# **Original Article**

# Three-dimensional palatal anatomic characteristics' correlation with dermatoglyphic heterogeneity in Angle malocclusions

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# ABSTRACT

**Objectives:** To assess correlation of dermatoglyphic (DG) pattern with quantitative palatal anatomic parameters measured using three-dimensional (3D) scanning of dental casts and to explore the possibility of utilizing these to predict future occurrence of malocclusion.

**Materials and Methods:** Pretreatment casts of 477 Saudi Arabian patients were divided into Class I, II, and III malocclusion groups. Fingerprints were recorded for all hand digits using a digital biometric device. Maxillary arch analysis was accomplished including intercanine, intermolar distance, palatal height, and palatal area. The results were statistically analyzed.

**Results:** The mean surface area of the palate was highest in Class II malocclusion. The DG pattern was not significantly associated with the type of malocclusion, except in the instance of the double loop characteristic (P = .05). There was a strong correlation, however, between DG characteristics like simple arch, loop, and double loop and palatal dimensions (intercanine, intermolar distance, and palatal height). Heterogeneity of DG pattern could be reliably used to predict palatal dimensions. Logistic regression revealed that only tented arch, symmetrical, spiral DG patterns and palatal area were significant but weak predictors of Angle malocclusion (P < .05).

**Conclusions:** A novel correlation of DG pattern with 3D palatal anatomic characteristics was assessed in different Angle malocclusion classes. Few of the DG characteristics and palatal dimensions showed significant correlations. However, only some of these were significant predictors of Angle malocclusion. (*Angle Orthod.* 2019;89:643–650.)

**KEY WORDS:** Orthodontic(s); Oral diagnosis; Growth/development; Dental anatomy; Craniofacial biology/genetics

# INTRODUCTION

Early interception in orthodontics during the growth phase is an important aspect in attaining proper esthetic and functional goals for a dental patient with maxillo-mandibular discrepancy. Some studies<sup>1</sup> on monozygotic and dizygotic twins demonstrated 100% and 90% concordance, respectively, for Angle Class II division 2 malocclusion. Hence, it can be concluded that genetics plays a major role in the development of Class II division 2 malocclusion. However, it was also observed<sup>2</sup> that monozygotic twins were not occlusally identical after analyzing their dental arch structure and individual teeth.

An important anatomic characteristic that is a sensitive predictor of various congenital anomalies and genetic disorders is dermatoglyphics (DG),<sup>3</sup> the study of epidermal ridges on the palmar surfaces of the

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hands. Several researchers<sup>4</sup> have claimed a high degree of accuracy in prognosis of disorders using DG patterns. DG can become a primary means of assessing complex genetic traits in the future. Various studies<sup>5</sup> have documented a relationship between DG and dental malocclusions. The heterogeneous nature of DG<sup>6</sup> can be a possible factor for distinguishing different malocclusions among the population.

Dental malocclusion has also been linked to the growth of the palate. It is said<sup>7</sup> to be a key anatomical structure, given its morphology and position in determining skeletal patterns. A review of the literature<sup>8</sup> revealed variations in the arch dimensions that exist between different malocclusion groups. Palatogenesis and dermatoglyphic development overlap during the first trimester (fourth through ninth weeks and sixth through 24th weeks, respectively).<sup>9</sup> Palatal dimension (PD) and its relationship to various Angle classes of malocclusion remains to be established for the ethnic Arab population in Abha, Saudi Arabia.

DG patterns that are unique and genetically influenced should exhibit a relationship with malocclusion, and vice versa.<sup>10</sup> Hence, this uniqueness could also bear a relationship to specific PD characteristics. Dermatoglyphic study is reliable, noninvasive, and comprises a low-cost digital technology that can be easily archived, yielding much better patient compliance than is associated with DNA tests.<sup>11</sup>

It would be beneficial to devise a methodology with which to predict future occurrence of malocclusion. There has been some reported literature<sup>12</sup> that was designed to assess DG pattern as a risk factor in Angle malocclusions. However, there is no reported study in a southwestern Saudi Arabian population. There has also been a lack of population norms with respect to maxillary arch dimensions for the Abha region of Saudi Arabia.

