ruga: A capital letter denotes the most anterior ruga on the right side. Several rugae go well together; the numbers on the right denote the other rugae. There is one sub-initial ruga on the left side, the most anterior of which is represented by a capital letter. Several sub-complimentary rugae have numbers assigned to them, while the other left rugae do not. Each ruga is assigned a number and letter that corresponds to its shape and size [Table 2].
3. Thomas and Kotze (1983) classification^[10]: Based on length, shape, orientation, and unification [Table 3]. Various computer software packages can be used to superimpose digital photographs or photographs for comparing rugae patterns. These are the computerized methods for researching rugae patterns.
1. Stereoscopy can produce a three-dimensional view of the anatomy of the palatal ruga and can be performed with a variety of computer software packages. Rugae Feature Point Identification (RUGFP-ID), for example, is Palatal Rugae Comparison Software (PRCS version 2.0).
2. Comparative analysis can be performed using calcorrugoscopy or overlay printing.
3. Stereophotogrammetry uses a specific gadget known as a traster marker to accurately determine the length and position of each ruga.

The goal of this study was to identify whether these palatal rugae from a live video stream are more practical and time-saving as the procedure for taking pictures might be associated with certain technical errors, such as focusing on the required area for taking palatal pictures. The indirect method has to be used with the help of oral photographic mirrors, and the present concept will be much easier and can be performed with the help of simple intraoral cameras or

Table 1: Trobo classification







Classification	Rugae type	Shape
Type A	Point	
Type B	Line	
Type C	Curve	
Type D	Angle	
Type E	Simuous	
Type F	Circle	

Table 2: Martins Dos Santos classification




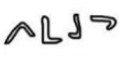






Rugae type	Shape	Anterior position	Other positions
Point		P	0
Line		L	1
Curve		C	2
Angle		A	3
Circle		C	4
Sinuous		S	5
Bifurcated		B	6
Trifurcated		T	7
Interrupt		I	8
Anomaly		An	9

Table 3: Thomas and Kotze classification

Criteria
Length
Primary Rugae
A - 5 TO 10 mm
B - 10 mm or more
Secondary rugae : 3-5 mm
Shape
Fragmentary rugae : less than 3 mm
curved
Wavy
Straight
Circular

intraoral scanners of the video sequence that are unnecessary. We count and examine the pattern and shape of rugae after segmenting them from the upper jaw region. As a result, the entire problem may be handled in just two stages.^[12]

Data collection

To distinguish these palatal rugae from a live video sequence, we must first remove the entire upper jaw region from the video sequence, as well as any other undesired elements. We count and examine the pattern and shape of rugae after segmenting them from the upper jaw region. As a result, the entire problem may be handled in two easy actions:

**Figure 1: Rugae patterns analyzed on cast**

1. From the video sequence, the rugae region is found and segmented.
2. In the video sequence, the layout and shape of the segmented rugae region are counted and examined.

Python in image processing

Image display, fundamental manipulations, such as cropping, flipping, rotating, and image segmentation, classification, and feature extractions, image restoration, and image recognition are all examples of picture processing jobs. Python is a fantastic image processing language. Many Python libraries are used for image manipulation in this study. These are the basic steps of rugae shape recognition.

STEP 1: Segment the rugae region

Obviously, the initial step in upper jaw recognition is to locate the rugae region in the video sequence by removing any other distracting elements. A video sequence is just a series of frames or images that run in order.

STEP 2: Background subtraction

We bring in rugae and tell the system that our rugae is a new entry into the background, which means it becomes the foreground item, after we have figured out the background. With the background subtraction, we will get rid of just the foreground.

Statistical analysis

Segmenting of the rugae region and background subtraction were performed to determine the most extreme points in the segmented upper jaw region's convex hull (a contour) (extreme top, extreme bottom, extreme left, and extreme right). The upper jaw's center was located using the convex hull's extreme points; using the upper jaw center, a circle with the maximum Euclidean distance (between the palm's center and the extreme points) as the radius was drawn; and finally, the threshold hand picture (frame) with the circular region of interest (ROI) in a bitwise and operation (mask) was combined. This displays the teeth and rugae slices, which can then be used to figure out how many rugae there are, as depicted [Figure 2a-e].

