Revista Contexto & Saúde
Editora Unijuí
Programa de Pós-Graduação em Atenção Integral à Saúde
ISSN 2176-7114 – v. 24, n. 48, 2024
http://dx.doi.org/10.21527/2176-7114.2024.48.13525

HOW TO CITE:
Araújo MM, de Oliveira X, de Freitas RAC, Marques JAM, Musse J de O. Three-dimensional analysis of palate roughness as a biometric identification tool . Rev. Contexto & Saúde, 2024;24(48): e13525

ORIGINAL ARTICLE

Three-Dimensional Analysis of Palate Roughness as a Biometric Identification Tool

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Highlights:
(1)The three-dimensional analysis of palatal roughness is a methodological proposal applicable to human identification processes.
(2) The three techniques used in the analysis of palatal rugae were not sufficient for human identification when used in isolation.
(3) The individual code generated by the association of the three methods proved to be unique for each model used, proving the applicability of the three-dimensional analysis of palatal wrinkles for human identification.

ABSTRACT

Palatal wrinkles are elevations of the oral mucosa that cover the palatine process and are located on the maxillary bone. Because its anatomy is immutable and unique to each individual, the method of human identification using palatal wrinkles has a lot of potential to become indisputable. Currently, with the incorporation of new technologies in dentistry, three-dimensional analysis of palatal wrinkles using scans has become a reality. The aim of this study was to analyze the applicability of three-dimensional analysis of palatal wrinkles for human identification, through the observation of 3D images resulting from digital scanning. This is an experimental study with a qualitative-quantitative approach, whose sample consisted of the scanning of 50 plaster models, where three-dimensional images were generated, the classifications used were with the techniques of Silva (1938), Carrea, (1937) and Basauri (1961). The 3D scanning was done by a software system from the Zirkonzahn company, using the s600 arti scanner, and the wrinkle analysis was carried out by the Meshmixer program. When used separately, the techniques were not sufficient for individual human identification. However, the individual code generated by combining the three methods proved to be unique for each model used. Thus, the results obtained proved the applicability of three-dimensional analysis of palatal wrinkles for human identification.

KEYWORDS: Human Identification, Hard Palate, Forensic Odontology

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1. INTRODUCTION

The purpose of human identification is to reveal the identity of a body. It can be carried out on both living and post-mortem individuals, in a wide variety of conditions (preserved, decomposing, charred, dismembered, mutilated and fragmented). It is carried out by trained technicians or professionals with differentiated and specific knowledge, and consists of comparing characters, looking for coincidences between previously recorded data and that obtained in the present[1].

In forensic anthropology, one of the most difficult tasks is human identification, which can be carried out using fingerprints, DNA comparisons and dental information [2].

The materials currently used to apply the dental arch identification technique are the documents produced during dental care, which generally consist of radiographs, dental records, plaster models and photographs[3], and the examination is carried out in three stages: examination of the cadaver's dental arches, examination of the suspect's dental documents and comparison, with the dental expert reaching a conclusion about the individual's identity.

If plaster models or digitized images of palatal rugoscopy are available, their detailed analysis can also be used as a parameter for comparison, since palatal wrinkles are unique and do not change even after morphological alterations, orthodontic and surgical treatments in the palate region, and can resist decomposition after death for up to seven days[1].

Due to the immutable and unique anatomy of each individual, the method of human identification using palatal wrinkles has the potential to become indisputable. Its study as a method of individual identification was first mentioned by Lopes de Léon in 1924, inspired by Vucetich. From then on, research began into palatal wrinkles and the quickest and safest ways of identifying people using them, with various classification systems being proposed, such as Carrea, Silva, Martins dos Santos, Basauri, Thomas and Kotze, among others[4-5].

Currently, with the incorporation of new technologies in dentistry, the imaging of dental arches from intraoral scanning has become a reality[6].

According to Souza[7], With the use of scanning, it is possible to reproduce the dental arch and analyze it in an average of 10 minutes. It is a fast and reliable method, which normally does not require repetition, providing a safe method of comparing the arches to be analyzed, since it does not alter the shape like traditional molding.

With the increasing use of technology, digital dentistry is a reality and is being used more and more[5]. Considering its possible applicability for human identification through palatal wrinkles, this study aimed to analyze the applicability of three-dimensional analysis of palatal wrinkles for human identification, based on images resulting from 3D scanning.

2. METHODOLOGY

This is an experimental study with a qualitative and quantitative approach, which analyzed the applicability of palatal wrinkles as a method of human identification through three-dimensional images. The methods for classifying palatal wrinkles defined by Carrea [8] were adopted as categorical variables, Silva[9] and Bassauri[10].

