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Determination of rugae pattern in non-treated normal angle class I, II and class III mal-occlusion

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***Abstract*---**Background: Palatal rugae are specialized patterns in keratinized mucosa of the anterior hard palate behind incisive papilla tis are unchangeable in their site and form, all over an individual's lifespan. Occlusion means "closure" which refers to the interaction among upper and lower teeth. Mal-occlusion is improper alignment of teeth when the upper and lower jaws are closed. Objectives: The

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objectives of this study is to assessment of palatal rugae arrangement in our population and the determination of rugae pattern in non-treated Class-II and Class-III mal-occlusions when related to Class-I normal mal-occlusions. Methodology: It's observational and cross-sectional study conducted at Orthodontics department, Lumhs jamshoro and Hyderabad. The sample size of study was 135, the Pre-treatment record of those patients who are receiving orthodontic treatment were enrolled as study participants their maxillary dental cast was assessed for assessment of rugae, Maxillary dental casts were assessed and maxillary impression were recorded using Alginate (irreversible hydrocolloid), impressions then were poured using dental stone. The Rugae pattern on the study casts were traced with a black graphite pencil to clarify the pattern. The study was carried out using Thomas and Kotze classification which is created on rugae's length with primary rugae >5mm, secondary rugae 3to5mm and fragmentary rugae <3mm. The rugae <2mm were not measured. The length of rugae was measured Vernier Caliper. The measurement on Vernier Caliper was recorded in millimeters scale. These patients were than divided into 3 groups according to Angle's classification and their maxillary cast will assessed for rugae pattern. The length and shape of rugae from 1 to 7 of right side and left 1 to 7 were assessed. The age, gender, qualification, address, Angle's classification, types of mal-occlusion, length and shape of rugae 1-7 were recorded. The data was analyzed by IBM SPSS statistics software version 24. Results: The mean age was 19.5852±4.26437. The males were 28.1% and females were 71.9%. The length of rugae in 135 subject of right 1 was 100% and left 1 was 97% primary. The shape of rugae of right 1 was 42.2% and left 1 was 42.2% curved. The length of rugae of right 2 was 93.3% and left 2 was 94.8% primary, the shape of rugae of right 2 was 51.9% and left 2 was 65.2% wavy. The length of rugae right 3 was 94.1% and left 3 was 91.9% primary, the shape of rugae of right was 77.8% and left was 74.1% wavy. The length of rugae right 4 was 81.5% and left 4 was 78.5% primary, the shape of rugae of right was 69.6% and left was 73.3% wavy. The length of rugae right 5 was 57.8% and left 5 was 60.7% primary, the shape of rugae of right was 59.3% and left was 65.2% wavy. The length of rugae right 6 was 13.3% and left 6 was 31.1% primary, the shape of rugae of right 6 was 20.7% and left 6 was 27.4% wavy, 6th pattern is mostly found absent. The length of rugae right 7 was 3% and left was 6.7% primary, the shape of right was 3% and left 7 was 5.2% wavy, 7th pattern is mostly found absent. Conclusion: There was no difference between male and female rugal pattern, primary rugae length > 5mm is found to be most common than secondary and fragmentary, the shapes of rugae curved and wavy is seen most common among individuals, the anterior rugae pattern is most prominent than the posterior and varies from 1 to 7 in number.

***Keywords*---**rugae pattern, postnatal palatal growth, determination.

Introduction

Plicae Palatinae, the dense irregular tissues behind the incisive papilla found at one third of hard palate, such anatomical wrinkles or folds known as palatal rugae. The rugae are anatomical folds running from latral border incisive papilla to the frontal region of the middle palatal raphe with uneven, asymmetric ridges. On each side of the midline their quantity, shape, length, width, and orientation vary among individuals. The palatal rugae never cross the midline and are numbered separately on either side of the palate from anterior to posterior.[1] The palatal rugae are distinctive features that remains at same location and pattern through the entire life of man, which are unique for forensic dentistry, with possible ramifications in human identification.[1-2] The folds on palate are transversely arranged also called (TRANVERSE PLICA PALATINAE), are irregular asymmetric mucosal elevations on the palatal anterior third portion[3]. The denture's palatal relief design may also be utilized to evaluate and identify people.[4] Past researches on the rugae pattern shows stastistical hereditary link which are different among the gender and races.[5,6,7] Palatal Rugae are situated on the upper maxillary jaw, found on anterior most part of the hard palate, having vague pattern making it special among people.[1] The Palatal Rugae vary in height, shape, width, number, and location from person to person, when compared the both sides of hard palate, demonstrating individuality.[8] This design illustrates non-specific and specific characteristics but moreover within-species individuality; among the people, On each side of the midline, there are between 2 and 7 rugae with varying morphologies.[9] The palatal rugae start developing in 3rd month of embryonic life,[10] the appearance of PR does not change after this period, but the length of rugae pattern increases which shows normal growth pattern.[9,11,12,13] PR and connective tissue formation and growth of palatine maxillary bone are controlled by epithelial-mesenchymal activity, during developmental period the specific extracellular matrix are expressed.[14] In human embryos the first formed rugae which lies just behind the incisive papilla are renowned by 32-mm (CRL) Crown rump length.[15] The rugae pattern are prominent in the prenatal stage of life.[16] Between the 12th-14th week of intra uterine life, the palatal pattern orientation and palatal rugae characteristics on both sides of palate are established.[17] The rugal analgen are believed to stiffen the palatal shelves and aid in horizontalizing it above the dorsum of the tongue.[18] They may increase in size as the palate grows, but their shape is preserved once the growth is accomplished.[19,20] During the development of fetus, the palatal rugae occupies the majority of portion of the palate during elevation time.[19] The rugae pattern becomes relatively regular toward the end of intrauterine life, with the anterior 6 of rugae becoming very apparent. They are complete at time of birth, their characteristic shape, length, width, and orientation making a distinct anatomy.[1,13] The palatal rugae facilitate swallowing and enhance the contact between food and taste sensors on tongue's dorsum surface.[21] In children, it also helps with speech and suction.[17] On either side of the palate, the number varies from 3 to 5. It never crosses the midline and do not grow to the posterior aspect beyond the front part of hard palate. The anterior rugae are greater and protruding over the posterior rugae.[2] The palatal rugae facilitates transportation of food, prevents the escape of food from mouth, plays a part in grinding food, also contributes in perceiving the taste and surface texture of food,[15] by developing friction surface to grasp the bolus in place and to emulate food by

