

A Sectional Study on the Useability and Reliability of Palatal Rugae in Identification Studies: The Case of Çorum Province

Palatal Rugaların Kimliklendirme Çalışmalarında Kullanılabilirliği ve Güvenilirliğine İlişkin Kesitsel Bir Çalışma: Çorum İli Örneği

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ABSTRACT Objective: To determine whether palatal rugae, which are defined as unique and personal characteristic like fingerprints, can be used for purposes such as age estimation and sex determination, palatal rugae were examined in terms of shape, location, direction and number in the sample of Çorum province. This study aimed to evaluate the reliability of the use of palatal ruga research articles as an additional and supportive method to forensic identification procedures.

Material and Methods: In the study, 200 maxilla models, 110 female and 90 male, aged 18-84 years, who applied to Çorum Oral and Dental Health Center for examination and treatment purposes were used. 1,416 palatal rugae in the maxillary jaw models were marked with an acetate pen and measured with a digital caliper with an accuracy of 0.01 mm. The evaluation of palatal ruga measurements included the direction, length, type, fusion patterns, and numbers of the rugae, using the Thomas and Kotze classification system. For shape/orientation assessments, the "Kapali Classification System" was employed. This study was carried out following the principles of the Declaration of Helsinki.

Results: A statistically significant negative relationship was detected between the number of palatal rugae and age in both male and female ($p < 0.05$). In the distribution of palatal rugae lengths by gender, it was determined that the most common measurement type in both genders was the "primary (<10 mm) type". **Conclusion:** Palatal rugae can be used as a supporting tool in age, gender, resurfacing studies, ethnicity research and forensic identification procedures.

ÖZET Amaç: Parmak izi gibi eşsiz ve kişiye özgü bir karakteristik olarak tanımlanan palatal rugalarının, yaş tahmini ve cinsiyet tayini gibi amaçlarla kullanılıp kullanılmayacağını saptamak üzere Çorum ili örneğinde palatal rugalar, şekil, yerleşim, yön ve sayı bakımından incelenmiştir. Bu çalışmada, adli kimliklendirme prosedürlerine ek ve destekleyici bir yöntem olarak palatal rugaların kullanımının güvenilirliğinin değerlendirilmesi amaçlanmıştır. **Gereç ve Yöntemler:** Çalışmada, muayene ve tedavi amaçları ile Çorum Ağız ve Diş Sağlığı Merkezine başvuran 18-84 yaş aralığındaki 110'u kadın 90'ı erkek olmak üzere 200 adet maksilla modeli kullanılmıştır. Maksiller çene modellerinde bulunan 1.416 palatal rugalar asetat kalemi ile işaretlenmiş, 0,01 mm hassasiyete sahip dijital kumpas vasıtasıyla ölçülmüştür. Palatal ruga ölçümlerinin değerlendirilmesinde rugaların yönü, uzunluğu, tipi, birleşme biçimleri ve sayıları Thomas ve Kotze sınıflandırma sistemi, şekil/yön değerlendirmelerinde ise "Kapalı sınıflandırma sistemi" kullanılmıştır. Bu çalışma Helsinki Deklarasyonu prensiplerine uygun olarak gerçekleştirilmiştir. **Bulgular:** Hem erkeklerde hem de kadınlarda palatal ruga sayısı ile yaş arasında istatistiksel olarak negatif yönlü anlamlı ilişki tespit edilmiştir ($p < 0,05$). Palatal ruga uzunluklarının cinsiyete göre dağılımında her iki cinsiyette de en yaygın ölçüm tipinin "birincil (<10 mm) tip" olduğu saptanmıştır. **Sonuç:** Palatal rugalar, yaş, cinsiyet, yeniden yüzeylendirme çalışmalarında, etnik köken araştırmalarında ve adli kimliklendirme işlemlerinde destekleyici bir araç olarak kullanılabilir.

Keywords: Palatal rugae; identification; palatoscopy; forensic odontology; forensic sciences

Anahtar Kelimeler: Palatal ruga; kimliklendirme; palatoskopi; adli odontoloji; adli bilimler

Forensic sciences use parameters such as dental records, DNA analysis, fingerprints and human bones to identify an individual. However, in severely

burned individuals and the absence of antemortem records, fingerprints cannot be used for identification.^{1,2}

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Therefore, alternative methods with low cost and high reliability can be used for identification. One of these alternative methods is rugoscopy (palatal rugoscopy) or palatoscopy, which is used in identification due to its low cost, simplicity and reliability. Rugoscopy is a method used for identification by examining the palatal rugae through upper jaw models.^{3,4} Palatal rugae, called ruga palatina and palatinae transverse, are symmetrical, irregular mucosal ridges or folds extending laterally from the palatal raphe located on the anterior 1/3 of the hard palate, behind the incisive papilla.

