Int. J. Morphol.,
35(4):1224-1229, 2017.

Model Analysis of Anatomical Morphology Changes of Palatal Rugae Before and After Orthodontic Treatment

Análisis de Modelo de Cambios de la Morfología Anatómica de Rugas Palatinas Antes y Después del Tratamiento Ortodóntico

Li Bing[1]; Tae-Geon Kwon[2]; Wu Xiao[1] ; Hee-Moon Kyung[2]; Ke-Ming Yun[3] & Xiu-Ping Wu[1]

LI, B.; TAE-GEON, K.; WU, X. ; HEE-MOON, K. ; KE-MING, Y. & XIU-PING, W. Model analysis of anatomical morphology changes of palatal rugae before and after orthodontic treatment. *Int. J. Morphol., 35(4)*:1224-1229, 2017.

SUMMARY: Model analysis was performed to identify palatal rugae anatomical morphology patterns, evaluate their individual-specific properties and stability before and after orthodontic treatments, and investigate their reliability in the use for individual identification from the perspective of forensic dentistry. Maxillary models of 70 patients were collected before and after orthodontic treatments, palatine images were taken under standard conditions. Pattern-based individual identification was performed through measuring some indices including changes in number, orientation, shape, and length of palatal rugae, as well as mesial and distal endpoint displacement of palatal rugae in the anteroposterior (AP) and mesiodistal (MD) direction. At the same time, maxillary models of 10 patients were randomly selected for individuality confirmation and the average rate of correct matches was calculated. palatal rugae anatomical morphology patterns were highly individual-specific. Palatine of the same pattern were not found before or after orthodontic treatment. Model-based analysis confirmed the high individual-specificity properties of the palatal rugae anatomical morphology patterns, and also showed that the incidence of any morphological change in the patterns after orthodontic treatment was 45.7 % for anteroposterior displacement of the distal endpoint of palatal rugae, 40 % for mesiodistal displacement of the distal endpoint of palatine, 32.9 % for anteroposterior displacement of the mesial endpoint of palatal rugae, and 17.1 % for mesiodistal displacement of the mesial endpoint of palatal rugae. The incidence of change in length, orientation and shape of palatine after orthodontic treatment was 28.6 %, 1.4 % and 1.4 % respectively; and the incidence of palatal segmentation and unification after orthodontic treatment was 4.3 % and 2.9 % respectively. The mean percentage of correct matches of the palatine patterns after orthodontic treatment to their duplicates was 99.05 % and the mean percentage of correct matches of the palatine patterns between before and after orthodontic treatment was 92.19 %. Palatal rugae anatomical morphology patterns are unique to each individual. After orthodontic treatment, palatal rugae have diverse presentation patterns. Although the diverse palatine patterns to a certain degree, influence individual identification in the field of forensic identification, palatal rugae patterns can be used as a novel method for individual identification in forensic dentistry.

KEY WORDS: Forensic anthropology; Palatal rugae; Anatomical morphology; Identification; Orthodontics treatment.

INTRODUCTION

Individual identification in forensic dentistry refers to an event to identify unknown individuals according to the features of teeth, jaw bones, cheilogramma, and cheeks based on stomatological knowledge (Bailey *et al*., 1996; Bing *et al*., 2014; Wazir *et al*., 2015; Ali *et al*., 2016). The palatal rugae may remain intact during major disasters because of their position in the oral cavity. They are also of great research value, and are therefore, an increasing area of interest in the field of forensic dentistry all over the world (Gondivkar *et al*., 2011; Adisa *et al*., 2014; Patil *et al*., 2016; Wu *et al*., 2016). Clinical orthodontic treatment can cause morphological change in palatal rugae patterns, which make palatal rugae-based forensic identification more complex Shukla *et al*., 2011; Deepak *et al*., 2014; Selvamani *et al*., 2015; Mustafa *et al*., 2015). In China, there are scant reports about palatal rugae pattern stability after orthodontic treatment and the accuracy of taking palatal rouge pattern as a reference in forensic dentistry. In this study, we used model-based analysis to identify palatal rugae patterns, evaluate their individual-specific properties and their stability before and after orthodontic treatments, and investigate their reliability in use for individual identification from the perspective of forensic dentistry.

