Electronic palatal rugae impression: a potentially relevant technology in personal identification

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Article history

Abstract

Forensic medicine is now able to identify people through lots of different systems. Actually, fingerprints identification is the most used identification method. To avoid identifying, many people alter or erase their fingerprints through chemical and / or abrasive systems. The study of palatal rugae (palatoscopy) is an identification technique today accepted by the international scientific community as an alternative, safe and effective identification system, because of their characteristic feature of immutability and individuality. Currently, the most used procedure is dental impression through plaster casts or photographs. The difficulties in the recording and cast's storage limited the use of this identification system in comparison with others techniques. In order to improve the palatal rugae analysis system, we designed a software, connected to a camera device that allows to acquire the palatal impression, to easily identify the salient palatal features and to store them in a database. This would permit a fast, simple and economic recognition method that could be used without the need of specific staff training and that could easily be integrated with the existing fingerprint identification systems.

Introduction

Biometrics (from the Greek words bios = "life" and metros = "count" or "measure") measures physiological or behavioral variables of some organisms, through mathematical and statistical methods, which are compared with data previously acquired and incorporated in a database, through of algorithms and data acquisition sensors. Fingerprints identification is a biometric system based on two key principles: *immutability* and *individuality*. Fingerprints formed definitively in the fetus on the seventh month and they do not change for a lifetime. Fingerprint surgery change is almost impossible in fact a doctor would recognize the scars or the attempted fingerprint alteration easily [1].

Computerized systems which allow the acquisition and comparison of fingerprints data, such as AFIS (Automatic Fingerprint Identification System), despite being at present the most common method for individual

identification, is not the only available biometric system [2].

Palatoscopy, and in particular rugoscopy, studies the shape, size and position of the palatal rugae, in order to advance in human identification [Fig. 1-5].
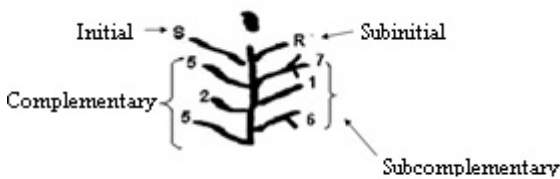

Figure 1. Palatal rugae according to Martins dos Santos Initial rugae: It is represented by a capital letter; it is the most anterior ruga on the right side. Complementary rugae: the other right rugae, they are represented by numbers. Subinitial rugae: It is represented by a capital letter; it is the most anterior ruga on the left side. Subcomplementary rugae: the other left rugae, they are represented by numbers [18].
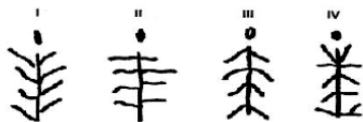

Figure 2. Palatal rugae classification according to Carrera in 1937 [18] I: Posterior-anterior directed rugae; II: Rugae perpendicular to the median raphae; III: Anterior-posterior directed rugae; IV: Rugae directed in several directions.
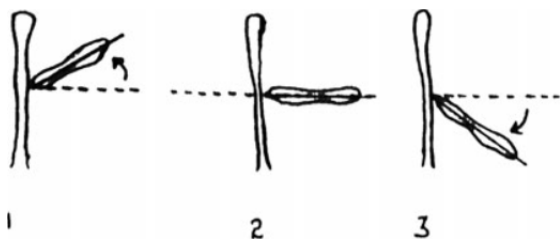

Figure 3. Primary palatal rugae direction: 1. forward directed, 2. perpendicular, 3. backward directed [13]. Primary palatal rugae direction measures the angle between the line perpendicular to the median raphae and the line joining the beginning and the end of the rugae.
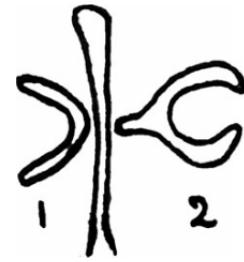

Figure 4. Unification: 1. Diverging: rugae with the same origin but immediately diverged; 2.Converging: rugae with different origins which joined on their lateral portions [13].
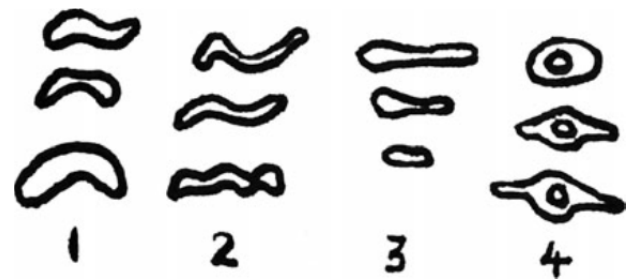
Figure 5: Rugae shapes according to Thomas e Kotze: 1. Curved, 2. Wavy, 3. Straight, 4. Circular [13].