intraepithelial sensory receptors.[17,22] One of its function is to aid in tongue position. It also show a role in phonations due to its irregularity sound waves are dispersed in diverse directions producing different sounds and add resonance to voice. The palatal mucosa is protected from the trauma of hard and tough chewing food due to its morphology and retains the saliva.[5,15] Rugae are trauma safe and protected because of its location in the mouth, the rugae are protected from traumas. Rugae have heat insulation properties, because of its protection from tongue, soft tissues and the retained saliva.[9,23] The palatal rugae facilitates transportation of food, prevents the escape of food from mouth, plays a part in grinding food, also contributes in perceiving the taste and surface texture of food.[24] Anthropometry, is a branch of science it's the scientific study of human characteristics and measurements, has been utilized in differing areas counting life structures and in individuals identification and to gain a better knowledge of human physiological variability, paleo anthropometry, i.e: the scientific study that tries to link physical characteristics to ethnic and psychological characteristics, legal sciences, and restorative surgery.[25,26,27] Curve length, facial stature, and rugae patterns have all been used as individual criteria in various studies on dental anthropometry..[28,29] However for forensic identification teeth have been used, but several times they are absent due to caries, surgical events or due to any traumatic incident, in such cases the soft tissue examination is evident. In soft tissue examination rugae on anterior palate is examined (rugoscopy) as it is secured by soft tissues lips, cheeks, buccal fat pad, tongue, teeth and bony covering due to its internal location thus helps in forensic identification.[24] As a necro-identification method, palatal rugoscopy can be used. It may be of special importance in cases where no fingerprints are available, such as degraded bodies, burned bodies, or situations where both upper appendages are missing. It is the foremost profitable method in aeronautical mishaps to guarantee distinguishing proof of pilots making utilize of antemortem information[30] The anterior rugae, according to Van der Linden, do not grow in length beyond the age of ten.[24] Palatal rugae are taken down in maxillary impression and detected on maxillary cast; these bilaterally anatomical eminences on front ridge of hard palate. Rugae pattern of a person may be regarded a valuable tool for gender determination and identification, as well as to ease population identification of various races.[31] At both the social and legal levels, human identity is very important.[32] Identity verification of individual is an important task in forensic analysis that include different methods such as taking photographs, fingerprints, DNA evidence, teeth and lip marks.[31,33] These methods may provide accurate and rapid information but due to some disadvantages for example.[34] DNA testing is expensive and time taking for use in large populations, fingerprinting also cannot be performed in certain cases such as burn victims.[21,35] For accurate and more reliable results in forensic identification, new technique is invented such as forensic odontology.[2,22] Forensic sciences is gaining prime importance by courts and laws, Forensic Odontology is the science of handling, examining, and evaluating dental evidence that will be presented in court and it requires the skill as dentist to study and use palatoscopy, i.e. The examination of the rugae pattern in determination of individual identity.[24,36] Rugae vary from individual to individual, in patients with drastic crowding and spacing the rugae pattern is altered from usual ones, after orthodontic treatment rugae marks changes because of firm forces applied and after orthognathic surgeries or in patients with habitual thumb sucking.[2] They are often used in orthodontics