A pilot study was carried out beforehand in order to calibrate the researchers, test the data collection methods and the program, and this stage was analyzed by calculating the intraclass correlation coefficient.

Data was collected by undergraduate dentistry students from the Feira de Santana Higher Education Unit (UNEF). The data obtained was analyzed by a pair of observer-researchers, who classified the palatal roughness using three-dimensional images.

Fifty plaster models, 25 female and 25 male, were scanned using a software system from the Zirkonzahn company, using the s600 arti scanner, thus generating files in STL format. Data analysis was carried out using Meshmixer, a free software program used for editing 3D meshes (Figure 1).

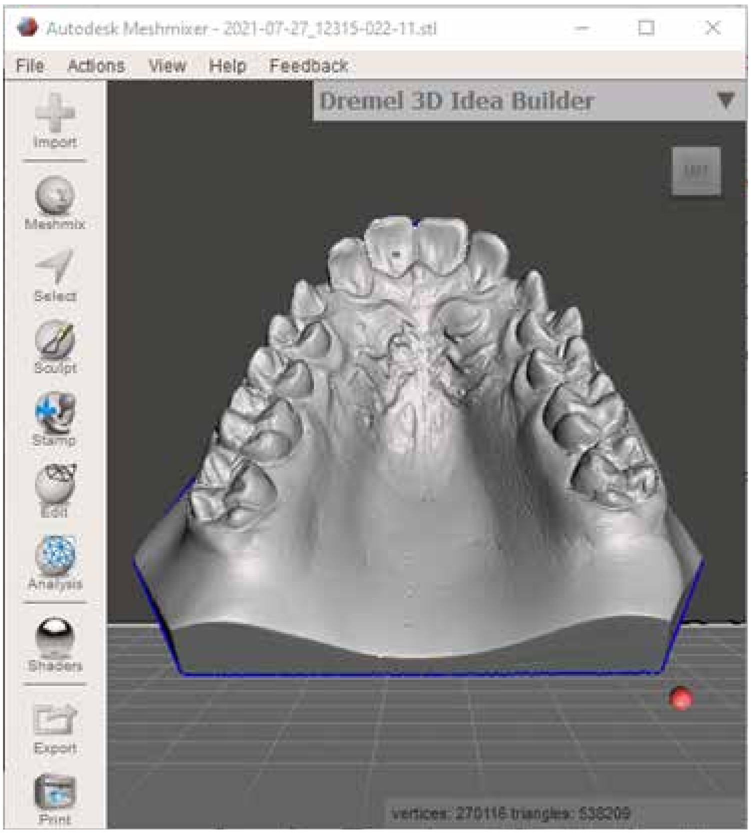

Figure 1- Three-dimensional image of palatal wrinkles.

The images of the upper models were made available on a pen drive and analyzed according to the classifications of Carrea[8], Silva[9] and Bassauri[10]. The data was recorded on a specific form, already validated in a previous study by the researcher responsible for this project, using the plaster model and not the 3D image.

The Carrea[8] Method, was used to delineate palatal roughness by dividing the wrinkles into right and left, separating them by a vertical line up to the incisive papilla. Based on the bilateral direction, the wrinkles were analyzed under four circumstances: wrinkles that converge on the palatine raphe in the posteroanterior direction were type I, those located horizontally and perpendicular to the palatine raphe were type II and wrinkles that are directed anteroposteriorly and converge on the palatine raphe were type III. Finally, those in different directions were classified as type IV (Figure 2).

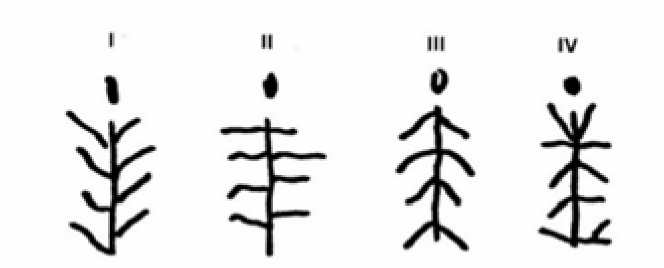

Figure 2. Classification proposed by Carrea (1937) Source: FONSECA, FLÓREZ (2009)[11].

In Silva's[9], method, wrinkles were analyzed individually, adopting the following conformation: type 1: straight; type 2: curved; type 3: angled; type 4: circular; type 5: sinuous, type 6: dotted and compound "Y", cup, racket or branched wrinkles. Wrinkles smaller than two millimeters were disregarded. The method ends with the sum of the wrinkles, according to the quantity of each conformation (Figure 3).

