



ORIGINAL ARTICLE

# Conversion of palatal rugae pattern to scanable Quick Response code in an Arabian population



Sadatullah Syed <sup>a\*</sup>, Ibrahim Alshahrani <sup>b</sup>,  
Abdulaziz Alshahrani <sup>b</sup>, Rafi Ahmad Togoo <sup>b</sup>, Master Luqman <sup>a</sup>,  
Azhar A. Dawasaz <sup>a</sup>

<sup>a</sup> Department of Diagnostic Sciences and Oral Biology, College of Dentistry, King Khalid University, Abha, Saudi Arabia

<sup>b</sup> Department of Preventive Dental Sciences, College of Dentistry, King Khalid University, Abha, Saudi Arabia

Received 29 October 2015; Final revision received 25 January 2016

Available online 10 April 2016

## KEYWORDS

forensic sciences;  
palatal rugae;  
code;  
characteristics;  
strength;  
uniqueness

**Abstract** *Background/purpose:* Palatal rugae (PR) are situated in the anterior part of the hard palate and possess unique and stable characteristics that can be used in human identification. Their pattern of orientation is established early in life and remains stable thereafter. The purposes of this study were to convert PRP into alphanumeric codes in order to generate scanable Quick Response (QR) codes, to demonstrate uniqueness of PRP using the codes in the study population, and to determine the sexual dimorphism of PRP in the study population.

*Materials and methods:* Orthodontic dental casts of 256 Saudi male and female patients were photographed after ensuring standardization. Individual rugae characteristics, strength and their displacement from incisive papilla and midpalatine raphe were recorded in the form of an alphanumeric code which was subsequently converted to a QR code. Computer assisted check was performed for possible match in the 256 alpha numeric codes while QR codes were scanned using a bar code scanner to determine uniqueness. Sexual dimorphism of palatal rugae (PR) was also analysed.

*Results:* All alphanumeric codes of the study population were unique. Mean number of PR in males and females differed significantly ( $P = 0.0001$ ). Differences in rugae characteristics and strengths in males and females were also present.

*Conclusion:* The alphanumeric and QR code of the rugae pattern are unique for each individual and can be used for digital record keeping and person identification. A high degree of sexual dimorphism in PR exists in the studied Arab population studied.

Copyright © 2016, Association for Dental Sciences of the Republic of China. Published by Elsevier Taiwan LLC. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

\* Corresponding author. King Khalid University, College of Dentistry, P.O Box 3263, Abha 61471, Saudi Arabia.  
E-mail address: [dr.sadat@hotmail.com](mailto:dr.sadat@hotmail.com) (S. Syed).

