

# Application of Palatal Rugae Morphology in Forensic Identification

Aplicación de la Morfología de las Rugas Palatinas en la Identificación Forense

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**SUMMARY:** To investigate the feasibility of application of digital images of the palatal rugae in forensic identification. One hundred patients, consisting of 50 males and 50 females, who received treatment between January 2015 and June 2015 at Shanxi Medical University Stomatological Hospital, China, were included in this study. High-resolution digital image of the palatal rugae was taken from each patient using a digital SLR camera and then processed using a digital image recognition system, including noise reduction, contrast enhancement, image segmentation, feature extraction, edge detection and information matching. Using an MATLAB software system, match results and the time taken by each operator for information matching were recorded. The digital image recognition system assisted in information matching of the palatal rugae. Three oral physicians had a 100% correction rate in information matching. Two other operators failed in formation matching in one or two cases. The time taken by oral physicians for information matching was shorter than that taken by the other two operators. Unique palatal rugae morphology has gradually become a novel marker for forensic identification. Digital images of the palatal rugae morphology contribute to rapider and more accurate forensic identification.

**KEY WORDS:** Forensic anthropology; Forensic stomatologia; Palatal rugae; Identification.

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## INTRODUCTION

Forensic identification is a challenging work that has been always an area of interest in the field of forensic science all over the world (Bing *et al.*, 2014; Gondivkar *et al.*, 2011). The morphology of human palatal rugae has a genetic genes-mediated individual-specific feature which remains unchanged during an individual's lifetime. Human palatal rugae are protected against trauma, high temperatures and decomposition by lips, cheek, tongue, skeleton and artificial teeth because of their position in the oral cavity (Bhagwath & Chandra, 2014; Ohtani *et al.*, 2008; Acharya, 2014; Hermosilla Venegas *et al.*, 2009). Palatal rugae have increasingly become a novel marker for forensic identification owing to its stable and unique morphology (Virdi, *et al.*, 2008; Shetty, *et al.*, 2005; Chatterjee & Khanna, 2011). In this study, we took digital images of the palatal rugae morphology under particular conditions, performed a series of image processes (including noise reduction, contrast enhancement, image segmentation, feature extraction, edge detection and information matching) and also evaluated the

feasibility of application of palatal rugae morphology in forensic identification based on an MATLAB software system.

## SUBJECT AND METHOD

One hundred patients, consisting of 50 males and 50 females, who received treatment between January 2015 and June 2015 at Shanxi Medical University Stomatological Hospital, China, were included in this study. Inclusion criteria: (1) Age  $\geq 20$  years; (2) having no history of skull and jaw trauma; (3) having not orthodontic and orthognathic history. Exclusion history: (1) having congenital anomalies/malformations; (2) candidate for orthognathic surgery; (3) being allergic to impression materials; (4) bone and soft tissue protrusion, active lesions and (5) palatal deformity or scars or trauma.

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Instruments and software. Digital SLR cameras (Canon EOS 300 D); light reflector for orthodontic surgery; MATLAB software for performing numerical calculations (MathWorks, USA); PRCSVersion 2.0 software; SPSS13.0 software.

Harvesting of palatal rugae images. Under particular conditions, high-resolution digital image of the palatal rugae was taken from each of 100 individuals using a digital SLR camera with the same parameters at the designated position. The camera was equipped with a special instrument to ensure unified images. JPEG images were saved in a database in the computer (Fig. 1).

Matching of palatal rugae images. Images of subject's palatal rugae were randomly selected, and image feature extraction and magnification (Fig. 2) and edge detection (Fig. 3) were performed by one surgeon who worked in department of common surgery, three oral physicians, and one radiologist. The processed data of the palatal rugae were matched with those saved in the database. A "positive match" is displayed by the digital image recognition system, which indicates that the person in question has been found in the database, and identity information of the person will be displayed; a new match will be started when the first identical authentication is unsuccessful, and "no match" is displayed when the processed data are not identical to the information of any identity throughout the database (Figs. 4 and 5).

Results recording. Information matching results and the time taken by each operator for information matching were recorded.



Fig. 1. Palatal rugae images.



Fig. 2. Image feature extraction and magnification.



Fig. 3. Detection of palatal rugae edge.



Fig. 4. Matching of palatal rugae images.



Fig. 5. Non-matching information of palatal rugae images.

## RESULTS

Digital image recognition system assisted in information matching of the palatal rugae. Three oral physicians had a 100 % correction rate in information matching. Two other operators failed in one or two cases (Fig. 6). The time taken by oral physicians for information match was shorter than that taken by the other two operators (Fig. 7).

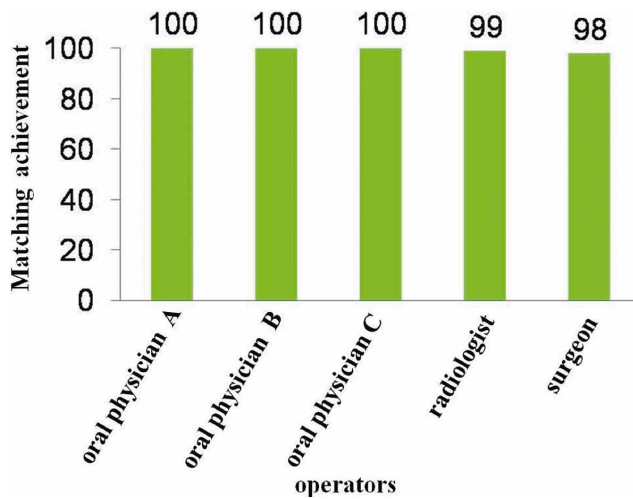


Fig. 6. Matching achievement ratio of palatal rugae images information.