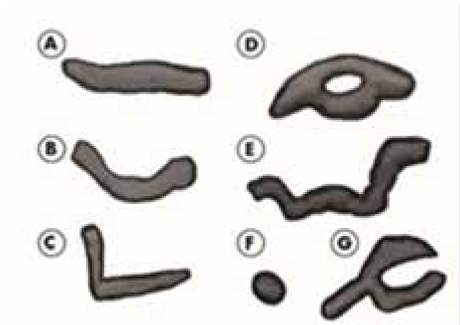

Figure 3. Silva's classification (1938).

Source: CASTRO-SILVA, SILVA E VEIGA (2014)[12].

The Bassauri[10] Method analyzes the shape of the palatal wrinkles. The main wrinkle, located more anteriorly, was classified with capital letters (A, B, C, D, E, F, X) and the accessory wrinkles with numbers (1, 2, 3, 4, 5, 6, 7), thus allowing classification into more than one type and on both sides of each impression (Chart 2).

Table 2. Classification system proposed by Basauri.

Main wrinkle	Accessory wrinkle	Anatomy
A	1	Point
B	2	Line
C	3	Angle
D	4	Sinuous
E	5	Curve
F	6	Circle
X	7	Polymorphic

Source: Tornavoi, Silva[13].

At the end of the analysis and classification of all the 3D images, an electronic table was drawn up with the information on palatal roughness in the Excel program (Office 2010, Microsoft Corporation, Redmond, Washington, USA), showing the quantitative values of the palatal wrinkles. Three methods were applied with individualized codes in order to prove the uniqueness of the palatal wrinkles.

The study complies with National Health Council Resolution No. 466/12, which regulates ethics in research involving human beings, and was approved by the research ethics committee of the State University of Feira de Santana, under CAAE 37278920.2.0000.0053.

3. RESULTS

Carrea's[8] method found a predominance of type IV wrinkles (36%), followed by type II (34%) and type III (28%). Type I (2%) was the least common type of wrinkle found in this study's total group.

Table 3. Evaluation of palatal roughness according to Carrea's method (1937), Feira de Santana, Bahia, Brazil, 2021.

Classification Frequency Percentage	Frequency	Percentage
I	**1**	**2,0**
II	**17**	**34,0**
III	**14**	**28,0**
IV	**18**	**36,0**
Total	**50**	**100,0**

Morfotipos Silva's[9] rugoscopic classification is based on numerical morphotypes that define palatal roughness (type 1: straight; type 2: curved; type 3: angular; type 4: circular; type 5: sinuous; type 6: point and type 7: compound), with the sum of wrinkles ranging from simple to compound. This type of analysis found values ranging from 16 to 57, with an average of 32.4 (Chart 4).

Table 4. Evaluation of palatal roughness according to Silva's[9] method. Feira de Santana, Bahia, Brazil, 2021.

Measurements	Values
Average	32,4
Minimumm	16
Maximum	57

According to the analysis of palatal wrinkles using the Basauri[10] method, shown in Table 5, the wrinkles were classified according to their morphotypes. In this method, two models were classified as LDE44424LEF524522 and two others as LDX2421LED245.

Table 5. Evaluation of palatal roughness according to the Basauri[10] method, Feira de Santana, Bahia, Brazil, 2021.

Classification	Frequency	Percentage
LDB15554LEE24552	1	2,0
LDB242LEB224	1	2,0
LDB252LEB4455	1	2,0
LDB4445LEX442	1	2,0
LDB44554LEX7432	1	2,0

LDB4544LEB425244	1	2,0
LDB7525LEE422	1	2,0
LDC444LEC44222	1	2,0
LDD224LED442	1	2,0
LDD452LEF74	1	2,0
LDD5445LEE7432	1	2,0
LDE14522LEE7544	1	2,0
LDE2252555LEE444	1	2,0
LDE2414LEE4445	1	2,0
LDE244LED245	1	2,0
LDE24532LEE24423	1	2,0
LDE24544LEF24	1	2,0
LDE25424LEE222	1	2,0
LDE25455LEX145	1	2,0
LDE4144LEX4117	1	2,0
LDE436LEB45152	1	2,0
LDE44424LEF524522	**2**	**4,0**
LDE44444LEE4445	1	2,0
LDE45252LEE2545	1	2,0
LDE452LEE5445	1	2,0
LDE542LEE24	1	2,0
LDE5445LEE2534	1	2,0
LDE732LEX44	1	2,0
LDE741LEF444	1	2,0
LDE74LEX4	1	2,0
LDEX754LEX2427	1	2,0
LDF532LEX143	1	2,0
LDX21444ÇLEX24444	1	2,0
LDX22LEF27	1	2,0
LDX2421LED245	**2**	**4,0**
LDX2445LEX42122	1	2,0
LDX254LEB545	1	2,0
LDX25LEF545	1	2,0
LDX314LED442	1	2,0
LDX4142LEX457	1	2,0
LDX414LEX5445	1	2,0
LDX434LED7445	1	2,0
LDX44LEX44	1	2,0
LDX454LEX424	1	2,0
LDX4LEE242	1	2,0
LDX52LEF5	1	2,0
LDX52LEX54	1	2,0
LDX5434LEX474	1	2,0
Total	50	100,0