Actually, the dental impression identification method is the most used method by investigators, mainly for the ante-mortem and post-mortem comparison; these systems are ineffective if, for example, the subject has no teeth [3].

Figure 6. Overlay of ante-mortem and post-mortem dental impression [3]

These findings underline the palatoscopy significance; with this system we can get the design of the palatine folds directly from the palate.

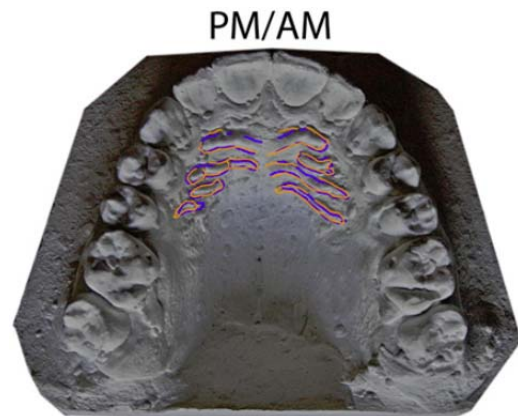Since they formed, in the third pregnancy month, the rugae only change in their size due to the normal growth and development of the palate.

On the biometrics point of view, the palatal rugae met all the characteristics mentioned for fingerprints, such as immutability, permanence, low cost, thus supporting their use in forensic identification [3-7].

Some factors limiting the use of rugoscopy information are the recording and storage methods (actually through plaster casts or photographs) and comparison techniques [3,4,5,8].

Considering the recognized palatoscopy validity in certifying, univocally, the individual identity and the difficulties in data treatment and storage, with this paper, we propose a software, with a camera device. It allows to acquire the palatal impression, to identify the salient palatal features and to store them in a database. This would permit a fast, simple and economic recognition method that could be used not only by expert researcher, but also by the police.
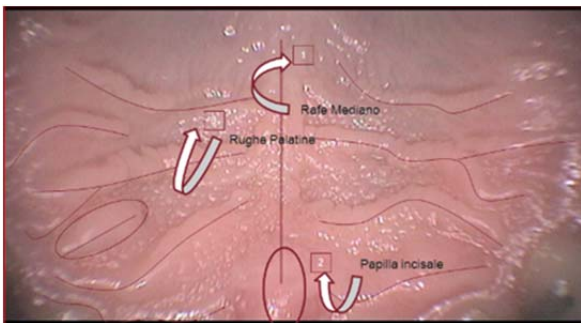
Figures 7. Biometric analysis of Id.P. project (Identification Palate project).

Materials and Methods

In order to improve the analysis system of the palatal rugae, at the Department of Oral and Maxillo-facial Sciences, Oral Diagnosis Unit, of "Sapienza" University of Rome, we designed a software connected with an intraoral camera that allows quickly and easily acquiring and storing the palatal impression. The procedure consists of five phases:

    a.   Palatal rugae acquisition
    b.   Highlighting rugae
    c.   Classification and parameterization
    d.   Signature creation
    e.   Electronic storage

Acquisition

Figures 8. VistaCam iX, Durr Dental, intraoral camera used for palatal rugae acquisition.

The acquisition of palatal rugae must be rapid, non-invasive and should be practicable by unskilled personnel wherever it is required. To comply with these features, the intraoral camera used is VistaCam iX (Durr Dental) with the "Cam" interchangeable head for intraoral images. This camera, with its depth of field and image quality, meets the highest requirements for digital transmission; allowing the reconstruction of a faithfull three-dimensional image of the palate.

Figure 9. Image taken during a police check simulation.