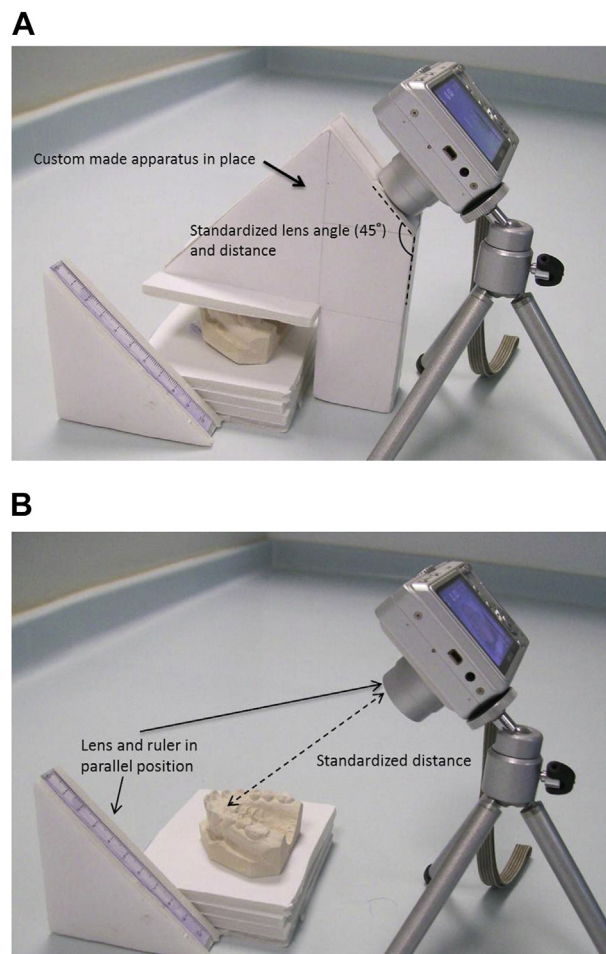
## Introduction

In today's world when crime and subsequent mutilation of human bodies are on a rise, personal identification is an integral part of forensic science, especially when the damage is beyond recognition.<sup>1</sup> Palatal rugae (PR) are asymmetrical, irregular mucosal folds or ridges that are present in the anterior part of the hard palate. They are well formed at birth and exhibit a pattern of orientation unique to a person.<sup>2,3</sup> Earliest scientific literature on PR was by Winslow in 1732 as reported by Thomas and Kotze.<sup>4</sup> According to English et al<sup>5</sup> the use of PR was suggested as a method of identification first in 1889. Since then, many studies have reported its possible use in forensic odontology. PR are situated in a safe environment protected by the lips, cheeks, tongue, teeth, bone, and prosthetic oral appliances. Therefore, they are able to endure trauma, excessive heat, and other physical insults. As the jaws grow so do PR and this change stops when the growth is complete.<sup>2</sup> The number, type, and arrangement of PR creates a unique pattern known as PR pattern (PRP),<sup>6</sup> which retains its shape throughout life<sup>6,7</sup> and is as unique to humans as their fingerprints.<sup>6,8</sup> Trauma, chemical aggression, surgery,<sup>6</sup> extraction, orthodontic tooth movement,<sup>8</sup> and rapid palatal expansion<sup>9,10</sup> do not modify PRP. They can withstand postmortem changes and remain stable even 7 days after death.<sup>11</sup> Clinicians have used PR to assess the amount of anteroposterior tooth movement, as they remain stable throughout life.<sup>6</sup> They are so stable that a surgically placed PR graft over gingiva leads to the development of similar rugae patterns on gingival tissue.<sup>12</sup> In addition, PRP are also specific to racial groups facilitating population identification.

Thus, its uniqueness, resistance to immediate postmortem changes,<sup>11</sup> stability,<sup>13</sup> and low cost for analysis make PR an ideal forensic identification parameter in cases of individual as well as mass disaster cases. Coding of PRP is a simple and effective means of digitization for person identification as proposed by Dawasaz and Dinkar.<sup>14</sup> Based on the criteria developed by Dawasaz and Dinkar,<sup>14</sup> this study is an attempt towards establishing individuality of PRP taking into consideration the ratio of distance of ruga from incisive papilla and linear displacement of each ruga from the midpalatal raphe in addition to ruga strengths and characteristics. The purposes of this study were to convert PRP into alphanumeric codes in order to generate scanable Quick Response (QR) codes, to demonstrate the uniqueness of PRP using the codes in the study population, and to determine the sexual dimorphism of PRP in the study population.

## Materials and methods

The study comprised of 256 maxillary pretreatment orthodontic study casts divided equally between women and men aged between 15 years and 30 years. They were selected from orthodontic clinics of King Khalid University Dental Clinic, Abha, Saudi Arabia after obtaining ethical clearance from the Scientific Research Committee of King Khalid University, College of Dentistry, Abha, Saudi Arabia. The age of the study individuals were taken from the dates



**Figure 1** (A) Custom made apparatus in position ensuring standardized distance and angulation; (B) dental cast at standardized position.

shown on the patient registration file. All patients were from one demographic area (Abha City of Saudi Arabia) without any history of orthodontic or palatal surgical treatment. Only good study casts including all forms of dental or skeletal occlusions were included. Upon inclusion the age, sex, date of birth, and date of the impression of study casts were recorded. Each cast was then given a number to allow "blind" analysis of PRP.

## Digital photography and standardizations

The casts were photographed focusing on the palatal area using Pentax Optio Digital Camera (Ricoh Imaging Company, Shinjuku-ku, Tokyo, Japan). The photographs were standardized using custom made apparatus (Figure 1). The apparatus aided in maintaining the angle of the camera lens in relation to the occlusal plane of the cast. The apparatus also standardized the distance of the cast from the lens. All casts were photographed and the digital images were stored in a computer hard disk. Each image was then resized to a 1:1 ratio using Adobe Photoshop CS3 (Adobe Systems Software Ireland Ltd) (Figures 2A and 2B).