The combination of the three methods generated an individual code (Chart 6) for each model used, proving the uniqueness of the palatal wrinkles.

Table 6. Evaluation of individual code units, Feira de Santana, Bahia, Brazil, 2021.

Code	Frequency	Percentage
I23LDE45252LEE2545	1	2,0
II16LDB242LEB224	1	2,0
II20LDB252LEB4455	1	2,0
II21LDE25424LEE222	1	2,0
II22LDB7525LEE422	1	2,0
II23LDX25LEF545	1	2,0
II25LDX254LEB545	1	2,0
II28LDD224LED442	1	2,0
II30LDE2252555LEE444	1	2,0
II30LDE24544LEF24	1	2,0
II31LDE436LEB45152	1	2,0
II32LDX2421LED245	1	2,0
II33LDB44554LEX7432	1	2,0
II34LDC444LEC44222	1	2,0
II36LDB4445LEX442	1	2,0
II37LDX314LED442	1	2,0
II37LDX454LEX424	1	2,0
II39LDE25455LEX145	1	2,0
II54LDE4144LEX4117	1	2,0
III18LDE542LEE24	1	2,0
III21LDX22LEF27	1	2,0
III21LDX52LEF5	1	2,0
III26LDE452LEE5445	1	2,0
III26LDE74LEX4	1	2,0
III27LDE732LEX44	1	2,0
III29LDD452LEF74	1	2,0
III31LDB15554LEE24552	1	2,0
III35LDD5445LEE7432	1	2,0
III44LDX434LED7445	1	2,0
III45LDX4142LEX457	1	2,0
III46LDX5434LEX474	1	2,0
III47LDX414LEX5445	1	2,0
IV21LDX4LEE242	1	2,0
IV24LDX52LEX54	1	2,0
IV26LDE244LED245	1	2,0
IV29LDE5445LEE2534	1	2,0
IV31LDF532LEX143	1	2,0
IV32LDE741LEF444	1	2,0
IV33LDX2421LED245	1	2,0
IV34LDE24532LEE24423	1	2,0
IV34LDE44424LEF524522	1	2,0

IV34LDX44LEX44	1	2,0
IV35LDE44424LEF524522	1	2,0
IV38LDB4544LEB425244	1	2,0
IV38LDE14522LEE7544	1	2,0
IV38LDE2414LEE4445	1	2,0
IV41LDX2445LEX42122	1	2,0
IV42LDEX754LEX2427	1	2,0
IV46LDE44444LEE4445	1	2,0
IV57LDX21444ÇLEX24444	1	2,0
Total	50	100,0

5. DISCUSSION

This study used the method of human identification by palatal wrinkles, respecting their biological and anatomical aspects for an accurate and coherent analysis. According to Brígido[2], wrinkles remain stable throughout life, undergoing only a few changes in position and length, triggered by the natural development of the individual.

In view of the diversity of methods for analyzing palatal wrinkles, it is necessary to validate and standardize their use. Thus, for surveys to be reliable, it is essential to have methodological rigor so that the data can be reproduced legitimately and reliably. In this sense, Andrade[14] affirms that intra-examiner and extra-examiner agreement is an important process for reducing errors in surveys. Influencing the accuracy of data collection.

For this reason, intra-examiner calibration was carried out in this study, obtaining an intraclass correlation coefficient considered by McBride[15] to be almost perfect, with a value of 0.9985.

A study carried out by Veloso[4], using Carrea's[8] method on palatal wrinkles in monozygotic twins in the city of João Pessoa/PB, found that the twins had between 8 and 14 wrinkles, with type IV wrinkles prevailing. The most common form of wrinkle was the sinuous type.

Castro-Silva, Silva and Veiga[12] carried out a study in Niterói-RJ, in 2013, with the aim of assessing the effectiveness of palatal rugoscopy as a human identification technique, using 184 plaster models and applying Carrea's[8] method. It was observed that the individuals had a higher prevalence of type IV. These data were similar to the present study, where there was a higher prevalence of type IV wrinkles, which were found in 36% of the models analyzed, followed by type II (34%). Type I was the least common (2%).