The primary aims of this novel study were to assess the heterogeneity of DG patterns and to record PD (palatal area, height, and intercanine and intermolar distances) in a three-dimensional (3D) format in Angle Class I, II, and III malocclusion patients and to correlate these two independent variables. The objective was to explore the possibility of utilizing DG pattern and PD in predicting future occurrence of malocclusion. Thus, the results of this study can aid in interceptive orthodontic treatment.

# MATERIALS AND METHODS

A cross-sectional study was designed with nonprobability convenience sampling. This study was registered and completed in the dental clinics of King Khalid University, Abha, Saudi Arabia, after obtaining ethical approval from the institutional ethical committee



Figure 1. Fingerprint pattern classification.

(Ethical Clearance No. SRC/ETH/2017-18/092). Systemically healthy dental patients between the ages of 21 and 35 years who attended orthodontic clinics at the College of Dentistry from August 2016 until February 2018 without any history of previous orthodontic treatment were recruited. Based on the previous records, these patients were subdivided into three broad groups of Angle malocclusion Classes I, II, and III (no subdivisions) by an orthodontist.

This human observational study manuscript conforms to STROBE guidelines for cross-sectional studies.

# Dermatoglyphics

The DG patterns of these patients were recorded for all 10 digits of the hands using a Green Bit Dactyscan<sup>®</sup> 84C fingerprint reader (Fulcrum Biometrics, Haryana, India) and categorized into loops, whorl, and arch, with their subtypes based on the modified classification<sup>13</sup> (Figure 1), as follows:

- 1. Loops: One or more ridges entering from one side and exiting from the same side comprises a loop. All loops have one delta. Loops were subclassified as single loop or double loop.
- 2. Whorl: Must contain at least two deltas and a type line. One ridge must complete the circuit. Ridge may be spiral, oval, or any variant of a circle.<sup>14</sup> The whorl was further subdivided into symmetrical and spiral whorls.
- Arches: They do not have a type line, deltas, or cores. Simple arch is the simplest and constitutes ridges extending from one side of the print to the

#### 3D PALATE AND FINGERPRINT IN MALOCCLUSIONS



Figure 2. Orientation of casts in the X-, Y-, and Z-axes.

opposite side at the center of the pattern, thus forming a wave-like structure. The tented arch is similar, but rises sharply in the center, causing a thrust/spike, or the ridges meet at an angle less than  $90^{\circ}$ .<sup>13</sup>

#### **Cast Analysis**

Good pretreatment casts of all the patients with a complete set of maxillary teeth with or without third molars were scanned using a inEos X5<sup>®</sup> 3D cast scanner (Sirona Dental Systems GmbH Fabrikstraße 31, 64625 Bensheim, Germany). The palatal area on the 3D images was examined on the computer screen using Minimagic 2.0 software (Materialise, Technologielaan 15, 3001 Leuven, Belgium).

The global coordination system in Rhino 5 software (McNeel Europe Roger de Flor, 32-,34 Barcelona, Spain) was used to orient all the cast images with the X-axis in line with the midline of the palate and the Z-axis in line with the frontal view (Figure 2).

#### Palatal Area (PA) Calculation

After orientation, the casts were transferred to another Meshmixer software (Version 3.5, Autodesk Inc, San Rafael, California, USA) for PA calculation in mm by extracting the palatal surface from the image (Figure 3). This was achieved by creating a closed loop by drawing a starting line at the distal end of the gingival contour of tooth 16 up to the distal end of tooth 26. Then this line was extended anteriorly along the free gingival margin of the anterior teeth and back up to the starting point. This selected area was then raised 11 mm from the original meshwork using the "extract" command. Finally, the area of this extracted palate was calculated using Rhino 5 software.

# Intercanine Distance (ICD) and Intermolar Distance (IMD) Measurement

ICD was measured as the distance between maxillary canine cusp tips or estimated cusp tips in attrited teeth. IMD was measured as the distance between the mesio-buccal cusp tips of the maxillary first molars or the estimated cusp tips in attrition cases.<sup>15</sup> ICD and IMD were measured using the "distance" tool of Minimagic 2.0 software in an axial view between the respective points on the teeth, as described.