in pre- and post-treatment cephalometric tracings which are reliable reference markers.[34] However, tooth removals, finger sucking throughout childhood, and orthodontic treatment, which in-cur reliable weight on the teeth and alveolar preparation, may supply cause changes in the location and direction of palatal rugae.[11,37] Teeth and palatal rugae have been linked as both form during the similar time of intra-uterine life. Palatal rugae serves as stable landmark and thus plays a significant role in clinical orthodontics.[38,39,40] Orthodontists have utilised PR as a trustworthy reference point for assessing the level of orthodontic movements. The significance of rugoscopy merits its accurate assessment. Orthodontics have always given importance to the early diagnosis of mal-occlusion and are always in search for non-invasive tool for the early diagnosis of mal-occlusion PR pattern is set up at an early age and thus can be used as an additional tool for early diagnosis of mal-occlusions.[38,39, 40.41,42,43] Furthermore, with timely identification of mal-occlusion, preventive and interceptive treatment modalities using growth modifications with functional and orthopedic appliance can be done to improve sagittal skeletal relationships. Early treatment in adolescence maximizes the skeletal effects, Reduces severity of skeletal problems as well as the expense of therapy.[44,45,30,46] Researchers explored and revealed that different populations' palatal rugae patterns differed.[44,45] However, only a few studies have been done in the past to determine the link of rugae pattern with various skeletal and dental mal-occlusions.[34,46,47,48] Oral et al reported wavy and curved rugae pattern with different skeletal and dental mal-occlusions[8]. Fatima n Fida in their study reported no particular pattern was related with different sagittal skeletal pattern[34]. Evaluation of palatal rugae characteristics; primary (>5mm), secondary (3-5mm), or fragmented type (3mm) based on length.[31] The length, structure, and orientation of the anterior three rugae are categorized rugae 1, 2, and 3. Rugae were categorised according to Hauser et alapproach's for assessing pattern and orientation[9]. Furthermore, the shape of individual rugae, as classified by Thomas and Kotze[49], are shown in Figure 1 and 2 and described as (1) Curved; a crescent form with a mild curve, (2)Wavy: a slight curvature at the origin or termination of curved rugae, (3) Straight: they appear straight from their origin to termination of rugae, (4) Circular: a definite continuous ring of rugae, and (5) Unification: when two rugae are joined at their origin or termination.[31]

Objective

The objectives are to assess the characteristic array of rugae in untreated Class II and Class III malocclusions compared to normal Class I occlusions and to examine palatal rugae pattern in different malocclusions in our population

Literature Review

The rugae pattern of every individual is unique and different in one person to another which can be used in individual’s identification. I have to assess the palatal rugae in different mal-occlusion whether there is any contrasting difference in untreated different classes of mal-occlusion to normal occlusion. Harrison Allen in 1889 concluded, Palatoscopy, also known as rugoscopy, is a form of identifying the individual as an alternative to fingerprinting.[50] Palatal rugae, first was described by Winslow (1753),[51] Santorini in (1775),[52] They came

to the conclusion that In the court of law, rugoscopy is among the most efficient characteristic of personal identification. Because no two sides of the hard palates appeared to be identical, the rugae pattern, incisive papilla, median palatal raphae, and dental arch morphology were discovered for being unique to the individual. In forensic medicine, palatoscopy might have been a valuable tool in identifying individuals. Thabitha RS et al[53] mentioned that in 1889 Harrison Allen, defined The biologists and the medical persons are equally interested in the body's very stable and dynamic structures. They are acknowledged as sensitive tests for the efficiency of both the nutritional and developmental processes when they are consistent or when changeable, they exhibit traits that may be used in categorization. In this context, he advocated studying the creases or rugae on the hard palate in study participants after infant stage. The palatal rugae, according to Fatima et al, are intriguing structures that are fixed in their place and style during lifetime of a person which confers them an extraordinary part in measurable dentistry, having potential suggestions within the pattern of human distinguishing proof. It is also suggested by them that further studies need to be done on 3D examination and properties of the ridge in order to determine the relationship between the palatal rugae and the sagittal skeletal pattern.[34] Bruno nehme barbo et al mentioned that the Palatal rugae assessment is an opportunity technique in human identification, mainly in instances of street/road side accidents, terrorism acts, mass screw ups in aeronautical or blast incidents, whilst it's far tough to spot people thru finger prints and DNA testing which might be expensive in cost. The finding of initial studies showed that small sample of ridge assessment does not exhibits a size pattern with respect to shape and number so individual patient assessment with large sample size required to identify the variation with respect to the form and size of a particular palatal rugae.[54] Malekzadeh et al, All of this is part of forensic sciences, which play a key role in criminal and civil law. Forensic dentistry, also known as forensic odontology, is a discipline of dentistry that aids in the identification of individuals. Fingerprints can be difficult to interpret after death due to postmortem factors such as time, temperature, and humidity. Compared to other body parts which disintegrate quicker than teeth. However sex identification, teeth alone cannot be solely relied upon because of possible alterations due to dental treatment between last dental records and in complete edentulous individual. They discovered that the morphologies of rugae patterns varies significantly between males and females. Clearly, palatal rugae patterns have enough properties to distinguish among gender and verify the concept of palatal rugae uniqueness, and so might be used for the purpose forensic identification,[31] Gadicherla P et al, While DNA profiling is dependable, which is both costly and time demanding. to apply to large numbers of people. Postmortem alterations linked with time, temperature, and humidity, however, limit physical identification and the use of fingerprints. Even though teeth are expected to be more reliable than other body parts, dental records can be inconclusive if the person receives dental treatment between the time the record is generated and the time of death, if any teeth were lost during the tragedy, as well as if the person was edentulous. In Bengaluru's population, the rugae pattern might be utilised to predict gender. The exploratory research paves the path for larger-scale investigations with a broader age range to be conducted in forensic cases, the palatal rugae can be used as a certain instrument for identifying individuals. Males and females in the Bangalore community had a different pattern of palatal rugae distribution within the

restrictions of the current research, it is possible to infer that the rugae pattern may be used to identify gender among Bengaluru residents. The exploratory investigation paves the path for larger-scale studies with a broader age range to establish the palatal rugae as a reliable forensic identification tool.[35]