[1] Stomatology Hospital, Shanxi Medical University, Taiyuan, China.
[2] School of Dentistry, Kyungpook National University, Daegu, Korea.
[3] School of Forensic Medicine, Shanxi Medical University, Taiyuan, China.
Funding: Doctoral Fund of Shanxi Medical University, No. 03201428.

SUBJECT AND METHOD

Object of study. Seventy patients, consisting of 35 males and 35 females, who received treatment in the Department of Orthodontics, Shanxi Medical University Stomatological Hospital, China between June 2014 and December 2014, were included in this study after screening against the inclusion and exclusion criteria. Inclusion criteria: (1) age ≥18 years; (2) having no history of skull and jaw trauma; (3) having permanent dentition before orthodontic treatment; (4) subjected to orthodontic treatment with straight wire for 12-24 months. Exclusion criteria: (1) having congenital anomalies/malformations; (2) bone and soft tissue protrusion, active lesions; (3) palatal deformity, scars or trauma; (4) mouth opening limited; (5) having a history of wearing a maxillary denture; (6) smoking.

Instruments and software. Silicone rubber impression material (DMG, Hamburg, Germany); type 3 dental super hard plaster (Heraeus Kulzer, Germany); perforated stainless steel instrument trays (Heraeus Kulzer); 2B pencil; magnifier; light source; Vernier caliper.

Preparation of palatal rugae models. Maxillary models of 70 patients were collected before and after orthodontic treatments. A perforated stainless steel instrument tray that had been filled with a silicone rubber impression material was pressed over the teeth. Type III dental stone casts were prepared. Each palatal rugae model should have complete clear surface without defects or air bubble. Palatal rugae models prepared before orthodontic treatment were included in group A and those prepared after orthodontic treatment in group B.

Fig. 1. Depicted morphology of palatal rugae patterns under magnification.

Analysis of palatal rugae models. According to Thomas and Kapali classification, under appropriate illumination and application conditions, midpalatal suture, palatal rugae, and incisive papilla were marked and the edge of the palatal rugae was depicted using a pencil Fig. 1.) The length of each palatal rugae, the vertical dimension between the mediodistal end of the palatal rugae and midpalatal suture, and the vertical dimension between mediodistal end of the palatal rugae and incisive papilla were measured using a Vernier caliper. Palatal rugae models of each patient were numbered, and those taken before and after orthodontic treatment were tagged as 'a and b' respectively, so these palatal rugae models were numbered as 1a, 1b, 2a, 2b, 3a, 3b, 70a, 70b. The morphology of palatal rugae patterns was categorized according to Thomas & Kapali classification and detailed as follows according to the method of Mustafa *et al*.: (1) the number of changes; (2) the direction of the change; (4) the length of the change; (5) far from the midpoint of the distal to the displacement; (6) near the midterm (7) the displacement of the proximal end of the center in the front and rear; (8) the displacement of the distal midpoint in the forward and backward directions.

Detection of individuality of the palatal rugae patterns. The individuality of the palatal rugae patterns was confirmed when the teeth of each model and the assigned number for each model were covered. In each group, one palatal rugae pattern model was matched to the remaining 69 models, thus there were 2415 matches in each group. Matches were made based on the following 17 questions. (1) Are they the same to the naked eye (2) Are the right palatal rugae the same (3) Are the left palatal rugae the same? (4) Is the total number of palatal rugae the same? (5) Is the number of primary palatal rugae the same? (6) Is the number of secondary palatal rugae the same? (7) Is the total number of the broken palatal rugae the same? (8) Is the total number of transversal palatal rugae the same? (9) Is the total number of forward palatal rugae the same? (10) Is the total number of backward palatal rugae the same? (11) Is the total number of irregular palatal rugae the same? (12) Is the total number of straight palatal rugae the same? (13) Is the total number of arc-shaped palatal rugae the same? (14) Is the total number of wave-shaped palatal rugae the same? (15) Is the total number of ring-shaped palatal rugae the same? (16) Is the total number of assembled palatal rugae the same? (17) Is the total number of scattered palatal rugae the same?