Palatal rugae, which are anatomically located in the inner part of the oral cavity and are formed in the 12th or 14th week of uterine life and are thought to remain constant throughout life from this time onwards, remain unchanged even in cases such as chemical burns, high temperatures, decay, trauma, tooth eruption and palate infections due to buccal and tongue oils.⁵ Therefore, they can play an important role in the identification of burnt corpses since they can withstand high temperatures compared to other skeletal remains in identification studies in forensic sciences.^{6,7}

Studies have been conducted in various fields in the past to investigate sexual dimorphism and biological differences. Therefore, features such as ethnicity, age and sex in identification should be examined and evaluated in different populations. Van der Linden argued that the length of the rugae changes after the age of 10 years and Harrison Allen argued that the length of the rugae changes during development and the shapes remain the same throughout life. Based on these two ideas, we think that the number of palatal rugae may decrease with age and the shape of the rugae may change with the effect of decreasing bone mineral density with age.⁸

FORENSIC ODONTOLOGY: HISTORY AND INVESTIGATIVE TECHNIQUES

Forensic odontology techniques are used in murder cases, sexual abuse, armed incidents, domestic violence, child abuse, bite marks, malpractice cases, chemical explosions, bioterrorism, radiological explosions, nuclear attacks, fire, work accidents, organized crime, terrorist incidents, natural disasters

public transportation accidents, oral cavity, dental anthropology. Documents that forensic odontologists use for personal identification; laboratory requests, molds, photographs, examination forms, dental radiographs or treatments provide information about dental profiling.⁹

Dental radiographs include impacted teeth, bridges, fillings, implants and root canal treatments.¹⁰ Radiological analysis can be used in religious appeals when an autopsy is not possible or prohibited due to ethical concerns (Figure 1).¹¹

Biting, a primitive type of attack, is associated with crimes such as violent fights, sexual offenses, animal attacks (dog, cat) and child abuse.¹³ Canine (rectangular/triangular), incisive (rectangular) and premolar or molar (point/spherical) teeth leave different scars on the skin due to their structure.¹⁴ Bite marks provide information about structural changes, restoration, treatments and distance/angle between teeth.¹⁵

Age determination in sub-adult (non-adult) individuals is based on the eruption times of deciduous teeth and the developmental stages of deciduous/permanent teeth. In adult individuals, evaluation is made by looking at pathological, morphological or biochemical changes in permanent teeth. In the mixed dentition period, age determination is made with standard scales related to the development of teeth.¹⁶

Teeth are also used in sex determination studies. It is known that the bucco-lingual width and mesio-distal dimension of the molar teeth of female are narrow. The teeth of male individuals are larger, bulky,

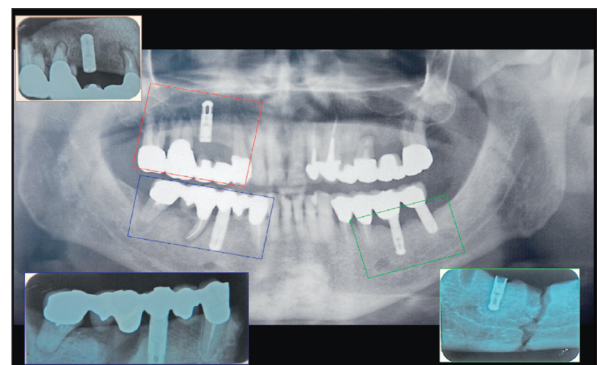


FIGURE 1: Comparison of post-mortem intraoral X-rays and ante-mortem orthopantomography.¹²

heavy and have prominent corners/edges. In females, the canine teeth are more prominent. There are differences in the lateral and central anterior teeth in the upper jaw in males and females. While the size difference between the lateral and central anterior teeth of the upper jaw is greater in females, it is less in males. The lower jaw is “U” shaped in females and “V” shaped in males. Sex determination based on dentition is difficult because it depends on tooth size and shape.¹⁷