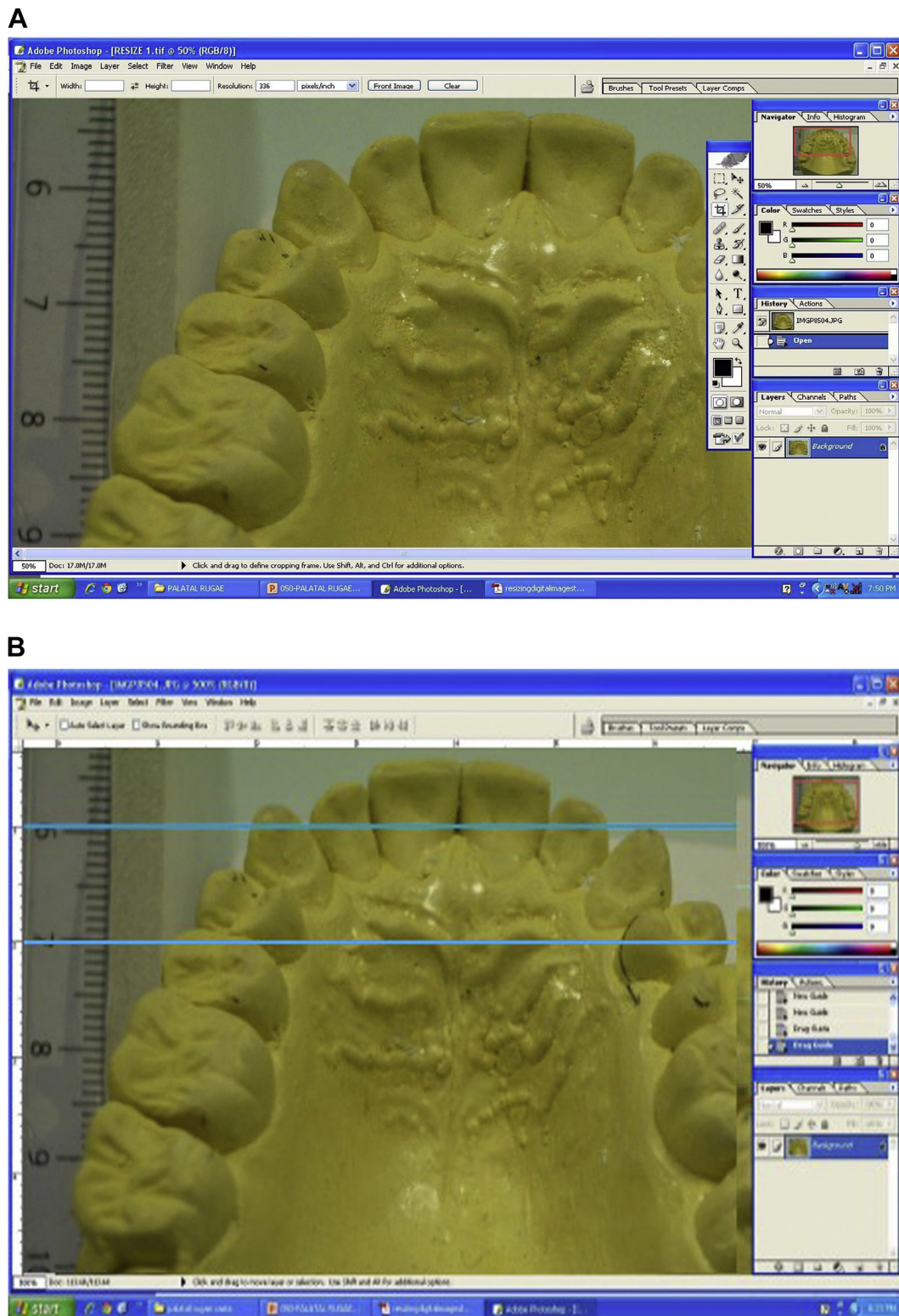


Figure 2 (A) Picture opened using Adobe Photoshop; (B) picture resizing to a 1:1 ratio.

### Anatomic landmarks and their identification

PR, incisive papillae, and midpalatine raphe were the three anatomic landmarks used for pattern analysis (Figure 3). The strengths of the rugae were digitally measured using

Adobe Photoshop CS3 (Table 1) and recorded at the maximum thickness of the PR. The various recognized PR shapes, referred to as characteristics, were recorded based on the modified classification of Thomas and Kotze<sup>15</sup> and Hauser et al<sup>16</sup> and denoted as a single lower case alphabet

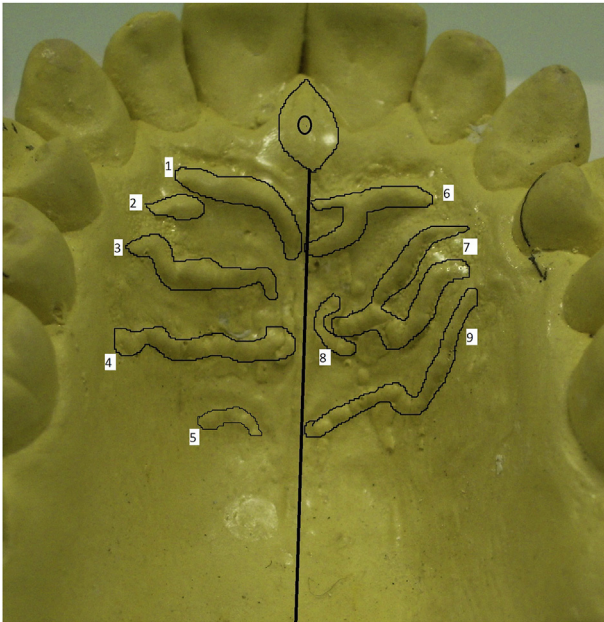


Figure 3 Anatomic landmark identification.