Matching test of palatal rugae patterns. The matching test of palatal rugae patterns was performed by 10 professional dentists. According to the morphological patterns of the palatal rugae, the models from group B were matched to those in group A (the teeth of each model and the assigned number were not exposed to the dentists

responsible for matching test). The duplicates of group B were included in group B'. Similar matching tests were made between group B' and group B. Each matching test was performed in triplicate. The mean percentage of corrected matches was calculated across triplicate matching tests.

Statistical analysis. All statistical analyses were performed using SPSS22.0 software. The frequency and percentage of each morphometric change of the palatal rugae were calculated. Paired t-test was used for match outcomes.

RESULTS

Morphological changes in palatal rugae patterns. The frequency of each morphometric change of the palatal rugae after orthodontic treatment (Fig. 2) is shown as follows. (1) Number of the palatal rugae: manifested as segmentation and unification of the palatal rugae, which increased or decreased the number of the palatal rugae. After orthodontic treatment, palatal segmentation occurred in 3 (4.3 %) patients and palatal unification in 2 (2.9 %) patients. (2) Orientation of the palatal rugae: change in orientation within a limited range occurred in 1 (1.4 %) patient. (3) Shape of the palatal rugae changed in 1(1.4 %) patient. (4) Length of the palatal rugae: elongated or shortened. (5) Palatal rugae distal endpoint displacement: distal endpoint displacement of the palatal rugae occurred in a relatively large proportion of patients: anteroposterior and mesiodistal displacement in 45.7 % and 40 % of patients, respectively. (6) Palatal rugae mesial endpoint displacement: anteroposterior and mesiodistal displacement in 32.9 % and 17.1 % of patients, respectively.

Individuality of palatal rugae patterns. Palatal rugae have a high degree of individual specificity, orthodontic treatment before and after the model did not find the same palatal rugae pattern.

Matching tests of the palatal rugae patterns before and after orthodontic treatment. The mean percentage of correct matches of the palatal rugae patterns after orthodontic treatment to their duplicates was 99.05 % and the mean percentage of correct matches of the palatal rugae patterns between before and after orthodontic treatment was 92.19 % ($P < 0.05$) (Tables I, II, Figs. 3-5)

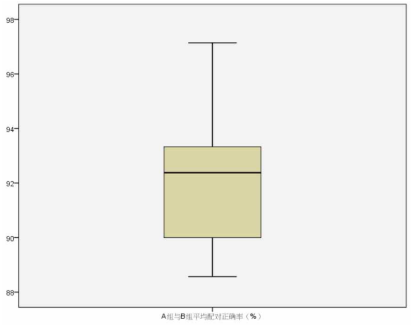

Fig. 3. Box plot of the mean percentage of correct matches of the palatal rugae patterns between groups A and B.