Ethnicity is determined using serological, histological, radiological and biochemical methods. For example, the chisel-like shape of the front incisors and the carabelli tubercle belongs to the Caucasians. Midline diastema belongs to Negroids. While European and Asian individuals have protruding chins, Australian aborigines have retracted and rounded chins. Curved jaws are seen in Hawaiian individuals. The shovel-shaped front teeth seen in Indians and Asian Mongolians are one of the most distinctive features of the teeth.¹⁸

DNA ANALYSIS

DNA is an important source of information in identification because it can be preserved in bones and teeth for a very long time. DNA is obtained from teeth, oral mucosa cells and saliva. DNA is found in the pulp tissue, cementum, dentin, alveolar bone and periodontal ligament in oral data. Among these, pulp tissue is an excellent source of DNA due to the hard tissue of the teeth and its resistance to environmental conditions. Pulp tissue is a widely used option in DNA studies because it is not contaminated with non-human DNA and is more abundant than normal. Pulp tissue samples are collected in three ways: vertical or horizontal sections, crushing and endodontic. Ancient DNA studies are carried out by extracting small amounts of DNA remaining in ten- and hundred-thousand-year-old samples.¹⁹

This lip print classification; Type I: Vertical grooves with clear cuts that extend across the entire lip, Type I': Similar to Type I but do not cover the entire lip, Type II: Branched grooves, Type III: Intersecting grooves, Type IV: Reticular grooves, Type V: Not falling into any of the pattern are grooves (Figure 2).²⁰

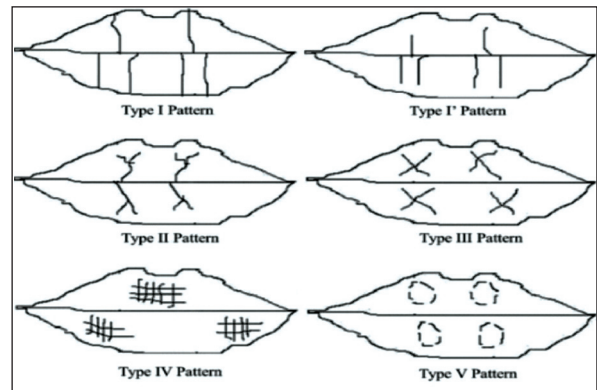


FIGURE 2: Suzuki and Tsuchihashi lip print classification.

In 1732, Winslow stated that palatal rugae shapes were unique and simple.²¹ In 1989, Harrison Allen suggested that palatal rugae could be used as an alternative method for personal identification. In 1932, the term “palatal rugoscopy” was coined by Trobo Hermosa, a Spanish researcher (Figure 3).²²

Some situations make identification difficult in human identification studies in forensic sciences. For example; nuclear explosions, fires, terrorist acts, vehicle accidents and situations where fingerprints cannot be taken. Therefore, in cases where reliable and scientific methods cannot be used in forensic identification, alternative methods are used. One of these alternative methods is the palatoscopy method. Reasons for using palatal rugae as an alternative method for post-mortem identification; It is resistant, stable and individual-specific.⁷

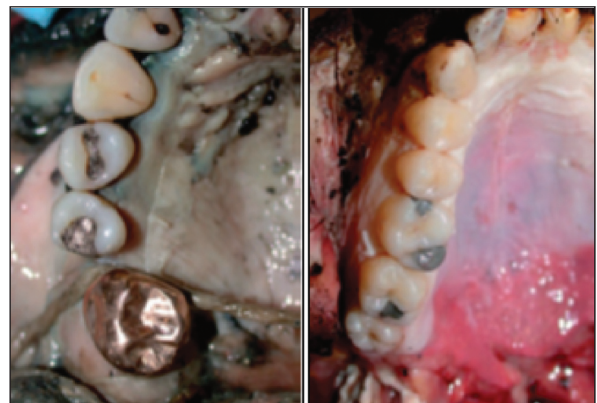


FIGURE 3: Restoration and palatal rugae (bomb explosion) and Palatal rugae (Fire).²³

MATERIAL AND METHODS

Our study was conducted on patients aged 18 and over who applied to Çorum Oral and Dental Health Center for treatment or examination, with the ethics committee permission dated November 05, 2020 and numbered 2020-120, obtained from the Hitit University Non-Interventional Clinical Research Ethics Committee. This study was carried out following the principles of the Declaration of Helsinki. Consent was obtained from the patients whose data were accessed through an informed consent form.

Study data were collected using IBM SPSS Statistics 27.0.1 (IBM Company, USA) program. Normality test, Cronbach alpha reliability analysis and Pearson correlation analyzes were applied to the study data and the relationships between the parameters were evaluated.