Tooth movements and orthodontics treatment changes

The risk of alterations in palatal rugae patterns as a result of orthodontic treatment, palatal expansion, and extraction of neighbouring teeth has been noted as a source of worry. Bailey et al published a study in 1996[39] in which they equated the pre- and post-treatment stability of the palatal rugae pattern in orthodontic two maxillary premolars with and without extraction. Only the extraction group showed statistically significant anteroposterior alterations over time, according to the research. The third ruga's medial and lateral points, on the other hand, were regarded to be stable landmarks that might be employed in dental cast analysis as anatomic reference points. Barbieri et al(2012)[94] Rugoscopy's usefulness as a human identification method was assessed. There were no morphological alterations in the palatine rugae pre- and post-rapid palatal growth, according to the study. In every example tested, rugoscopy showed to retain the biological and technical prerequisites for a reliable human identification method. The rugae lengths were influenced by orthodontic treatment, according to Saadeh et al, with the lengths decreasing in the extraction group but increasing in the palatal expansion group. The third rugae showed higher length alterations than the first rugae with fast maxillary extension with the hyrax device.[95] During palatal expansion, the posterior teeth are inadvertently buccal tipped, despite the fact that the midpalatal suture opens in a V-shaped pattern that is wider anteriorly. As the lateral tips of the palatal rugae stretch outward in response to the tooth movement, the inter-lateral distance of the rugae increases. The rise in inter-lateral and inter-medial distances is also due to the increase in arch circumference. The alterations, however, are asymmetric, indicating that the underlying dentoalveolar and basal bone motions are varied. The inter rugae distance could be used in clinical practise to measure the amount of palatal separation after palatal expansion.[96] Carrea claims that orthodontic therapy has no influence on the form of the rugae, and that tooth loss has no effect on the shape of the rugae. The rugae remain unchanging from the time they grow until the oral mucosa degenerates at death, according to Leontsini in 1952.[97] In 1950, Hausser hypothesised that the rugae were related to the degree of tooth movement in a sagittal orientation.[98] Friel used a serial research to show that the teeth migrate forward in relation to the rugae as the jaws mature. He demonstrated that until the age of twenty, the rugae's posterior limit in regard to the teeth tends to shift rearward.[99]

Postnatal palatal growth

During the first five years after birth, somatic growth is the fastest and most intensive. Somatic growth occurs at a faster rate during childhood than at any other time after birth.[105] For example, in the first three years of life, children in the United States demonstrate a significant slowdown in recumbent length growth.[102] Because somatic and craniofacial growth and development are so closely linked, higher rates of craniofacial growth may be expected throughout the

first few postnatal years. Although evidence of significant craniofacial growth during infancy and early childhood is sparse, there is evidence of it.[103,106,107]

John Hunter's pioneering work established the basic concept of bone formation as a combination of outer surface deposition and inner surface resorption. Brash's vital-staining research led to the conclusion that cranial growth follows a similar pattern of periosteal bone formation and corresponding endosteal loss. Sutures are also thought to undergo structural changes to preserve functional contact between neighbouring bones.[108,109] However, Massler and SchourZG[110] have hypothesised, that sutures themselves are major developmental sites. Since then, the effect of concomitant soft-tissue expansion on sutural growth has been investigated, and it's been proposed that the developing brain, tongue, and eye all create a constant separation of overlying sutures, driving bone growth at their free borders. Detailed histologic and histogenetic studies of connective tissue structure and organisation within such emerging sutures have also been conducted.[111-112] [113] During osteogenesis, the different interstitially forming cartilages of the developing braincase have been proposed as major growth stimulants. The cartilaginous nasal septum is thought to be a fundamental force in pacing the morphogenesis of the maxilla and other neighbouring bones throughout face development. The septum's forward and downward expansion would tend to "take" the maxilla with it, separating its numerous sutures and stimulating new bone deposition on the same sutural surfaces.[114,115] Maxillary Growth as Measured by Lateral Implants Beginning at the Age of 4 Years Previous implant research (Bjork in 1955 and 1966) have established that the maxillary height increases as a result of growing at its processes: usually toward the frontal and zygomatic bones, and appositionally on the lower aspect of the alveolar process in conjunction with tooth eruption. Apposition can also be seen at the orbital floor, where restorative remodeling of the lower surface occurs. At the same time, restoration lowers the nasal floor and apposition occurs at the hard palate. Although the general principles of maxillary growth in height have been clarified previously, it is useful to have an idea of the mutual magnitudes of these various growth factors, which are currently unknown.[116,117]