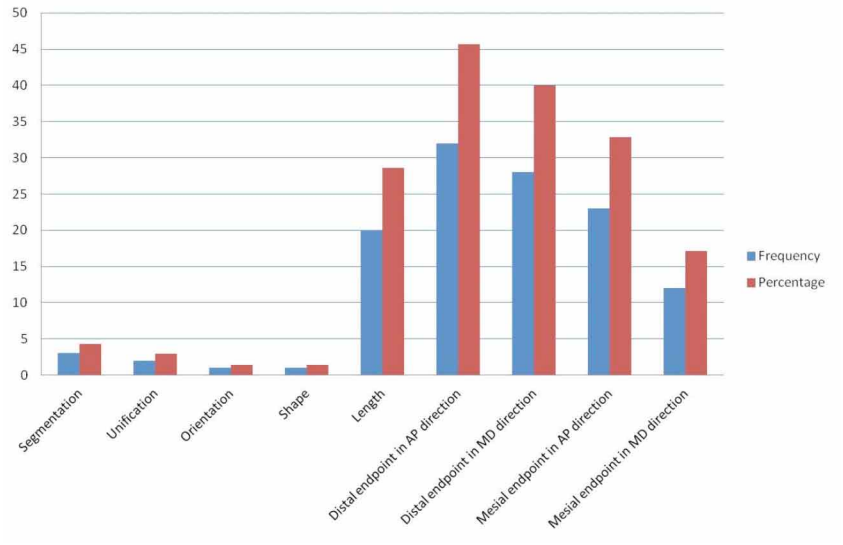

Fig. 2. Distribution of morphometric changes of palatal rugae patterns before and after orthodontic treatment.

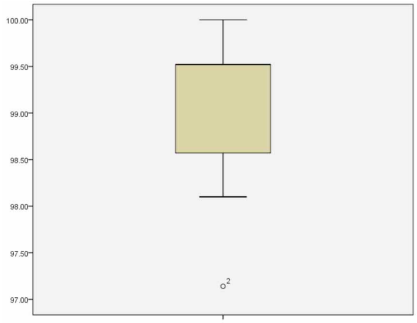

Fig. 4. Box plot of the mean percentage of correct matches of the palatal rugae patterns between groups B and B'.

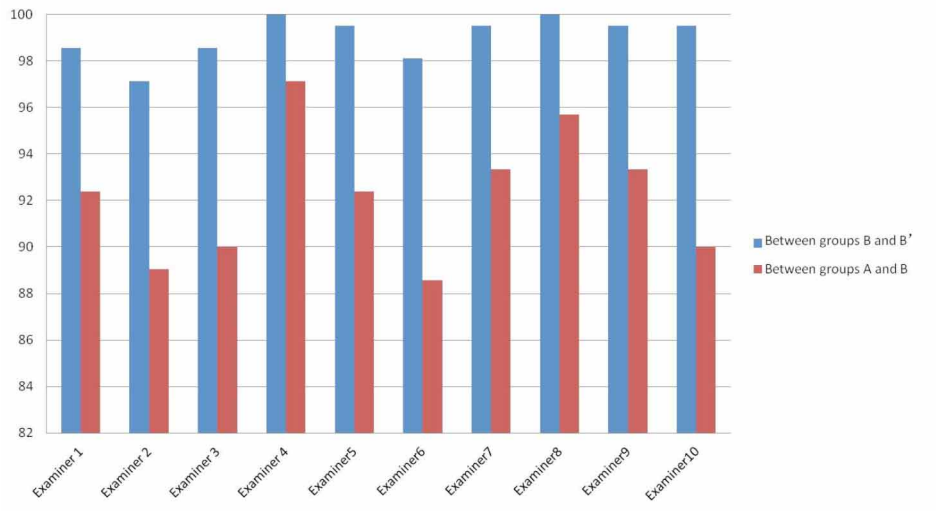

Fig. 5. The mean percentage (%) of correct matches of the palatal rugae patterns between groups B and B' and between groups A and B.