Table 1 Rugae strength (maximum thickness in mm).

Strength of ruga	Measurement (mm)	Abbreviation
Strong	≥0.8	S
Medium	0.4–0.7	M
Weak	≤0.4	W











Individual rugae characteristics used in the study	Denoted as
1. Straight 	a
2. Curved 	b
3. Wavy 	c
4. Annular/ring 	d
5. Papillary 	e
6. Cross linked 	f
7. Branch 	g
8. Breaks 	h
9. Converging 	i
10. Diverging 	j

Figure 4 Modified classification of rugae characteristics.

(Figure 4). If a ruga existed between the twigs of a branched ruga, the branched ruga was given a lower unit number. Strict protocol was followed with regards to the numbering of rugae. Right side rugae were marked first in

an anteroposterior direction followed by the left side. Rugae that were vague on the image were discarded.

PRP code

In this novel approach, the PRP code (PRPC) was defined as a set of alphanumeric characters derived from established parameters (strength, characteristics, and displacement measurements) that are anatomically related to the PR.

Example of PRPC: 1.5S0.8cd,1.9S1.1aeg,2.4M0.7bc; 1.4S0.6cd,2.1M1.3bcg,2.8W1.1ac

Steps for the generation of PRPC

Step 1: identification of anatomic landmarks on a color light-emitting diode display monitor as described above. Step 2: evaluation and recording of PRPC parameters. Four parameters involved in the creation of PRPC are described below.

Parameter 1: the ratio of the distance from most anterior point on incisive papilla to the lateral end of ruga and the anterior point on incisive papilla to the medial end of ruga (Figure 5A). This parameter appears first in the unit and was recorded as numerical in centimeters. Measuring tool of Adobe Photoshop CS3 was used to measure the distances.

Example: 1.5S0.8cd,1.9S1.1aeg,2.4M0.7bc;1.4S0.6cd, 2.1M1.3bcg,2.8W1.1ac

Parameter 2: strength of the ruga (Figure 5B). This parameter appears second and was recorded as an upper case alphabet according to Table 1.

Example: 1.5S0.8cd,1.9S1.1aeg,2.4M0.7bc;1.4S0.6cd, 2.1M1.3bcg,2.8W1.1ac

Parameter 3: displacement from medial end of ruga to midpalatine raphe (Figure 5C). This parameter appears third recorded as a numerical in centimeters. Like previous measurements, the measuring tool of Adobe Photoshop CS3 was used to measure this distance.