Highlighting rugae

Captured image is converted to black and white format colour, this shows the raised sections (rugae) and removes the bottom (palate). Therefore, you have a clear picture of the lines and curves that make up palatal rugae and median raphe.

Figure 10. Image obtained by the software through algorithm of rugae highlighting.

Classification and parameterization

Classification consist of the analysis and the acquisition of the shape, the size and position of each ruga in relation to the median raphe. These information allow, in case of deformations due to the variable position of the intra oral camera during acquisitions, to apply the necessary image corrections to be able to compare with the one stored in the database. The informations thus acquired are:an object (the number of the ruga, considering as number 1 the first ruga in the upper right of the median raphe and continuing the numbering clockwise), and the parameters (the rugae size and shape).
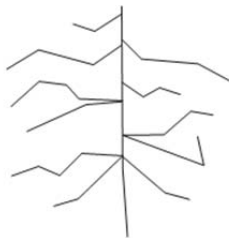

Figure 11. Representation of the parameterization scheme of rugae.

Signature creation

The comparison of a lot number of palatal impression would entail a considerable hard work in fact it would require the analysis of all the parameters relating to each ruga. To improve performance, it was decided to generate, by means of a mathematical algorithm, a unique signature for each palatal impression, so that the comparison of the palatal rugae becames a comparison of signatures. This method would facilitate the integration of this system with the AFIS.

Electronic storage

Due to the importance of these data and the need to access them from everywhere, the storage system of data must safeguard the integrity, the availability and, preferably, the integration with the current identification system.

Figure 12. Prototype of palatal rugae analysis software.

Expected Results

Implementing the proposed design functional is simple, due to the simplicity of the palate scanning and to dental equipment already running intra-oral scans for prosthetic purposes. It would also be possible to perform the palate scanning without the help of dental professionals like it could take place in military bases or police stations.

As is clearly shown by now, the electronic storage with signatures improves the comparison performance; also, it solves the problem of individual privacy safeguard, in fact, the mathematical function that generates the "electronical signature" is not reversible, thus it's impossible to trace the individual identity bottom-up from the signature.

Compared with traditional palatal rugae impression techniques, this method results in:
- Fast image capture
- No privacy violation [9,10].
- Potential availability in all the police districts and military bases, hospitals, prisons, rehabilitation centers etc … without the need of specific staff training.
- It is possible to integrate the rugae images with that of fingerprint using the AFIS system. Thus to compare digital, palate and lip signs (further cheiloscopy development).

 At the same time
- it permits subject identification also in the absence of fingerprints in case of a repeat offense

- Potential use in infants
- Possible aiding tool to the Istat statistics
- Possibility during the step of scanning to retain DNA

Discussion

To date, the fingerprint is the best recognizing tool used by the judicial authorities for the application of specific restrictive measures in respect of dangerous or internationally wanted subjects or, as is happening today, for the recognition of people fleeing their countries of origin, uncontrollable mass migration.

It is a reasonably rapid and effective procedure also thanks to the modern technology.
Fingerprints are compared each other through computerized systems called AFIS (Automatic Fingerprint Identification System) which allow the comparison of the imprint design [2].

Figures 13. AFIS system.

The system, in fact, acquires and stores the photo-signage badges, it ranks them, detects and encodes the distinctive points and, finally, compare the fingerprints with those stored in the central server.

Thanks to the AFIS system, international police can identify a person who commits a crime worldwide, although he changed name or appearance.

A judgmen of the Constitutional Court of Strasbourg limited the AFIS system. It stated that it is as privacy invasion storing the fingerprints of people who have not committed a crime [9,10]. In addition, according to a 2005 judgment , people with abraded fingertips cannot be sentenced because it is impossible to conclusively established their identity. Thus, to avoid identifying, lots of people alter or erase their fingerprints through chemical and / or abrasive systems [11].

The study of the hard palate morphological characteristics, like fingerprints, has the same reliability in the unique individual identification.
The international literature highlighted the palatal rugae validity in univocally certifying the individual identity [3,5-7,12-18].

