Rugoscopy: Human identification by computer-assisted photographic superimposition technique

Rezwana Begum Mohammed,
Rajendra G. Patil[1],
V. R. Pammi[1], M. Pavana
Sandya[2], Siva V. Kalyan[2],
A. Anitha[2]
*Department of Oral Medicine &
Radiology, GITAM Dental College &
Hospital, Rushikonda, Visakhapatnam,
[1]Narayana Dental College &
Hospital, Chintareddypalem, Nellore,
[2]Department of Public Health Dentistry,
Mamata Dental College & Hospital,
Khammam, Andhra Pradesh, India*

Address for correspondence:
*Dr. Rezwana Begum Mohammed,
GITAM Dental College
and Hospital, Rushikonda,
Visakhapatnam - 530 045,
Andhra Pradesh, India.
E-mail: dr.rizwanamds@
gmail.com*

Abstract

Background: Human identification has been studied since fourteenth century and it has gradually advanced for forensic purposes. Traditional methods such as dental, fingerprint, and DNA comparisons are probably the most common techniques used in this context, allowing fast and secure identification processes. But, in circumstances where identification of an individual by fingerprint or dental record comparison is difficult, palatal rugae may be considered as an alternative source of material. **Aim:** The present study was done to evaluate the individualistic nature and use of palatal rugae patterns for personal identification and also to test the efficiency of computerized software for forensic identification by photographic superimposition of palatal photographs obtained from casts. **Materials and Methods:** Two sets of Alginate impressions were made from the upper arches of 100 individuals (50 males and 50 females) with one month interval in between and the casts were poured. All the teeth except the incisors were removed to ensure that only the palate could be used in identification process. In one set of the casts, the palatal rugae were highlighted with a graphite pencil. All the 200 casts were randomly numbered, and then, they were photographed with a 10.1 Mega Pixel Kodak digital camera using standardized method. Using computerized software, the digital photographs of the models without highlighting the palatal rugae were overlapped over the images (transparent) of the palatal rugae with highlighted palatal rugae, in order to identify the pairs by superimposition technique. Incisors were remained and used as landmarks to determine the magnification required to bring the two set of photographs to the same size, in order to make perfect superimposition of images. **Results:** The result of the overlapping of the digital photographs of highlighted palatal rugae over normal set of models without highlighted palatal rugae resulted in 100% positive identification. **Conclusion:** This study showed that utilization of palatal photographs is highly viable. The photographic superimposition technique using Adobe Photoshop 8.0 software (used in this study for comparison of palatal rugae) was proved effective for human identification and can be used when ante-mortem data regarding palatal rugae is provided. This study also concluded that palatal rugae are highly individualistic and play an important role as a complementary method in personal identification.

Key words: Forensic odontology, human identification, palatal rugae, photographic superimposition, rugoscopy

Introduction

Forensic odontology plays an important role in personal identification. It is a fact that establishing a person's identity either living or deceased is a difficult task and also, one of the main objectives of forensic sciences. The identification of an individual is the prime requisite for certification of death and for personal, social, legal, and

humanitarian reasons. To perform this identification process, five technical requirements are required. They are variability, immutability, perennity, practicability, and possibility of classification, which are applicable to palatal rugae.[1] Most commonly employed methods in this context are dental, fingerprint, and DNA comparisons, as they provide fast and secure identification processes. The dental records play an important role in identifying a deceased person, based on the comparison of ante-mortem and post-mortem records.[2,3]

The palatal rugae appear towards the third month of intrauterine life. They are asymmetrical and irregular elevations of the mucosa located in the anterior third of the palate.[4-6] The study of palatal rugae patterns for human identification is described as rugoscopy[7] and may play an important role in medico-legal identification because their individual morphological characteristics are stable throughout life.[8] Even diseases, chemical attack, or trauma does not alter the form of the rugae. The rugae patterns have been studied for various purposes, mainly in the fields of anthropology, comparative anatomy, genetics, forensic odontology, prosthodontics, and orthodontics.[5,9,10]

The palatal rugae can be used as an alternative method for comparison at times when identification of an individual by fingerprint or dental record comparison is difficult and when post-mortem dental identification is not possible as in edentulous mouths.[8,11-13] The palatal rugae are well-preserved even after third degree burns because of their anatomical position inside the mouth. This keeps them well protected from trauma and insulated against high temperatures, more resistant to decomposition and thermal effect.[8,10-12] The study of palatal rugae is advantageous over other methods, as they are highly individualistic, unique, and consistent in shape throughout life and have low utilization costs (with no much training of individuals assessing them) and can be ideally used for forensic identification.[5,7-10,14,15]

This study evaluates the use of palatal rugae patterns for forensic identification by photographic superimposition technique with an indigenously developed computer software program.