España et al.[16] carried out a data storage study using the method proposed by Silva[9] on a sample of 20 firefighters from the University of Los Andes Mérida in Venezuela. The study models were analyzed to create a database with individualized palatal wrinkle characteristics for each of the firefighters analyzed. The study showed an average of 13 wrinkles for each individual. This fact, however, is different to that found in this study, with an average of 32.4 wrinkles per individual, a higher average than the result presented by España.

Arone et al.[17] analyzed the characteristics of palatal wrinkles at the UNSAAC dental clinic in Cusco, Peru, using the Basauri[10] identification technique. An analysis was carried out on 62 study models and intraoral photographs obtained from 28 men and 34 women. The aim of the study was to identify the individuals using Basauri's classification. Each individual generated a unique identification code, confirming the individuality of the wrinkles. This study, however, showed a different result. In the Basauri[10] technique, there were two situations in which the classifications were repeated with the code LDE44424LEF524522 and LDX2421LED245, contradicting the result found by Arone and Eliceni[17], confirming that the Basauri technique alone is not sufficient for identification. The combination of the techniques proposed by Carrea[8], Silva[9] and Basauri[10] generated a unique code for each individual, proving uniqueness.

According to Oliveira and Marques[18] with the current use of digital technology, it is possible to analyze palatal wrinkles through 3D scanning, which gives us precise quality in three-dimensional images. Scanning is a non-invasive, fast, reliable and high-resolution method that makes it possible to obtain a copy of models and the human dental arch in any state. Cardoso et al.[19] state that, although traditional molding is more commonly used in dental offices, it is known that the plaster model can cause alterations if it is not stored correctly, making the impressions obtained inadequate for a possible comparison of images at the time of human identification.

For this reason, this research opted for 3D scanning, because according to Pagano[20] they state that digital information has brought us a great advantage, making the work faster, reducing the chance of error and generating quality images. In addition, they allow us to easily change the file as many times as necessary to simulate different angles and situations.

Studies are currently being carried out on the use of 3D scanners to assess palatal roughness. According to Oliveira and Marques[18], CAD/CAM has become increasingly used as a tool in dentistry, being used to print these models and has been used for research due to its ease of handling and the quality of the three-dimensional images.

According to Cechelero, Bellan and Bisi[21] the material used for molding considered to be the gold standard is elastomer and even then it has disadvantages when compared to scanning, such as: distortions related to molding, execution time, material costs, patient discomfort, the need to disinfect the trays and the operator-dependent technique. Digital scanning is a technique that has been reported to be faster and more convenient for both the patient and the dentist, with digital impressions being more accurate and superior to traditional impressions, according to the literature.

Therefore, according to Souza[7], three-dimensional images are, in fact, a reality in dentistry and have been used in several areas, including prosthodontics, implantology, dentistry, orthodontics, endodontics, orthognathic surgery, and now in forensic dentistry, helping with human identification through palatal wrinkles.

It's worth noting that although these anatomical structures meet the biological and technical requirements that make them important in forensic investigations, such as stability, durability, uniqueness, practicality and classifiability, the diversity of classification alternatives makes them controversial in terms of their reliability. For this reason, it is suggested that different forms of classification be combined, as was done in this study.

6. CONCLUSION

The three-dimensional analysis of palatine wrinkles is a useful method that can be applied in Official Forensic Institutes. The combination of the three classification methods used in this study proved the uniqueness of palatal wrinkles.

The scanner proved effective in classifying wrinkles, simplifying and facilitating the process. It was possible to move the plaster models 360°, zoom in and zoom out without distortions and alterations, allowing the details of each wrinkle to be visualized and classified according to the proposed methods.

In this way, the technique of human identification through the analysis of palatal wrinkles using 3D scanning becomes an effective method with a lot of potential to be introduced into the routine of forensic odontology

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Submitted: July 30, 2022
Accepted: August 24, 2023
Published: February 23, 2024

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Xaiane de Oliveira: Conceptualization; Methodology; Resources.

Ricardo Almeida Caribé de Freitas: Methodology; Software; Validation; Visualization; Writing – original draft.

Jeidson Antônio Morais Marques: Conceptualization; Data curation; Formal analysis; Supervision; Writing – original draft; Writing – review & editing.

Jamilly de Oliveira Musse: Conceptualization; Data curation; Formal analysis; Project administration; Supervision; Writing – original draft; Writing – review & editing.

All authors have approved the final version of the text.

Conflict of interest: There are no conflicts of interest.

Financing: Does not have financing.

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