Prenatal development of the palatal rugae

In 1987, Simmon’s et al researchers looked at the anteroposterior stability of the medial rugal area to see if the anticipated tooth motions based on palatal rugae markers are achievable.[118] The rugae emerge during the third month of intrauterine life and cover the majority of the extent of the palatal shelves, according to Farheen Fatima in 2019. They comprises a sequence of anatomical folds in front section of the palatal mucosa, on either side of the median palatal raphe, behind the incisive papilla.[9] They appear before the palatine shelves fuse in a quantity ranging from four to six on each side. The interaction between epithelial and mesenchymal cells is what regulates their growth and development. The pattern becomes uneven as intrauterine life progresses, the posterior ones fade away, and the anterior ones become more prominent.[62,119,71] The craniofacial growth and development occur via complex interaction between fibroblast growth factors and Hedgehog signalling pathways.[57,120,121] According to several researchers, genetic factors play a significant role in malocclusion susceptibility.[122,123] Polygenic inheritance has been documented for Class II

subdivision 1; however, autosomal dominant inheritance has been recorded for Class II subdivision 2 and Class III malocclusion.[121,124,125] Peterkova and Peterka discovered that palatal rugae formation is induced by epithelial-mesenchymal interactions that begin during palatogenesis. The first rugal anlage forms posterior to the incisive foramen, and the succeeding rugae form behind it, commencing medially and extending laterally towards the dental lamina. The rugal anlage burrows into the mesenchyme at first, forming transverse grooves. Through epithelial thickening and mesenchymal condensation, these mature into definitive rugae by producing a connective tissue core covered by epithelium. When the placodes protrude into the mouth cavity, the overall corrugated appearance is generated.[37] In cooperation with the anteroposterior expansion of the palate, activation-inhibition mechanisms generate a local inhibitory field close to the last formed rugae, resulting in periodic patterning and asymmetric rugae interposition. [126] The posterior rugae appear after the palatal shelf has been elevated and are less pronounced than the anterior rugae. The rugae appear to operate as struts, horizontalizing the palatal shelves,[127] this change results in a cleft palate. The growing palatal rugae patterns and different morphologies may be used as odontogenesis and palatogenesis stage indicators. A diagnosis of sub mucosal cleft palate is suggested whenever the palatal rugae bend towards the area of the bony notch.[128]

Postnatal growth changes of palatal rugae

According to Sassouni et al, two palates are the same in terms of configuration, and the palatoprint does not alter as a child grows. They're thought to be stable for the rest of their lives (after they've finished growing), however, there's a lot of controversy about it. They do not alter shape or length (due to natural growth) once developed, and they stay in the same location for the rest of a person's life.[129,130] The rugae's form and orientation pattern, which are unique to each person, are determined at birth. [1] Despite this, their length changes their placement does not change during palatine development, although it does change during life.[5] As a result, it has been established that they form their usual orientation pattern from birth, attain their ultimate shape in adolescence, and then remain stable throughout their lives.[71]

Histology of palatal rugae

The rugae are squamous (layered scales) and mostly parakeratinized histologically,[131] Epithelium on a connective tissue base is securely linked between the submucosa fatty tissue and the stratum reticulum of the palatum.[10,132] Rugae cores collected from human embryos over 20 weeks have fragile reticulin fibres in their cores, as well as a distinct quantity and size of fibroblasts in surrounding palatal tissue. Even before the palatal shelves are raised, rugae palatinae appear as localised epithelial proliferation and thickening.[133] Fibroblasts and collagen fibres gather in the connective tissue beneath the thickened epithelia. The core fibres within the curve and in concentric curves across the base of each ruga determine the orientation antero-posteriorly.[134] Because of the presence of these fibres and the presence of glycosaminoglycan, which allow the tissue to swell due to their hydrophilic nature, the form is maintained throughout life.[52] Rugae go through various stages

of growth. They have a relatively prominent look in the early stages of their elevation, occupying the majority of the length of the palatal shelves.[9] They appear as ridges at a later stage, at 55 mm, with the anterior ones beginning at the median raphe and the others laterally. With the elimination of the posterior rugae, compression, and an increase in prominence of the anterior rugae, the rugae patterns become less regular towards the conclusion of intrauterine life.[71] The morphology of palatal rugae and ethnic differences have been investigated by many researchers, but the individuality of palatal rugae has been studied by even fewer. Due to their interior location in the cranium, the tongue and buccal pad of fat protect the rugae from harm and heat. According to Sassouni, no two palatal patterns are the same in terms of structure, and the palatal print cannot modify as a person grows. They're thought to be stable for the rest of their lives (after they've finished growing), however there's a lot of controversy about it.[129] They do not alter shape or length (due to natural growth) once developed, and they stay in the same location for the rest of a person's life.[12,135] Thomas and Van Wyk[5] by comparing the rugae to the victim former denture's design, a severely burned edentulous body was successfully recognised; this suggests, among other things, that rugae are stable throughout adult life. As a result, palatal rugae shows unique nature, postmortem resistance, and stability are three characteristics of an ideal forensic identification parameter. The use of rugae pattern for identification purpose is known as palatal scopy or rugoscopy.[12]