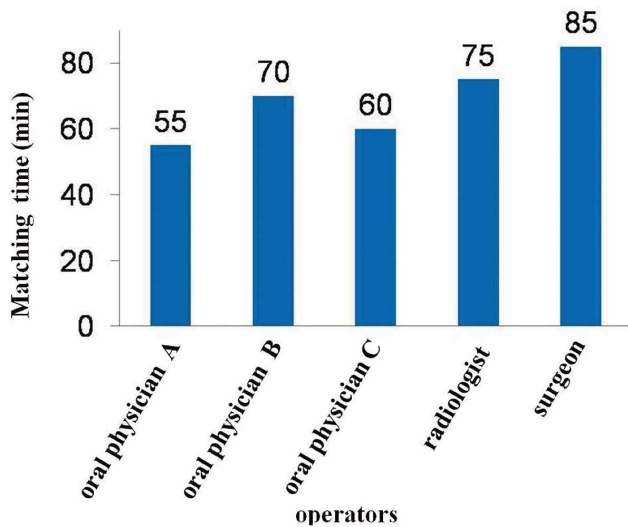


Fig. 7. Matching time of palatal rugae images information.

## DISCUSSION

Palatal rugae, also called plicae palatinae transversae, can be protected from trauma and high temperatures by lips, cheek, tongue, buccal pad, teeth and bone, and exhibit no age-related changes (Rajan *et al.*, 2013; Pretty, 2007; Verma *et al.*, 2014; Sharma *et al.*, 2009). The morphology of the palatal rugae is a genetic gene-mediated individual-specific feature that is unchanged throughout a lifetime. The palatal rugae are unique and stable landmarks that contribute to forensic identification (Shetty *et al.*, 2013; Acharya *et al.*, 2011; Byatnal *et al.*, 2014). Palatal rugae morphology-based forensic identification is performed according to the amount, position and distribution of the palatal rugae. In the field of

forensic stomatologia, individual identification is a changing task. Palatal rugae morphology for forensic individual identification can be considered when individual identification by fingerprints or teeth is hardly performed (English *et al.*, 1988; Rath & Reginald, 2014; Mishra *et al.*, 2014).

The local (detailed) features of the palatal rugae are applicable to safety authentication system, for example, individual identity. In this study, we extracted the features of the palatal rugae from the perspectives of dot, circle and line. In the preliminary experiments, we created moulage systems made of silicone rubber and then prepared into anhydrite models of the palatal rugae. But most of anhydrite models of the palatal rugae have problems such as gas bubbles and line breakage because of different human organism environments, pressures, moulage material categories, and gypsum power/water proportions. Thus, the acquired thinning binary images always contain a large number of feature artifacts, which greatly influence the matching speed and accuracy rate of the palatal rugae in identical authentication. Therefore, we took high-resolution images of the palatal rugae using a high-resolution camera under special conditions using the same parameters at the designated position to better extract features. According to matching results, the digital image recognition system can help to acquire good identification, three oral physicians acquired a 100 % correction rate, and the other two operators failed in match in one or two cases. This occurs possibly because of limited data of palatal rugae morphology either in database or processed.

In the present study, we performed a series of processes on the digital images of the palatal rugae, including information acquisition, feature extraction and edge detection. The processed information was recorded in a database and matched with the original data in the database. Edge detection is performed to locate the edge accurately and reduce noise. The quality of palatal rugae images influences forensic identification. The local (detailed) features of the palatal rugae are labeled by feature extraction and edge detection and matched with the information from the database, and a successful match would be displayed if identical information of the palatal rugae exists in the database. The digital image recognition system had a faster speed in information matching of the palatal rugae and oral physicians took less time. Oral physicians took less time taken for information matching because of their professional knowledge and collaboration across different professional teams.

Unique palatal rugae morphology has become a novel marker for forensic identification. Digital images of the palatal rugae morphology contribute to more rapid and accurate forensic identical authentication.

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**RESUMEN:** El objetivo fue investigar la viabilidad de la aplicación de imágenes digitales de rugas palatinas para la identificación forense. Se incluyeron 100 pacientes, 50 hombres y 50 mujeres, que recibieron tratamiento entre enero de 2015 y junio de 2015 en el Hospital Odontológico de la Universidad Médica de Shanxi, China. Se tomaron imágenes digitales de alta resolución de las rugas palatinas de cada paciente utilizando una cámara réflex digital y luego se procesaron mediante un sistema de reconocimiento de imagen digital, incluyendo reducción de sonido, mejora del contraste, segmentación de imágenes, extracción de características, detección de márgenes y coincidencia de la información. Mediante el programa MATLAB se registraron los resultados y el tiempo de cada operador para obtener información coincidente, además se utilizó el sistema de reconocimiento de imágenes digitales para hacer coincidir las con la información de las rugas palatinas. Tres odontólogos informaron una tasa de corrección del 100 % al realizar cruces de información. Otros dos operadores fracasaron en uno o dos casos. El tiempo asignado por los odontólogos para la coincidencia de la información fue menor al de los otros operadores. La morfología especializada de las rugas palatinas se ha convertido gradualmente en un nuevo marcador para la identificación forense. Las imágenes digitales de la morfología de las rugas palatinas contribuyen a una rápida y precisa identificación forense.

**PALABRAS CLAVE:** Antropología forense; Estomatología forense; Rugas palatinas; Identificación.

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