Table I. The mean percentage (%) of correct matches of the palatal rugae patterns among different subjects between groups

Examiner	Between groups B and B'	Between groups A and B	Difference
1	98.57	92.38	6.19
2	97.14	89.05	8.09
3	98.57	90.00	8.57
4	100.00	97.14	2.86
5	99.52	92.38	7.14
6	98.10	88.57	9.53
7	99.52	93.33	6.19
8	100.00	95.71	4.29
9	99.52	93.33	6.19
10	99.52	90.00	9.52

Table II. Paired t-test results

	$\bar{d}$	95% CI		t	p
		Lower	Upper		
The mean percentage of correct matches of the palatal rugae patterns between groups B and B' -the mean percentage of correct matches of the palatal rugae patterns between groups B and B'	6.86	5.30	8.41	9.96	.000

DISCUSSION

Palatal rugae patterns like fingerprints have genetic gene-matched individual-specific stability, diversity, and universality properties. From the point of view of forensic medicine, palatal rugae patterns contribute to forensic identification (Santos *et al*., 2011 Rath & Reginald, 2014; Poojya *et al*., 2015; Thabitha *et al*., 2015). There are controversies about whether diverse morphological changes of palatal rugae patterns after clinical orthodontic treatment can influence forensic identification.

Our results showed that after orthodontic treatment, the number of palatal rugae changed in 7.2 % of included patients, including segmentation in 3 (4.3 %) patients, and unification in 2 (2.9 %) patients. This differs from a previous

conclusion that the number of palatal rugae remained unchanged after orthodontic treatment. Our results occurred possibly because the methods and special procedures used in orthodontic treatment led to widened or narrowed palatal rugae. The moving teeth resulted in movement of the palatal rugae by drawing the soft tissue of the palatal rugae, which possibly cause unification or segmentation of the palatal rugae. Maxillary arch expansion treatment was not involved in previous reports.

No clinically significant changes in shape and orientation of the palatal rugae were previously reported. Our study showed that there were very limited changes in the shape and orientation of palatal rugae in 2.8 % of patients after orthodontic treatment. These findings suggest that the shape and orientation of the palatal rugae are likely to be the most stable morphological characteristics.

Our results also showed that the length of the palatal rugae changed greatly in 28.6 % of patients after orthodontic treatment, which is related to maxillary expansion treatment and front tooth restoring. After orthodontic treatment, the distal endpoint displacement of palatal rugae, in particular, the first and second rugae displaced greatly, in 85.7 % of the included patients. This is in agreement with a standpoint, proposed by Peavy & Kendrick that "the closer the rugae are to the teeth, the more prone they are to stretch in the direction that their associated teeth move" This is also consistent with the point of view of van der Linden & Almeida that change in shape of maxillary arch (for example expanding arch) and extraction of maxillary anterior teeth can lead to displacement of distal endpoint of the palatal rugae. The distal endpoint of the third palatal rugae is little influenced because of its position, so it is relatively stable.

The results in this study showed that the mesial endpoint of the palatal rugae was relatively unstable. The mesial endpoint of the palatal rugae displaced in 50 % patients (anteroposterior displacement in 32.9 % of patients and mesiodistal displacement in 17.1 % of patients). These results are contradictory with some previous reports that the mesial endpoint of the palatal rugae are stable and are therefore taken as the reference point for tooth movement in orthodontic treatment. Damstra considered that a rapid maxillary arch expansion in orthodontic treatment led to change in transversal size of the medioproximal end of the palatal rugae but it did not influence the anterioposterior size. This occurs possibly because the soft tissue of the palatal rugae stretched to different degrees during orthodontic treatment but recovered its original position.

The diverse morphological changes of the palatal rugae patterns hardly influence the matches before and after orthodontic treatment, with the average percentage of correct matches being 88.57-97.41 % (median 92.38 %), which is basically the same as previous reports. The average percentage of correct matches between duplicates and the palatal rugae following orthodontic treatment was 99.05 %, and it was 92.19 % between before and after orthodontic treatment. The difference between 99.05 % and 92.19 % was statistically significant.

Palatal rugae patterns are unique to each individual (Limson & Julian, 2004; Hemanth *et al*., 2010). After orthodontic treatment, palatal rugae have diverse presentation patterns. Although the diverse palatal rugae patterns to a certain degree influence individual identification in the field of forensic identification, palatal rugae patterns can be used as a novel method for individual identification in forensic dentistry.