Example: 1.5S0.8cd,1.9S1.1aeg,2.4M0.7bc;1.4S0.6cd, 2.1M1.3bcg,2.8W1.1ac

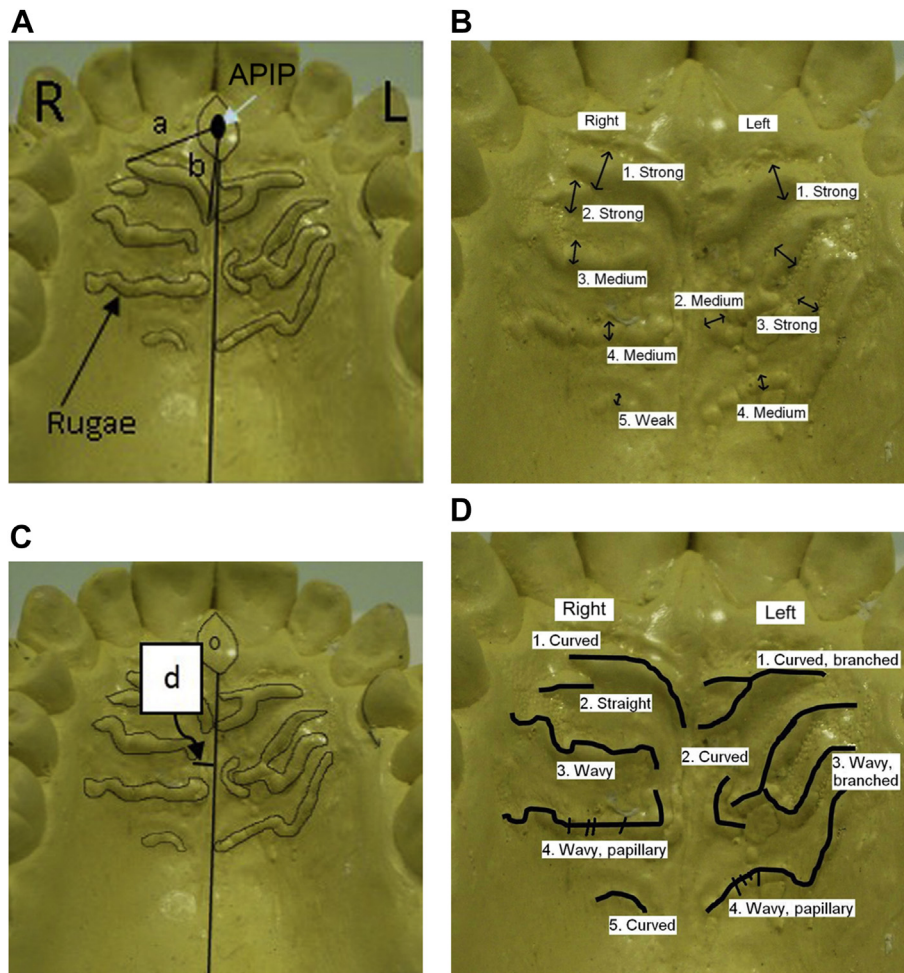
Parameter 4: individual PR characteristics used in this study are as described in Figures 4 and 5D. This parameter appeared fourth in the unit as lower case alphabet or alphabets according to Figure 4.

Example: 1.5S0.8cd,1.9S1.1aeg,2.4M0.7bc;1.4S0.6cd, 2.1M1.3bcg,2.8W1.1ac

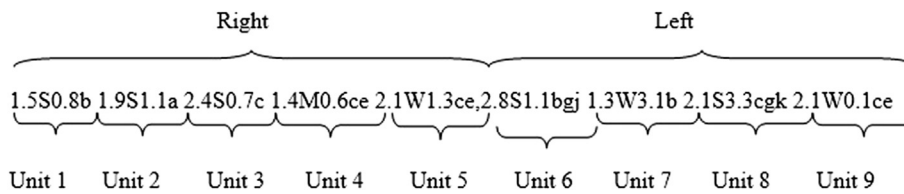
Step 3: formulation of PRPC units (Figures 3 and 6)

PRPC consisted of units representing individual ruga, based on the order of the four parameters mentioned above. The number of units in a PRPC was equal to the total of number of PR present for the cast. The first unit of PRPC represents the anterior most ruga on the right side. The next unit represents the subsequent ruga up to the posterior-most ruga on the right side. Subsequently, a similar order was followed for the left side starting from the anterior most ruga to the posterior most one. Each PRPC unit was separated by a comma (,) while the right and the left side units were separated by a semicolon (;).

Example: 1.5S0.8cd,1.9S1.1aeg,2.4M0.7bc;1.4S0.6cd, 2.1M1.3bcg,2.8W1.1ac



**Figure 5** (A) Recording parameter 1; (B) recording parameter 2; (C) recording parameter 3; and (D) recording parameter 4. APIP = Anterior point on incisive papilla; L = left; R = right.



**Figure 6** Palatal rugae pattern code units.

**Palatal PR-QR code**

QR code is a two dimensional matrix barcode (Figure 7) that is readable fast with a large storage capacity compared with the conventional Universal Product Code. It consists of black square patterns arranged in white background which are made of numeric and alphanumeric data. Once the PRPC was ready it was converted into a PR-QR code using a bar code generator online ([www.goqr.me](http://www.goqr.me)).

**Evaluation of uniqueness of PRP**

The evaluation of uniqueness of the PRP in the study population was carried out in two ways. (1) Uniqueness of PRPC: all the PRPC of the study population were entered in

Microsoft Excel 2013 software (Microsoft Corporation, Redmond, MA, USA). Each PRPC was checked with the remaining PRPCs for a possible match using the COUNTIF formula. If no match was found, the PRPC was considered unique. (2) Uniqueness of PR-QR code: all the PR-QR codes of the study population were scanned using a barcode scanner. If the scanner did not detect any duplicate match in the PR-QR codes it was considered unique.

**Determination of sexual dimorphism of PRP in the study sample**

The individual rugae characteristics and strengths were assessed and recorded in men and women on both right and



Figure 7 Scanable Quick Response code.

left sides. These values were subjected to further statistical analyses.