This study was conducted on a total of 200 individuals, 110 female and 90 male, aged 18-84. Those with congenital malformations of cleft lip and palate, those with physical and mental disabilities, those with bones or soft protrusions on the palate, those with a history of orthodontic treatment, those with deformities or scars, those with lesions on the palate, those using braces and those using partial dentures were not included in the study. Maxillary tooth models taken from patients who applied for a crown-bridge prosthesis with alginate impression material and prepared by casting hard plaster were used. Age and sex are written on the maxillary tooth models. Each maxillary cast model is randomly numbered from 1 to 200.

The palatal rugae on the upper jaw plaster models were marked with a fine-tipped felt-tip pen. Then, measurements were made with a digital caliper with 0.01 mm precision. Measurements were made clockwise using the medial line starting from the papilla incisiva and ending at the Raphe Palatini as reference. 1,416 palatal rugae models were evaluated on maxillary plaster models of 200 individuals in the Anthropology Department laboratory of Hitit University (Figure 4).

The shapes, locations, length measurements, numbers of palatal rugae, age, gender, rugae number, rugae measurement and type were recorded on forms.



FIGURE 4: Upper jaw models of 200 individuals (original photo).

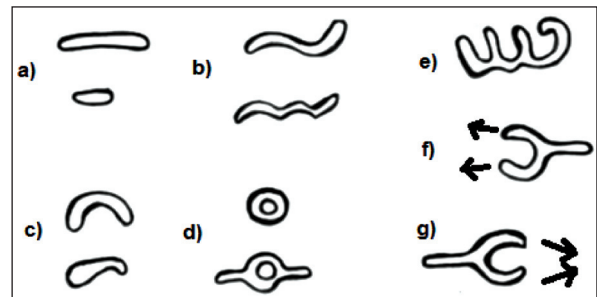


FIGURE 5: Schematic representation of palatal rugae patterns a) straight, b) wavy, c) curved, d) circular, e) nonspecific, f) divergent and g) converging.

Evaluation of rugae measurements was made with the Thomas and Kotze classification system. The direction/shape evaluation of the rugae was made with the Kapali classification system (Figure 5).

Thomas and Kotze's classification system (according to shape)

1. Linear/Flat: The patent leather should be straight from the starting point to the endpoint.
2. Circular: The shape of the patent leather is ring or circular.
3. Wavy: It is a wavy or curved palatal fold.
4. Curved: It is a curved rugae shape.
5. Unification: If two rugae start from the same starting point and then separate, they are "divergent". If two rugae start from different points and then merge, they are "convergent".

Rugular are evaluated in three types according to their length;

Primary rugae: Rugae length of 5 mm and above (>5 mm).

Secondary rugae: It is the rugae length between 3-5 mm.

Segmented rugae: Rugae length of 3 mm and below (<3 mm).²⁴

RESULTS

When we made a statistical evaluation of our data without discrimination of gender, the average age of a total of 200 individuals was 47.52, while the standard deviation was 14.16. When the standard deviation is taken into account, regardless of gender, it is understood that the ages are not very close to each other and deviations from the average are observed (the youngest age is 18, the oldest age is 84). The average of the rugae numbers of 200 individuals is 7.08. The standard deviation is shown in Table 1 as 1.84.

When 110 female and 90 male individuals in the sample group were evaluated, the average age of female was 46.5, while the average age of male was found to be 48.76. While the standard deviation of female individuals was 14.68, the standard deviation of male individuals was observed to be 13.43. In other words, the age distribution of male and female individuals in the sample group is close to each other. The mean number of rugae of female individuals is (7.1) and the standard deviation is (1.87). In male individuals, the mean number of rugae is (7.05) and the standard deviation is (1.81). The distribution of rugae numbers is quite close to each other. Table 2 shows the average values.

When the distribution of the number of rugae in male and female individuals is calculated, it is observed that they are very close to each other. Only four outliers were detected in male and female individuals. However, it is not affected because it represents a very small portion of the data. A maximum of

seven palatal rugae are seen in both male and female. Palatal rugae density varies between 6-8.

A statistically significant, negative, moderate relationship was detected between age and the number of rugae in the female group shown in Table 3 ($p < 0.05$). According to the correlation results, there is a weak, negative relationship between the number of rugae female have and their age.

A statistically significant, negative and moderate relationship was detected between age and the number of palatal rugae in the male individuals in the sample group ($p < 0.05$). This relationship is shown in Table 3. According to the correlation results, there is a non-negative relationship between the number of rugae in male individuals and age. In other words, the number of rugae decreases as age increases in male individuals, but it cannot be said that they affect each other much.