LI, B.; TAE-GEON, K.; WU, X. ; HEE-MOON, K. ; KE-MING, Y. & XIU-PING, W. Análisis de modelo de cambios morfológicos anatómicos de rugas palatinas antes y después de un tratamiento ortodóntico. *Int. J. Morphol., 35(4)*:1224-1229, 2017.

RESUMEN: Se realizó un análisis de modelo para identificar los patrones de morfología anatómica de las rugosidades palatinas, evaluar sus propiedades individuales y estabilidad antes y después de los tratamientos ortodónticos e investigar su fiabilidad en el uso para la identificación individual desde la perspectiva de la odontología forense. Se recogieron modelos maxilares de 70 pacientes, antes y después de tratamientos ortodónticos, y se tomaron imágenes palatinas bajo condiciones estándar. La identificación individual basada en patrones se realizó a través de la medición de algunos índices incluyendo cambios en el número, orientación, forma y longitud de las rugas palatinas, así como el desplazamiento mesial y distal del punto final de las rugas palatinas en dirección antero-posterior (AP) y mesiodistal (MD). Al mismo tiempo, los modelos maxilares de 10 pacientes fueron seleccionados aleatoriamente para la confirmación de la individualidad y se calculó la tasa promedio de coincidencias correctas. Los patrones de morfología anatómica de las rugas palatinas eran altamente específicos de cada individuo. Una ruga palatina del mismo patrón no se encontró antes o después del tratamiento ortodóncico. El análisis basado en modelos confirmó las altas propiedades individuales de los patrones de morfología anatómica de las rugas palatinas y también mostró que la incidencia de cualquier cambio morfológico en los patrones después del tratamiento ortodóncico fue del 45,7 % en el desplazamiento anteroposterior de la porción distal de las rugas palatinas. Los porcentajes para el desplazamiento mesiodistal de la porción distal de la ruga palatina fue del 40 %, el desplazamiento anteroposterior del extremo mesial de las rugas palatinas presentó un porcentaje del 32,9 %, y 17,1 % para el desplazamiento mesiodistal del extremo mesial de las rugas palatinas. La incidencia de cambio de longitud, orientación y forma de la ruga palatina después del tratamiento ortodóncico fue de 28,6 %, 1,4 % y 1,4 %, respectivamente; la incidencia de segmentación y unificación de rugas palatinas después del tratamiento ortodóncico fue

de 4,3 % y 2,9 % respectivamente. El porcentaje medio de coincidencias de los patrones de rugas palatinas después del tratamiento ortodóncico con sus duplicados fue del 99,05 % y el porcentaje medio de coincidencias correctas de los patrones de las rugas palatinas antes y después del tratamiento ortodóncico fue del 92,19 %. Los patrones de morfología anatómica de las rugas palatinas son únicos para cada individuo. Después de un tratamiento ortodóncico, las rugas palatinas presentan diversos patrones. No obstante, los diversos patrones de rugas palatinas influyen en cierto grado en la identificación individual forense; los patrones de las rugas palatinas pueden ser usados como un nuevo método para la identificación individual en odontología forense.

PALABRAS CLAVE: Antropología Forense; Rugas palatinas; Morfología anatómica; Identificación; Tratamiento de ortodoncia.

REFERENCES

Adisa, A. O.; Kolude, B. & Ogunrinde, T. J. Palatal rugae as a tool for human identification. *Niger J. Clin. Pract., 17(5)*:641-3, 2014.

Ali, B.; Shaikh, A. & Fida, M. Stability of palatal rugae as a forensic marker in orthodontically treated cases. *J. Forensic Sci., 61(5)*:1351-5, 2016.

Bailey, L. T.; Esmailnejad, A. & Almeida, M. A. Stability of the palatal rugae as landmarks for analysis of dental casts in extraction and nonextraction cases. *Angle Orthod., 66(1)*:73-8, 1996.