Discussion

Deep learning is a subset of ML that uses multilayer neural networks to replicate human decision-making. This entails

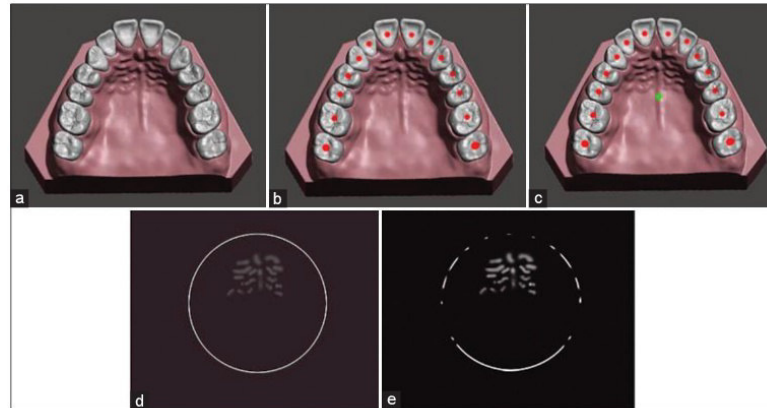


Figure 2: (a) Upper jaw, (b) Convex hull + extreme points, (c) Finding the center of the upper jaw, (d) Construct a circle with the upper jaw center and around the teeth, (e) Bitwise and between teeth region circle mask

the creation of machines or computers capable of learning, reasoning, adapting, self-correction, and other human-like mental processes, as well as acting logically. Deep learning algorithms may recognize patterns in data and classify, categorize, and classify them. It is what allows AI systems to learn on the job, allowing them to enhance the quality and accuracy of their output by judging whether their decisions were correct. A neural network, often known as an artificial neural network, is a type of artificial neural network. In artificial intelligence, a neural network is a collection of microscopic processing units known as neurons that take in data and learn to make judgments over time. Deep learning approaches become more efficient as data sets expand in size because neural networks are often layer deep. In this study, we indicate the use of image processing using Python and OpenCV. A method of refining or extracting information from an image by conducting operations on it is known as picture processing. It is a sort of signal processing in which a picture is used as the input and the image or its characteristics or features are used as the output.

The intermediate steps used in the study are contours, bitwise-AND, Euclidean distance, and convex hull. They are all image processing concepts that must be understood.

Contours outline the object of interest or its boundaries. A contour is the line that connects all the points with the same intensity along the image's boundaries. The OpenCV contour function `cv2` can be used to find contours () in a binary image. This method returns a list of all the contours in a binary image if you feed it one. Each member in this list is a NumPy array containing the (x, y) coordinates of the contour's border points (or the object).

Between two items, bitwise-AND conducts a bitwise logical AND. You may see this as applying a mask to an image and extracting the regions that exist solely beneath the mask. The `cv2.bitwise` and `Q` function in OpenCV can be used to accomplish this operation—bitwise-AND.

Distance in Euclidean Space is the distance between two points and is calculated using the equation provided above. Pairwise Euclidean distance—scikit-learn includes a method named `pairwise`. In a single line of code, `Euclidean distance ()` calculates the Euclidean distance between two places. Then, using NumPy's `argmax ()` function, we calculate the maximum of all these distances.

Convex hull is a dynamic, flexible envelope that wraps around the item of interest.

The following study will be able to record the rugae and their patterns, in the easiest possible way with simple tools without utilizing much manpower to store them as data, which will be analyzed and further used for human identification on par with the present standard identification procedures.

Limitations of the study

Although this study can prove to be quite a breakthrough in forensic identification, there are some limitations, such as examining vast amounts of evidence, such as images, videos, and audio for forensics, which is painstaking, time-consuming, and prone to human errors due to fatigue and bias. The struggle to handle the complexities and errors may hinder investigations and justice.

Future prospects

We believe that with the help of our study we can record the rugae and their patterns, store them as data, and use them for further studies, and with the help of these data, we can draw definitive conclusions in cases of human identifications.

CONCLUSION

Human identification, whether living or dead, is a complex, time-consuming process. The morphology of the palatal rugae has been demonstrated to be very unique and stable throughout life. Because the palatal rugae pattern is as distinctive as a person's fingerprints, its use in forensic identification is both justifiable and necessary. As a result, palatal rugae pattern analysis, when used

in conjunction with other approaches, is an important alternative and supplementary tool for human identification, as well as a tool that can aid criminal investigations.

The field of forensic science and criminal investigation is highly advancing and automated with the help of technologies based on artificial intelligence. With its various approaches, such as pattern recognition, data analysis, computer vision, image processing, data mining, statistical analysis, and probabilistic methods, AI is currently assisting practically all of the major fields of forensic science and criminal investigation, artificial olfaction, mathematical computational methods, and graphical modeling. These AI-powered tools and technologies are highly supportive of forensic science and criminal investigation by delivering accurate, strategic, and rapid conclusions.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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of Faculty Of Dentistry, Pacific Academy Of Higher Education And Research University, Udaipur
has Presented Paper entitled Use Of Artificial Intelligence For Human Identification In Forensic Odontology

in this International Virtual Conference on 15th-16th January 2022 held at Pacific Academy of Higher Education and Research University, Udaipur.

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