In Table 4, where male and female individuals were evaluated, a statistically significant negative moderate relationship was detected between age and the number of palatal rugae ($p < 0.05$). Negative relationships were detected in the analyzes carried out between both genders separately/together in the sample group and between age and rugae numbers. Rugae indicate that numbers decrease with aging. It is shown in Table 4 that there was no statistically significant relationship between the number of palatal rugae and sex ($p < 0.05$).

When we look at the distribution of palatal rugae types according to sex in Table 5, 32.34% of male individuals are linear, 28.65% are wavy, 24.39% are curved, 6.5% are oval and 5.91% are oval. 1 was the palatal rugae type that was separated and 2.21% was united. As for female individuals, 26.51% are linear, 34.87% are wavy, 23.03% are curved, 7.24% are oval, 6.94% are separated and 1.41% are It was ob-

TABLE 1: Average age and number of rugae.

	Number	Mean	SD	Minimum	Maximum
Age	200	47.52	14.16	18	84
Number of rugae	200	7.08	1.84	2	13

SD: Standard deviation.

served as a fused rugae type. While the “linear (32.34%)” palatal rugae type is more common in male individuals of the sample group, the “wavy (34.87%)” palatal rugae type is seen in female individuals. According to the rugae type and distribution between genders shown in Table 5, the “combined” palatal rugae type is the least common rugae type in both sex groups.

When the age distributions of the individuals in the sample group are calculated in detail, the age ranges of the rugae types are densely divided into “separated (34-56)”, “linear (36.25-57)”, “wavy (34-56)”, “curved (40-56)”, It is seen as “oval (30.5-53)” and “converging (33-51.75)”. When the palatal rugae

TABLE 2: Average values of the sample group.

		Male	Female
Age	Number	90	110
	Mean	48.76	46.50
	SD	13.43	14.68
	Minimum	18	18
	Maximum	84	80
Number of rugae	Number	90	110
	Mean	7.05	7.1
	SD	1.81	1.87
	Minimum	4	2
	Maximum	13	12

SD: Standard deviation.

TABLE 3: Correlation analysis between the number of rugae and age in both groups.

Age	Number of rugae	
Female	r value	-0.425*
	p value	0.006
Male	r value	-0.415
	p value	0.005

*p<0,05

TABLE 4: Correlation analysis between rugae numbers and general age and gender.

Both groups	Number of rugae	
Age	r value	-0.453**
	p value	0.000
Sex	r value	-0.12
	p value	0.866

**p<0,01

TABLE 5: Distribution of rugae types between genders.

Rugae type	Female	Male
Linear	26.51%	32.34%
Wavy	34.87%	28.65%
Curved	23.03%	24.39%
Oval	7.24%	6.5%
Diverging	6.94%	5.91%
Converging	1.41%	2.21%

TABLE 6: Distribution of palatal rugae measurement types between genders.

Rugae type	Female	Male
Primary (<10 mm)	85.58%	75.19%
Secunder (3-5 mm)	10.16%	9.57%
Partially (<3 mm)	4.26%	15.24%

lengths of the individuals in the sample group are examined according to gender, the most common measurement type in both sex groups is seen as the “primary (<10 mm)” rugae type. The primary rugae measurement type is 85.58 in female individuals. In male individuals, it is seen as 75.19%. While the least common rugae measurement type in female individuals in the sample was partial (4.26%), the least common measurement type in male individuals was secondary (59.57%). The primary type of measurement seen in female individuals is evidence of the presence of wavy and linear rugae type. The evidence of the presence of wavy and linear rugae types in male individuals is an indication that they have the primary rugae measurement type. The distribution of palatal rugae measurement types between genders is shown in Table 6.

DISCUSSION

It is emphasized that forensic identification of people is legally important in natural disasters, tsunamis, plane crashes, traffic accidents, nuclear, chemical and bomb explosions, ethnic origin research and judicial investigations.²⁵ In such events where mass deaths occur, it is not possible to visually identify burned and dismembered corpses.²⁶ Techniques such as dental records, fingerprints and DNA imprints are con-

sidered the most reliable, fast and common methods of identification.²⁷ Apart from these techniques, alternative methods are used in forensic sciences. Methods such as lip print and palatal rugoscopy are little-known alternative methods. Palatal rugoscopy is the process of determining human identity by examining the palatal folds inside the mouth. Human palatal rugae, unlike other animals, are unique, asymmetrical, subject to classification and invariance.^{28,29}