Bing, L.; Wu, X. P.; Feng. Y.; Wang, Y. J. & Liu, H. C. Palatal rugae for the construction of forensic identification. *Int. J. Morphol., 32(2)*:546-50, 2014.

Deepak, V.; Malgaonkar, N. I.; Shah, N. K.; Nasser, A. S.; Dagrus, K. & Bassle, T. Palatal rugae patterns in orthodontically treated cases, are they a reliable forensic marker? *J. Int. Oral Health, 6(5)*:89-95, 2014.

Gondivkar, S. M.; Patel, S.; Gadbail, A. R.; Gaikwad, R. N.; Chole, R. & Parikh, R. V. Morphological study of the palatal rugae in western Indian population. *J. Forensic Leg. Med., 18(7)*:310-2, 2011.

Hemanth, M.; Vidya, M.; Shetty, N. & Karkera, B. V. Identification of individuals using palatal rugae: Computerized method. *J. Forensic Dent. Sci., 2(2)*:86-90, 2010.

Limson, K. S. & Julian, R. Computerized recording of the palatal rugae pattern and an evaluation of its application in forensic identification. *J. Forensic Odontostomatol., 22(1)*:1-4, 2004.

Mustafa, A. G.; Allouh, M. Z. & Alshehab, R. M. Morphological changes in palatal rugae patterns following orthodontic treatment. *J. Forensic Leg. Med., 31*:19-22, 2015.

Patil, S. B.; Patil, M. S.; Smita, B. R. & Hebbar, K. G. Rugae dimensions and their significance in forensic dentistry. *J. Forensic Dent. Sci., 8(1)*:57-8, 2016.

Poojya, R.; Shruthi, C. S.; Rajashekar, V. M. & Kaimal, A. Palatal rugae patterns in edentulous cases, are they a reliable forensic marker? *Int. J. Biomed. Sci., 11(3)*:109-12, 2015.

Rath, R. & Reginald, B. A. Palatal rugae: An effective marker in population differentiation. *J. Forensic Dent. Sci., 6(1)*:46-50, 2014.

Santos, K. C.; Clemente, M. S. & Serra, M. C. Evaluation of a digital methodology for human identification using palatal rugoscopy. *Braz. J. Oral Sci., 10(3)*:199-203, 2011.

Selvamani, M.; Hosallimath, S.; Madhushankari; Basandi, P. S. & Yamunadevi, A. Dimensional and morphological analysis of various rugae patterns in Kerala (South India) sample population: A cross-sectional study. *J. Nat. Sci. Biol. Med., 6(2)*:306-9, 2015.

Shukla, D.; Chowdhry, A.; Bablani, D.; Jain, P. & Thapar, R. Establishing the reliability of palatal rugae pattern in individual identification (following orthodontic treatment). *J. Forensic Odontostomatol., 29(1)*:20-9, 2011.

Thabitha, R. S.; Reddy, R. E.; Manjula, M.; Sreelakshmi, N.; Rajesh, A. & Kumar, V. L. Evaluation of palatal rugae pattern in establishing identification and sex determination in Nalgonda children. *J. Forensic Dent. Sci., 7(3)*:232-7, 2015.

Wazir, S. S.; Arora, P.; Srivastava, R. & Rastogi, S. Forensic application of palatal rugae in dental identification. *J. N. M. A. J. Nepal Med. Assoc., 53(199)*:151-5, 2015.

Wu, X. P.; Han, J. N.; Fen, P.; Wang, Y. J. & Bing, L. Application of palatal rugae morphology in forensic identification. *Int. J. Morphol., 34(2)*:510-3, 2016.

Corresponding author:
Xiu-Ping Wu
Stomatology Hospital
Shanxi Medical University
63 Xinjian Road
Taiyuan 030001
CHINA

E-mail: 77wxp@163.com

Received: 13-05-2017
Accepted: 14-07-2017