### Statistical analysis

*T* test was used for the mean of PR number in men and women. Percentage distribution of individual rugae strengths and characteristics in men and women on the right and left sides were also analyzed.

### Results

#### Uniqueness of PRPC and PR-QR code

The total number of rugae observed in 256 casts were 3175, out of which 14 were discarded due to ill-defined boundaries. It was possible to convert all the rugae into PRPCs and PR-QR codes. No two casts had exactly matching PRPC codes. The COUNTIF formula in Microsoft Excel for PRP alphanumeric codes returned with no match. Similarly, no match of PR-QR codes was found following scanning, demonstrating the uniqueness of the PRP in the study population. Additionally, the reverse generation of PRP alphanumeric code from PR-QR code was possible.

The longest PRPC had 18 units (rugae) and the shortest had eight units with an average of 12.35 rugae in each cast. Maximum linear displacement of individual ruga from mid-palatal raphe was 2.23 cm whereas the minimum distance observed was 0.06 cm.

#### Sexual dimorphism of PRP

Details of PRP in study population has been summarized in Table 2. The total number of rugae observed was 3161 in 256 casts. The difference between mean PR in men and women was 2.15, with a 95% confidence interval from 1.56 to 2.75; the *t* test statistic was 7.16, with 254 degrees of freedom and an associated *P* value of 0.0001.

Men had a larger number of rugae than women (Table 3). The total number of characteristics observed in all the casts were 7296. The most common PR characteristic in men was

Table 2 Distribution of rugae characteristics and strengths in the study population.

Characteristics	% of rugae	Males (%)	Females (%)	Right (%)	Left (%)
Straight	11.86	10.33	22.10	13.01	10.56
Curved	17.89	22.51	13.00	15.60	20.45
Wavy	20.26	20.65	19.51	24.49	15.50
Annular	6.26	5.11	7.30	4.35	8.41
Papillary	20.05	17.62	13.16	19.60	20.56
Cross links	0.67	0.63	0.70	0.52	0.84
Branches	11.60	14.39	8.62	10.03	13.35
Breaks	5.52	5.38	5.57	6.14	4.83
Unification	5.89	3.39	10.27	6.25	5.50
Strength	% of rugae	Males (%)	Females (%)	Right (%)	Left (%)
Weak	23.00	16.35	36.74	12.97	32.07
Medium	42.99	34.60	49.01	49.77	48.75
Strong	34.01	49.05	14.25	37.26	19.17

*p* = 0.001

curved 22.5% (*n* = 824) while in women it was straight (22%, *n* = 818; Figure 7). The prevalence of cross-link patterns was least in both men and women (0.67% and 0.7%, respectively). Since one rugae can have more than one characteristic, an average of two characteristics were observed for each ruga. The total number of rugae characteristics (Figure 8) was more in women (3709) than men (3661).

The most commonly observed strength in men and women were "strong" and "medium" respectively (Table 2; Figure 9).

The study population had more weak rugae on the left half of the palate than the right (Table 2). Likewise, the total number of PR characteristics observed on the left half (3448) were less than those on the right half (3858) without any statistical difference.

Table 3 Mean number of rugae in men and women.

	Total rugae	Men	Women
Mean	12.35	13.40	11.25
Min	8	8	8
Max	18	18	18
SD	2.63	2.61	2.18

Max = maximum; Min = minimum; SD = standard deviation.

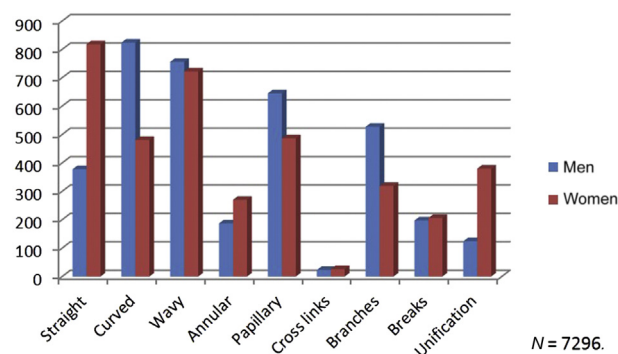


Figure 8 Rugae characteristics in men and women.