Objectives of the study

1. To assess whether palatal rugae can be used for identification of individuals.
2. To see whether the rugae patterns are sufficiently individualistic to confirm the human identification.
3. To test the efficiency and to assess how well the photographic superimposition of the images of palatal rugae can be carried out using computerized method.

Materials and Methods

In the present study, upper alginate impressions were made from 100 adult subjects (50 males and 50 females) attending the O.P.D of Narayana Dental College and Hospital, Nellore. Another set of alginate impressions of the same 100 individuals were made after a period of one month. The casts were poured with dental stone and bases with plaster [Figure 1]. These individuals agreed to participate in the study by signing an informed consent form, and the study was approved by the Ethical Committee of Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India.

The Individuals with cleft palate, those who had undergone surgery at anterior palatal region, orthodontic treatment, extraction of upper permanent teeth, those with palatal lesion, malocclusion were excluded from the study.

All the teeth except the incisors were removed, and the base was trimmed parallel to the occlusal plane. The posterior portion of the cast was trimmed [Figure 2] until the cast measured 3 cm from incisive papilla to eliminate bias and to ensure that only palate could be used in the identification process.

Figure 1: Cast showing palatal rugae

Figure 2: Trimmed cast with only incisors remained

For rugoscopy to be performed, ante-mortem data regarding palatal rugae should be made available. Here, the first set of models represents ante-mortem data, and the second set of casts with highlighted palatal rugae represents post-mortem data. The casts were randomly numbered. On second set of casts, rugae were delineated with a sharp graphite HB pencil under spot light [Figure 3]. Two sets of casts were photographed in same orientation. The photographs of all 200 casts were taken with a 10.1 Mega Pixel Kodak digital camera using a standardized technique by fixing the cast and camera position. All the 200 digital photographs were copied to a CD. The digital photographs were examined by superimposition technique by three evaluators to identify the matching of casts belonging to the same individual using Adobe Photoshop 8.0. software.

Photographic superimposition

This technique was first developed by John Glaister and his associates in 1935 and was used most commonly for craniofacial superimposition.[16] Kogon SL, Ling SC stated that photographic superimposition technique can be easily adapted to conventional photographic equipment for rugae comparisons.[17] The digital methods were successfully used for identification of human skeletal remains.[18] An effective way to match a photographic profile is to superimpose photographs, which were taken exactly in same orientation.[2] The use of ante-mortem photographs to permit facial superimposition of skeletal and teeth fractures have been used in cases of identification. This technique requires the availability of suitable ante-mortem photographs showing the teeth. The availability of ante-mortem data pertaining to palatal rugae is more. In our study, a second set of cast photographs delineated by graphite pencil were made transparent and made to superimpose on a normal set of cast photographs. If the two cast photographs belonged to same individual, they would match on superimposing (otherwise they mismatch). The remaining incisors were used as landmarks to determine the magnification required to bring the two set of photographs

to the same size in order to make perfect superimposition of images. The image superimposition was performed with Adobe Photoshop 8.0 software.

All the three evaluators (Two professors of Oral Medicine and one Forensic Medicine Professor) were given the digitized photographs of the models in a CD and were asked to match the images of two sets of casts. All the three evaluators were unaware of the previous cast models, specimens, and allotted codes, which assured the blind nature of this study, and the percentages of positive identifications were analyzed.

Results

In the superimposition of the digital photographs of the second set of cast models with highlighted palatal rugae over the normal set of cast photographs, the percentage of correct matches obtained by the three evaluators was 100%. Inter-observer variability was not found in the present study.

The Figures 4 and 7 show the normal digitized photographs of models showing palatal rugae, while the Figures 5 and 8 show their transparent corresponding match with highlighted palatal rugae. Also, Figures 6 and 9 show the superimposition of the images of both the sets.

Discussion

Palatal rugoscopy was first proposed in 1932 by Trobo Hermosa.[19] The analysis of palatal rugae was first proposed by Allen in 1889.[20] Rugoscopy is an old method of human identification where different patterns of rugae were analyzed for comparison. Sassouni stated that no two palates are alike in their configuration and that the palatoprint does not change during growth.[21] Rugoscopy may be used as a necro identification technique.[4] This method of
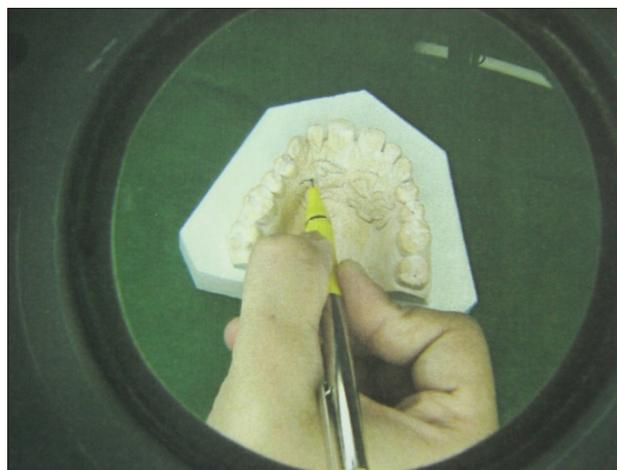
Figure 3: Highlighting of palatal rugae under spot light