Human identification

Caldas in 2006 and Kapali et al 1997, In the discipline of forensic dentistry, the palatal rugae have been regarded important for forensic identification. When the affectted individual without teeth or dental services were not done between the time the records were created and the patient dies. Palatal Rugae have been discovered and are comparable to fingerprints in that they have been unique to each person and preserve their form throughout their lives. Palatoscopy/rugoscopy, is the examination of the palatal rugae in order for identification.[12,134] Limson and Julian revealed an identification procedure using palatal rugae comparisons in 2004. Dental stone replicas were created after upper impressions were taken. A pencil was used to draw the rugae pattern, then castings were shot using a camera. The programme then processed the marked points. A dentist, a forensic odontologist, a computer engineer, and a physician were among the four observers who performed image matching against the collected records. The effectiveness of the software model evaluation was analyzed and use a criterion of 100 percent accurate fingerprinting. The forensic odontologist scored 97 percent right matches, while the computer programmer scored 93 percent, and the physician and dentist scored 92 percent. Because of the minimal inter observer error, this strategy was achievable. The authors stated that the high mistake rate might be attributable to the manual labour and time necessary in the digitising procedure; they also proposed using an intra-oral scanners.[73]

Physiology of rugae pattern

Physiological role of palatal rugae are; Rugae aids in speech, suction in infants and chewing food by developing friction surface to grasp the bolus in place and to

emulate food by intraepithelial sensory receptors.[17,22] With the exception of length, the palatal rugae pattern remains consistent throughout the life of man.[25] The array of palatal rugae vary in from individual to individual, in patients with drastic crowding and spacing the rugae pattern is altered from usual ones, after orthodontic treatment rugae marks changes because of firm forces applied and after orthognathic surgeries or in patients with habitual thumb sucking.[8] During development primary bony variations is revealed which show changes only in length of rugae pattern not in its shape and size.[17] Dentists frequently utilize them as a point of reference for assessing the degree of tooth movement. Forensic scientist, usually dentist use necro-identification technique in those cases where no fingerprints are available such as burned bodies, missing limbs and decomposed bodies.[17, 136]

Material and Methods

A Cross-Sectional Observational study.

Setting

The research will be completed at LUMHS Jamshoro/Hyderabad in the Department of Orthodontics.

Duration of Study

6 Months after approval of synopsis.

Sample size

The sample size for this study was generated using the Rao software sample size calculator, with error margin of 5%, a confidence interval of 95%, response distribution is 50%. The overall sample size will be 125; in an additional 10% more case will be recruited to accommodate possible incomplete participation of participants. Therefore, the final sample size for this study is 135 participants.[34]

Sample technique

Non-probability Convenience Sampling

Data collection procedure

After acceptance of synopsis from ethical review committee LUMHS, Jamshoro. Pre-treatment record of those patients who are receiving orthodontic treatment at LUMHS, Jamshoro meeting the inclusion criteria will be enrolled as study participants. Each participant will be informed about the study at the time of enrollment, and written consent will be collected. These participants will be divided into 3 groups according to Angle's Classification and their maxillary dental cast will assessed for rugae pattern. Rugae Pattern also be assessed in random patients coming to Orthodontics department to evaluate the difference in pattern design among individuals. For assessment of rugae, Maxillary impressions will be recorded using Alginate (irreversible hydrocolloid) impressions

then will be poured using dental stone. The direction of company will be monitored as the water/powder ratio along with proper spatulation. There should be no voids in the chosen cast, specially in front region of the hard palate. Rugae pattern on the study models was traced with a black graphite pencil in order to enhance the clarity of rugae pattern on the study casts. The assessment of palatal rugae pattern will be done using Thomas and Kotze classification.[49] The classification was based on length of rugae with primary>5mm, secondary 3-5mm and fragmentary <3mm in size. The rugae less than 2mm are disregarded. Rugae's length was calculated by using a Vernier Caliper to measure its greatest dimension, regardless of shape. The measurement on Vernier Caliper will be in millimeters scale. Based on these predominant shapes were curved (cresent shaped), straight (a straight line from origin to termination), wavy (slight curve at the origin or termination) and circular or round rugae (which forms a ring like structure). When two rugae are connected at their origin or end, it was believed that unification happened. Diverging occurs when two rugae share the same origin and branch out at the same time. Rugae with diverse origins from the midline converged laterally. The collected records will be evaluated for the statistical analysis. All the procedures will be done by me to reduce the bias.

Data analysis

Data will be stored in Microsoft office excel, (Microsoft corporation WA.USA) and transferred to EPI data3.1,EPI association for analysis. The data will be examined using the SPSS Version 23.0" computer software (IBM Corp, Armonk NY USA). The qualitative variable will be presented in form of frequency and percentage like age, gender, angle's classification, different types of mal-occlusion, rugae length and shapes of right and left side 1 to 7 rugae number, there mean, standard deviation and frequencies will be calculated. Post stratification Chi Square test (x^2) will be applied keeping up the value significant equal to or <than 0.05.