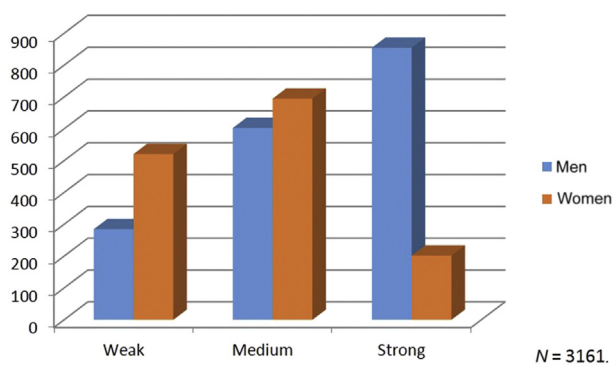


Figure 9 Rugae strength in men and women.

## Discussion

Photography of palatal rugae and evaluation of its uniqueness using a custom-made computer program is not new in literature.<sup>17</sup> This study was able to create a small digital database of images of palatal rugae on maxillary casts. The database included standardized JPEG extension photographs of casts kept at a fixed distance and angulation using specially built apparatus (Figure 1). Subsequently, a successful attempt at digitizing the PRP utilizing a novel coding system has been made. As a result, the physiognomy and anthropometry of rugae that can be described in words or captured as an image was translated into alphabets and numbers. These alphanumeric characters were very easily converted into a QR code, making the digitized PRP scannable. Reverse generation of PRP alphanumeric code from QR code was also possible which can be useful in creating a virtual PRP or an illustrated palatal impression. The digitized scannable PRP has the advantage of being easily archived and retrieved from computers, hard drives, and cloud storage. It can be easily transferred electronically over email and stored in digital as well as physical form. In this study, QR code was preferred over the conventional Universal Product Code (barcode), as the latter would become too long. The coding procedure was found to be technique sensitive in rugae where delineation of rugae was difficult. Not following the order or error in recording rugae invariably lead to false results. No two PRP of the study population had exactly matching PR codes or QR codes which meant that the Saudi population evaluated in this study has unique PRP, that is in congruity with results obtained from several similar studies conducted elsewhere.<sup>2,5,18–20</sup>

The study participants possess one of the largest numbers of PR reported in literature (mean 12.35; Table 3). This suggests an exaggerated tendency of ridge development and broader palates. In individual casts the highest number of rugae observed was 18 and the lowest was eight. The plausible reason for casts showing fewer ridges can be because rugae sometimes tend to merge with the rest of the palate on two-dimensional photographs leaving them undetected. The patient whose cast showed only eight rugae was not traceable to verify the number clinically. The total number of rugae in Saudi men outnumbered the women with a significant statistical difference, which was in contrast with studies by Bharath et al<sup>21</sup> and Rajan et al<sup>22</sup>

on an Indian population and Ahmed and Hamid<sup>23</sup> on a Sudanese population.

Each ruga possessed an average of two characteristics. The most prevalent rugae characteristic reported by Hermsilla et al<sup>24</sup> was wavy. This is in conformity with the present study when casts of men and women were considered together. Nayak et al<sup>18</sup> reported no incidence of circular/annular pattern in an Indian population while unification was rare. Cross-linked rugae followed by breaks were least prevalent in the present study. Nayak et al<sup>18</sup> also reported an insignificant difference in characteristics in men and women which is similar to our study. The total number of rugae characteristics was more in woman than men suggesting diversity in rugae forms in women.

A larger number of "strong" rugae occurring in men and "medium" rugae occurring in women can be due to the jaw size corresponding to the thickness of rugae. Similar results were reported in a Tibetan population.<sup>25</sup> Men had more curved rugae than women, while straight rugae were common in women: these findings are in conformity with Shetty et al's<sup>25</sup> findings and demonstrate the complexity and diversity of PRP. Paliwal et al<sup>26</sup> reported that the straight form of rugae was predominant in a central Indian population. PR development occurs throughout the palate as a whole and in a coordinated manner on both the right and left sides of the palate. The insignificant difference between the number of rugae on either side of the palate demonstrated in this study was in contrast to the findings of Dohke and Shigeo's<sup>20</sup> study. More rugae with "weak" strength and less characteristics occurring more commonly on the left side could mean that the Saudi population uses the right side teeth more for mastication than the left side. This is an assumption that needs statistical validation.

A successful attempt has been made to digitize PRP and generate scannable QR codes. The uniqueness and sexual dimorphism of the PRP has been reiterated in the examined Saudi population and a simple means of person identification and digital record keeping has been proposed. Further investigation utilizing three-dimensional imagery of the palate area and commercial feasibility of the digitized PRP needs to be explored. It is also imperative to analyze the effects of time on PRP.

## Conflicts of interest

The authors have no conflicts of interest relevant to this article.

## Acknowledgments

We would like to thank the Department of Orthodontics, King Khalid University College of Dentistry for allowing us to access their patient database. A special thanks to all the technicians in the Department for their support.