The resistance of the palatal rugae to changes such as trauma, aging, chemical injury and diseases due to its protected position by its anatomical structures is used as an ideal method for determining human identity.³⁰

The morphological structure of the palatal rugae of 105 Turkish orthodontic patients (over 10 and 35 years of age) with different sagittal malocclusions was evaluated. The number of palatal rugae, patterns, direction and incisor papilla shape of the subjects in this sample group were analyzed. The most common type of palatal rugae was wavy. The number of primary and secondary rugae on the right and left sides of the subjects' palate was not statistically significant among different sagittal malocclusions. Horizontal palatal rugae were abundant.³¹ In the Çorum sample, male individuals have a linear type and female individuals have a winged rugae type. Primary palatal rugae measurement type is commonly seen in male and female individuals in the Çorum sample. In this study, secondary and primary rugae measurement types were common. Segmented and secondary rugae forms were more common in the Nepalese population compared to the Indian population. In the Indian population, palatal rugae were more abundant on the right side of the palate. In the Nepalese population, the number of palatal rugae was higher on the left side. The shape of palatal rugae varies significantly in Nepalese and Indian populations.³² While the primary rugae measurement type is common in male and female individuals in the Çorum sample, segmented and secondary rugae measurement types are common in the Nepalese population.

Morphological models of palatal rugae were determined through the maxillary measurement models of a sample group of 100 (50 female and 50 male) students from the dentistry department at Omdurman

Sudan University of Science and Technology. Female have more rugae than male. On the right side of the palate, the flat rugae type is more common in female. In males, the wavy rugae type is more common. The curved rugae type on the left side is common in female individuals. The most dominant rugae type in male and female individuals is winged and flat. The least common type is circular rugae. This study shows that there is a distinction between the individuality of palatal patent leather. Analysis of the number, shape and length of rugae showed that there were statistically significant differences in male and female individuals. It has been observed that it is a tool to be used to distinguish between male and female individuals.³³ It was understood that the number of palatal rugae was high in female individuals in this study and the Çorum sample. It has been noted that there are significant differences in sex prediction. In our study, it was stated that there was no significant difference.

It was aimed to determine the sex differences in the number, length and type of rugae patterns by randomly selecting 50 subjects (25 female and 25 male) between the ages of 30-50 from the patients coming to Sığgah Dental Hospital. The average rugae length in male individuals was longer than in female individuals and was statistically significant. The flat rugae type is more common in female individuals than in male individuals. Parameters such as rugae shape and length showed significant differences in male and female individuals. Therefore, is an important tool in sex identification. Although there was no statistically significant difference in the number of rugae between male and female individuals, it was found that female individuals had fewer palatal rugae.³⁴ In this study, while the straight rugae type was common in female individuals, the linear rugae type was common in male individuals in the Çorum sample. Although it was determined that there was no statistically significant relationship between the number of rugae and sex in the Çorum sample, the number of rugae was higher in female.

CONCLUSION

As a result, the main determinant in the formation of the length and shape of the palatal rugae is genetics. Regional variations and environmental factors play a

minimal role. Differences in the average number of rugae between populations are known to be both quantitatively and qualitatively related. A palatal fold can provide practical evidence as it targets specific populations in terms of size, shape, direction and number. Post-mortem and ante-mortem rugae information (number, size and pattern), records of dental restorations and malocclusions facilitate the identification of individuals in forensic investigations. Therefore, studies on the number, direction, shape and size of rugae should be conducted in large samples consisting of individuals from different groups and different ethnic backgrounds within similar populations. If different rugae patterns are encountered, they should also be classified. In case the number of rugae decreases due to aging, it should be evaluated in larger sample groups. Palatal folds are used as support in age determination in identification studies; We think that it can be used as an additional tool with basic procedures in ethnicity and reconstruction studies.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Fırat Koç; **Design:** Fırat Koç; **Control/Supervision:** Vahdet Özkoçak, Fırat Koç; **Data Collection and/or Processing:** Sema İşler, Fırat Koç; **Analysis and/or Interpretation:** Fırat Koç, Vahdet Özkoçak; **Literature Review:** Sema İşler, Fırat Koç; **Writing the Article:** Sema İşler, Fırat Koç, Vahdet Özkoçak; **Critical Review:** Fırat Koç, Vahdet Özkoçak; **References and Fundings:** Fırat Koç; **Materials:** Sema İşler.

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