Table 1: Gender of Subject

Gender	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Male	38	28.1	28.1	28.1
Female	97	71.9	71.9	100.0
Total	135	100.0	100.0	

Table 1, shows the male and female distribution in 135 subject which were 28.14% male and 71.85% female i.e. 38 males and 97 females respectively

Table 2 Statistics for Gender, Angle's Classification and different types of mal-occlusions

		Gender of subject	Angle's Classification	Type Of Mal-occlusion
N	Valid	135	135	135
	Missing	0	0	0
Mean		1.7185	1.4444	1.6963
Median		2.0000	1.0000	2.0000

Mode	2.00	1.00	1.00[a]
Std. Deviation	.45140	.56867	.74587
Variance	.204	.323	.556
Range	1.00	2.00	3.00
Minimum	1.00	1.00	1.00
Maximum	2.00	3.00	4.00

Table 2, shows the detailed statistics for gender, angle's classification and different classes of mal-occlusion. The mean of gender is 1.7185 with standard deviation of 0.45140, mean of Angle's classification is 1.4444 with standard deviation of 0.56867, and mean for different classes of mal-occlusion is 1.6963 with standard deviation of 0.74587.

Table 3: Rugae pattern of right side

	Frequency	Percent	Valid Percent	Cumultative Percent	Mean	Std. Deviation
Rugae Pattern Right1						
Primary > 5mm	135	100.0	100.0	100.0	1.0000	0.00000
Rugae Pattern Right2						
Primary > 5mm	126	93.3	93.3	93.3		
Secondary 3-5mm	9	6.7	6.7	100.0		
Total	135	100.0	100.0		1.0667	0.25037
Rugae Pattern Right3						
Primary > 5mm	127	94.1	94.1	94.1		
Secondary 3-5mm	7	5.2	5.2	99.3		
Fragmentary < 3mm	1	0.7	0.7	100.0		
Total	135	100.0	100.0		1.0667	0.27859
Rugae Pattern Right4						
Primary > 5mm	110	81.5	81.5	81.5		
Secondary 3-5mm	25	18.5	18.5	100.0		
Total	135	100.0	100.0		1.1852	0.38989
Rugae Pattern Right5						
Primary > 5mm	78	57.8	57.8	69.6		
Secondary 3-5mm	39	28.9	28.9	98.5		
Fragmentary < 3mm	2	1.5	1.5	100.0		
00	16	11.9	11.9	11.9		
Total	135	100.0	100.0		1.2000	0.65563
Rugae Pattern Right6						
Primary > 5mm	18	13.3	13.3	13.3		
Secondary 3-5mm	19	14.1	14.1	27.4		

Fragmentary < 3mm	1	0.7	0.7	28.1		
Pattern not present	97	71.9	71.9	100.0		
Total	135	100.0	100.0		3.3111	1.14257
Rugae Pattern Right7						
Primary > 5mm	4	3.0	3.0	3.0		
Secondary 3-5mm	2	1.5	1.5	4.4		
Pattern not present	129	95.6	95.6	100.0		
Total	135	100.0	100.0		3.8815	0.56054

Right side

The rugae pattern of right 1 in 135 people is 100% primary, the rugae pattern of right 2 in 135 people is 93.3% primary, 6.7% secondary, the rugae pattern of right 3 in 135 people is 94.1% primary, 5.2% secondary, 0.7% fragmentary, the rugae pattern of right 4 in 135 people is 81.5% primary, 18.5% secondary, the rugae pattern of right 5 in 135 people is 57.8% primary, 28.9% secondary, 1.5% fragmentary and 11.9% are missing, the rugae pattern of right 6 in 135 people is 13.3% primary, 14.1% secondary, 0.7% fragmentary and 71.9% pattern not found, the rugae pattern of right 7 in 135 people is 3.7% primary, 1.5 secondary, 95.6% pattern not found showed with detailed description in Table 3

Table 4: Rugae Pattern of Left Side

	Frequency	Percent	Valid Percent	Cumultative Percent	Mean	Std. Deviation
Rugae Pattern Left 1						
Primary > 5mm	131	97.0	97.0	97.0		
Secondary	3	2.2	2.2	99.3		
Fragmentary	1	0.7	0.7	100.0		
Total	135	100.0	100.0		1.0444	0.29591
Rugae Pattern Left2						
Primary > 5mm	128	94.8	94.8	94.8		
Secondary 3-5mm	7	5.2	5.2	100.0		
Total	135	100.0	100.0		1.0519	.22255
Rugae Pattern Left3						
Primary > 5mm	124	91.9	91.9	91.9		
Secondary 3-5mm	10	7.4	7.4	99.3		
Fragmentary < 3mm	1	.7	.7	100.0		
Total	135	100.0	100.0		1.0889	.31067
Rugae Pattern Left4						
Primary > 5mm	106	78.5	78.5	79.3		
Secondary 3-5mm	28	20.7	20.7	20.7		
00	1	.7	.7	100.0		
Total	135	100.0	100.0		1.2000	.41967
Rugae Pattern Left5						
Primary > 5mm	82	60.7	60.7	66.7		
Secondary 3-5mm	44	32.6	32.6	99.3		