## References

1. Indira AP, Manish G, Maria PD. Palatal rugae patterns for establishing individuality. *J Forensic Dent Sci* 2012;4:2–5.

2. Gegenbauer C. Die gaumenfalten des menschen. *Morphologisches Jahrbuch* 1878;4:573–83 [In German].
3. Harjeet K, Keya S, Sanjeet S, Deepti J, Priyanka S. Determination of the biometric characteristics of palatine rugae patterns in Uttar Pradesh population: a cross-sectional study. *Indian J Dent Res* 2014;25:331–5.
4. Thomas CJ, Kotze TJ. The palatal rugae pattern: a new classification. *J Dent Assoc S Afr* 1983;38:153–7.
5. English WR, Robison SF, Summitt JB, Oesterle LJ, Brannon RB, Morlang WM. Individuality of human palatal PR. *J Forensic Sci* 1988;33:718–26.
6. Patil MS, Patil SB, Acharya AB. Palatine rugae and their significance in clinical dentistry: a review of the literature. *J Am Dent Assoc* 2008;139:1471–8.
7. Thomas CJ, van Wyk CW. The palatal rugae in an identification. *J Forensic Odontostomatol* 1988;6:21–7.
8. Caldas IM, Magalhaes T, Afonso A. Establishing identity using cheiloscopy and palatoscopy. *Forensic Sci Int* 2007;165:1–9.
9. Almeida MA, Phillips C, Kula K, Tulloch C. Stability of the palatal rugae as landmarks for analysis of dental casts. *Angle Orthod* 1995;65:43–8.
10. Hoggan BR, Sadowsky C. The use of palatal rugae for the assessment of anteroposterior tooth movements. *Am J Orthod Dentofacial Orthop* 2001;119:482–8.
11. Muthusubramanian M, Limson KS, Julian R. Analysis of PR in burn victims and cadavers to simulate PR identification in cases of incineration and decomposition. *J Forensic Odontostomatol* 2005;23:26–9.
12. Breault LG, Fowler EB, Billman MA. Retained free gingival graft rugae: a 9-year case report. *J Periodontol* 1999;70:438–40.
13. Bansode SC, Kulkarni MM. Importance of palatal rugae in individual identification. *J Forensic Dent Sci* 2009;1:77–81.
14. Dawasaz AA, Dinkar AD. Rugoscopy: predominant pattern, uniqueness and stability assessment in the Indian Goan population. *J Forensic Sci* 2013;58:1621–7.
15. Thomas CJ, Kotze TJ. The palatal rugae pattern in six southern African human populations, part 1: a description of the populations and a method for its investigation. *J Dent Assoc S Afr* 1983;38:547–53.
16. Hauser G, Daponte A, Roberts MJ, Palatal PR. *J Anat* 1989;165:237–49.
17. Limson KS, Julian R. Computerized recording of the palatal rugae pattern and an evaluation of its application in forensic identification. *J Forensic Odontostomatol* 2004;22:1–4.
18. Nayak P, Acharya AB, Padmini AT, Kaveri H. Differences in the palatal rugae shape in two populations of India. *Arch Oral Biol* 2007;52:977–82.
19. Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian Aborigines and Caucasians. *Aust Dent J* 1997;42:129–33.
20. Dohke M, Shigeo O. Morphological study of the palatal rugae in Japanese 1. Bilateral differences in the regressive evolution of the palatal PR. *Jpn J Oral Biol* 1994;36:127–40.
21. Bharath ST, Kumar GR, Dhanapal R, Saraswathi T. Sex determination by discriminant function analysis of palatal rugae from a population of coastal Andhra. *J Forensic Dent Sci* 2011;3:58–62.
22. Rajan VP, John JB, Stalin A, Priya G, Abuthagir AK. Morphology of palatal rugae patterns among 5-15 years old children. *J Pharm Bioallied Sci* 2013;5:S43–7.
23. Ahmed AA, Hamid A. Morphological study of palatal rugae in a Sudanese population. *Int J Dent* 2015;2015:650648.
24. Hermosilla VV, San Pedro VJ, Cantin LM, Suazo GIC. Palatal rugae: systematic analysis of its shape and dimensions for use in human identification. *Int J Morphol* 2009;27:819–25.
25. Shetty SK, Kalia S, Patil K, Mahima VG. Palatal rugae pattern in Mysorean and Tibetan population. *Indian J Dent Res* 2005;16:51–5.
26. Paliwal A, Wanjari S, Parwani R. Palatal rugoscopy: establishing identity. *J Forensic Dent Sci* 2010;2:27–31.