Figure 4: Digitized photograph of cast with non-highlighted palatal rugae
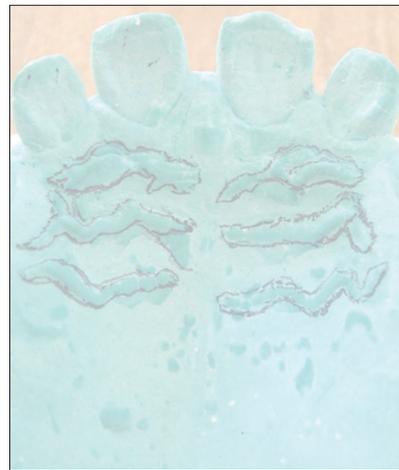
Figure 5: Transparent corresponding match of figure-4 with highlighted palatal rugae

Figure 6: Shows superimposition of the images of both sets [Figures 4 and 5]

Figure 7: Digitized photograph of cast with non-highlighted palatal rugae

Figure 8: Transparent corresponding match of figure-7 with highlighted palatal rugae

The superimposition technique is most commonly used for craniofacial comparisons and can be performed using ground glass and bromide/photographic paper, as published by Reddy, Suzuki in Japan, Gejvall (using a slightly modified technique), Klonaris and Furue, using only a maxilla fragment, Sognnaes, along with other evidence, in the Hitler and Bormann identifications and Webster *et al.* Thomas *et al.* offered a simple modification, in which the articulated cranium and the mandible were photographed and then projected onto a print of a photograph taken during life.[22]

Figure 9: shows superimposition of the images of both sets [Figures 7 and 8]

identification can be used only when ante-mortem data of the palatal rugae is available.[11]

In individual situations or in mass disasters, where identification by routine methods like fingerprinting, DNA analysis is not possible, the use of rugoscopy, by photographic superimposition method, can be very useful. In this study, the superimposition procedure of palatal rugae was carried out by making one photograph of model transparent. When the photographs of palatal rugae of the non-highlighted models were superimposed with the digitized photographs

of highlighted palatal rugae, there was 100% accuracy rate of identification by all the three evaluators.

Martins Filho[1] also got 100% identification in his study, and Limsons and Julani,[13] who compared some points of the rugae patterns using computer software reported that the percentage of correct matches ranged from 92-97%.[13] The study of Ohtani *et al.*[23] on the comparison of palatal rugae of edentulous individuals in dentures and against their models made by impressions from the patients had a percentage of 94% correct matches. English *et al.* and[15] Hemanth *et al.*[24] in their study used a manual method to compare the rugae patterns and got 100% accuracy rate of identification. They concluded that rugae are characteristic to differentiate between individuals. Thomas and Van Wyk described the identification of an edentulous individual by delineating the palatal rugae with the help of his dentures and performed superimposition by taking cast photographs and tracings of rugae on acetate paper.[25] Santos *et al.*[14] in their study on rugoscopy evaluated a digital method of GNU image manipulation program and proved it as effective for human identification. Hemanth *et al.*[10] did a study using palatal photographs and recorded 99% accuracy rate of identification with Palatal Rugae Comparison Software (PRCS Version 2.0).

Also, no significant inter- and intra-observer errors were noted in the present study, as the superimposition technique used here was carried out with utmost care so as to minimize the errors in the technique for the comparison of palatal rugae. It has established that rugae are unique and helps in individual identification. In this study, the utilization of digital photography, personal computers, and specific software to edit and use digital images allowed a significant improvement in the recognition with easy and quick identification of individuals. The photographic superimposition technique allows easy handling. It has simplified the analysis and comparison of rugae patterns by reducing manual errors, time taken, and also facilitates the storage of large amounts of data with quick retrieval and fast and effective identification in forensic work.

Limitations of the study
1. Proper positioning of digitized photographs is important since the slightest difference in orientation can prevent a successful match
2. This method required manual plotting of palatal rugae before matching and if not properly marked, can lead to discrepancies**.**

Conclusion

The ante-mortem records of palatal rugae are easily available with the dentist and serve as viable alternative for identification purpose. They are sufficiently characteristic to discriminate between individuals. This study showed that palatal rugae are unique for an individual and can be used for human identification. This study also concluded that the digitized method of photographic superimposition using Adobe Photoshop (Version 8.0) software used herein is reliable, easy, required less time to make correct matches, and efficient for comparison of palatal rugae pattern in individuals for forensic identification.

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