Fragmentary < 3mm	1	.7	.7	100.0		
00	8	5.9	5.9	5.9		
Total	135	100.0	100.0		1.2815	.58145
Rugae Pattern Left6						
Primary > 5mm	42	31.1	31.1	31.1		
Secondary 3-5mm	18	13.3	13.3	44.4		
Fragmentary < 3mm	2	1.5	1.5	45.9		
Pattern not present	73	54.1	54.1	100.0		
Total	135	100.0	100.0		2.7852	3.7481
Rugae Pattern Left7						
Primary > 5mm	9	6.7	6.7	6.7		
Secondary 3-5mm	3	2.2	2.2	8.9		
Fragmentary < 3mm	1	.7	.7	9.6		
Pattern not present	122	90.4	90.4	100.0		

Left side

The rugae pattern of left 1 in 135 people is 97.0% primary, 2.2% secondary, 0.7% fragmentary, the rugae pattern of left 2 in 135 people is 94.8% primary, 5.2% secondary, the rugae pattern of left 3 in 135 people is 91.9% primary, 7.4% secondary, 0.7% fragmentary, the rugae pattern of left 4 in 135 people is 78.5% primary, 20.7% secondary, 0.7% is missing, the rugae pattern of left 5 in 135 people is 60.7% primary, 32.6% secondary, 0.7% fragmentary and 5.9% missing, the rugae pattern of left 6 in 135 people is 31.1% primary, 13.3% secondary, 1.5% fragmentary, 54.1% pattern not found, the rugae pattern of left 7 in 135 people is 6.7% primary, 2.2% secondary, 0.7% fragmentary and 90.4% pattern not found, with detailed descriptions as showed in Table 4

Discussion

Palatal rugae doesn't alter over due to their location inside the mouth, in which they are protected from stress and high temperatures. Once generated, they only change in length as a result of normal growth. Stays in the same location for the remaining life.[135] The patterns of palatal rugae vary from person to person. Gender differences may exist, but a literature assessment reveals conflicting evidence across populations. Some studies have found no substantial changes in rugae pattern between male and female populations, whereas others have found considerable differences.[34]

In current research there were no significant differences between male and female groups in terms of the number, length and form of rugae whether primary, secondary, and fragmented rugae. Due to ethnic variation the difference may be found.[62] The present studies shows that primary rugae is most numerous in both genders, the shape of rugae; wavy and curved were found most common among other shapes. The right and left anterior three rugae were mostly primary which were more prominent than posterior rugae. The postrerior rugae were not prominent and secondary in length. The right and left 1 rugae was mostly found curved in shape the rest 2-7 was mostly wavy with variation in rugae 3, 5. The rugae number 6 and 7 was mostly found absent in individuals with variations

that some individuals contain all 1 to 7 rugae pattern. Kapoor et al,[62] reported contradictory results, that may be due to small sample size in their investigations and was unable to identify the alterations.

In 2017, Oral et al.[8] conducted a study on Turkish orthodontic patients with various anterio-posterior malocclusions to assess their rugae pattern. They looked at 105 maxillary castings from individuals who were classified into 3 categories on basis of mal-occlusions (Class-I, Class-II, Class-III). They discovered that wavy, curved rugae shapes were common, and that there was no substantial change in rugae pattern amongst skeletal groupings. This research discovered that there is no specific rugae pattern relationship between different types of mal-occlusion. As a result, extra procedures and equipment in identifying the palatal rugae pattern must be added to it in order to analyse the distinctions between palatal rugae among different classifications of mal-occlusion.[75] As shown in above Figures, the models of Class-I and Class-II div1 mal-occlusions. Mal-occlusion does not show any similarity between the rugae pattern and shapes.

There is a contrasting difference in rugae pattern of right side to the left side of rugae, number varies from 1 to 7 making the anterior 3 rugae more prominent than the posterior rugae, the Right and left 1,2,3,4 rugae are found mostly to be primary in length i.e. > 5mm the posterior 5,6,7 are mostly found to be secondary or fragmentary. The rugae number 6,7 are mostly not found in many individualsbut present in a few. The shape of rugae varies from 1 to 7, the right and left 1 are mostly found curved, the right and left 2,3,4 are found wavy, overall the most found rugae is wavy, sometimes the circular and unification rugae also found in anterior 1,2,3 rugae. The posterior 5,6,7 are found straight or wavy.

Limitation

1. Sample size is low.
2. The study does not include other factors such as arch form, crowding in upper arch, spaces in upper arch.
3. Dimensional evaluation of palatal rugae must be done for better accuracy and outcomes.

Conclusion

There are no statistically significant variations in rugae pattern between males and females.
The primary rugae length > 5mm is found to be most common than secondary and fragmentary.
The shape of rugae curved and wavy is found the most common among individuals.
The anterior rugae pattern is most prominent than the posterior and varies from 1 to 7 in number.

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