Histologically the rugae are composed of connective tissue and keratinized stratified squamous epithelium.
Anatomically, it consists of different structures: the median raphe, whit anteroposterior groove and the rugae, which originate from the median raphe and vary between three and five on each side. The length, configuration and direction of each of the rugae vary significantly among people, even among identical twins [12,15].

The tongue, cheeks and lips protect the palatal rugae, for their placement, from trauma and high temperatures. The rugae do not change in case of prosthesis stress, trauma or chemicals; infact in any event, they form again in the same position and with the same shape [7,8,19].
According to Ana A. Barbieri [20], at the end of a palatal rapid expansion treatment, in all of the studies, the rugae preserve all the technical and biological quality needed for the identification process.
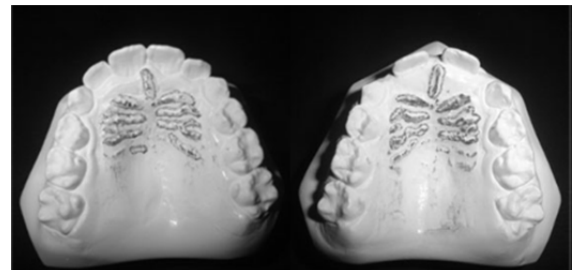

Figure 14. Chalk cast comparison before treatment and after treatment [20].

Teeth eruption does not alter the rugae shape or position. However, according to other authors, thumb-sucking and specific extractions can alter the pattern of the palatine rugae [21].

Figure 15. Study of rugae with alginate impression and construction of a plaster cast.

It would be very unlikely to store palatal rugae through dental impressions covering also the rugae impression, or

through other chemical impression material, such as liquid dam.

Due to the invasive procedures needed and to the necessary construction, study, scan and subsequently storage of the plaster casts. The plaster casts are too fragile, heavy and hard to place because of their overall dimensions.

Figures 16. Attempted indirect acquisition of rugae through light-curing liquid dam.
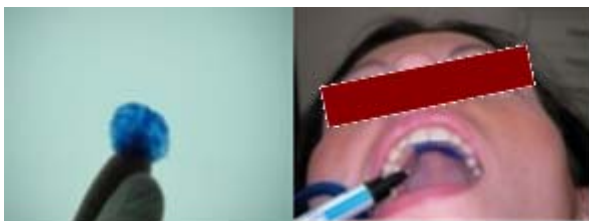
Figure 17. Attempted direct acquisition of rugae through light-curing liquid dam.

The construction of prepackaged atraumatic, sterile and vacuum impression tray, with already activated material and ready to immediately begin the curing phase, can speed up and simplify the procedure. In this case, too, there remains the problem of the storage and the scanning of the impression obtained. Police officers should also be prepared so as to be able to carry out this procedure with skill and expertise.

Therefore, it is more plausible the direct scanning procedure of the rugae within the oral cavity, with a non-invasive system that can be applied to all subjects and at any age.

As described, this is a specific photo software program with an appropriate camera to detect only the rugae with a simplified image storage; it can also associated with the AFIS system for the automatic identification of fingerprints connecting all the International Police districts .

The existence of an intra-oral camera that detects the dental impressions in the dental field, makes the Identification Palate project easily accomplished.

It should be ascertained however, that the majority of intra-oral cameras, have slow dental images acquisition and that most of the scanners cameras on the market acquire the images in black and white disregarding the oral mucosa.

In addition to the rugae shape and characteristics adopted to date in all the scientific studies (2D images)

[3-6,8], the ability to capture hard palate images in three-dimensional shape, allows to study the rugae depth and thickness; these are important biometric value that increases the safety and accuracy in subjects identification.

Indeed, informations gathered by rugoscopy give specific and sensible information on the individual identity, but are less likely to be useful in crime scene investigation, as fingerprints do.

Conclusions

The Id.P project, on account of technical progress of palatal rugae impression, aims to provide a tool that, integrating with the AFIS system, allows quick identification of individuals throughout the planet. Also it is a storing and biometric data managing method that both protects people privacy and facilitates their recognition when it is required. In fact the only stored data are the mathematically derived signatures.

The rugoscopy is an identification technique today accepted by the international scientific community that could facilitate and enhance the internal security of each nation.

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