#### Palatal Height (PH) Calculation

PH was measured (in millimeters) as the length of the perpendicular line from the deepest point on the palate on the midpalatal raphe joining a straight line from the deepest portion of gingival contours of teeth 16 and 26.



Figure 3. Palatal area extraction for 3D measurement.

# **Statistical Analysis**

All of the variables were analyzed by different observers having competence in analyzing DG pattern and utilization of 3D software to analyze maxillary arch parameters. Interobserver bias was evaluated using Kappa statistics (kappa index = 0.92). Skewness and kurtosis estimates for the dependent measures were within acceptable limits (skewness/standard error < 2.00).

Comparison of the three malocclusion classes (I, II, III) with DG patterns was done using Kruskal-Wallis analysis of variance (ANOVA), and comparison with PD was by one-way ANOVA. Spearman's rank correlation was used to assess the relationship between DG and PD, and ordered logistic regression was used to assess their predictive capability for malocclusion.

# RESULTS

A total of 498 participants were enrolled in this study, comprising 250 males and 248 females between 21 and 35 years of age. Out of 498 patients, two patients

did not give consent, while 19 casts had inadequate palatal surfaces and were excluded from the study.

The greatest number of patients in the sample population had Class II malocclusion (n = 239; 50.1%), followed by Class I (n = 154; 32.3%) and Class III (n = 84; 17.6%) malocclusions. 3D surface analysis revealed mean area in Class I, II, and III malocclusion groups to be 1453, 1500, and 1498 mm<sup>2</sup>, respectively (Table 1). The differences between malocclusion classes and simple arch, tented arch, loop, and symmetrical and spiral patterns were statistically not significant (P > .05). However, there was a significant difference for the double loop pattern (P < .05) (Table 2).

Spearman's rank correlation between DG and various PD parameters (Table 3) showed significant negative relationships between IMD and loop characteristic (R = -0.1066, P < .05), PD, and simple arch (R = -0.1205, P < .05), and a positive relationship was observed between ICD and the double loop characteristic (R = 0.1249, P < .05).

Ordered logistic regression (Table 4) showed tented arch, symmetrical, spiral DG patterns, and PA were significant predictors of malocclusion class (P < .05).

Table 1. Comparison of Three Malocclusion Classes (I, II, III) with Palatal Dimensions by One-way Analysis of Variance  $^{\rm a}$ 

Dimensions	Mean	SD	Median IQR		F-Value	P-Value
IMD						
Class I	37.09	3.31	36.72	2.30	0.8172	.4423
Class II	37.18	3.45	36.70	2.12		
Class III	37.66	3.50	37.04	2.27		
ICD						
Class I	33.02	2.82	32.75	1.62	1.6739	.1886
Class II	33.12	2.77	33.09	1.73		
Class III	33.69	2.90	34.22	2.10		
PH						
Class I	20.76	3.17	20.97	2.05	0.9599	.3837
Class II	20.35	2.71	20.65	1.79		
Class III	20.52	2.88	20.83	2.17		
PA						
Class I	1453.86	195.50	1485.98	152.63	2.8799	.0500*
Class II	1500.82	203.43	1489.66	144.29		
Class III	1498.48	183.21	1489.56	85.29		

 $^{\rm a}$  SD, standard deviation; IQR, interquartile range; IMD, intermolar distance; ICD, intercanine distance; PH, palatal height; and PA, palatal area. \* P < .05.

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In this study, no possible confounders were considered, and the above data reflected unadjusted estimates.

#### DISCUSSION

The dermatoglyphic investigation is cost-effective, convenient, and does not require any form of hospital

Table 2. Comparison of Three Malocclusion Classes (I, II, III) with Dermatoglyphic Patterns by Kruskal-Wallis Analysis of Variance^  $\,$ 

Patterns	Mean	SD	Median	IQR	H-Value	P-Value
Simple arch						
Class I	1.36	1.26	1.00	1.00	0.1030	.9500
Class II	1.36	1.19	1.00	1.00		
Class III	1.33	1.03	1.00	0.88		
Tented arch						
Class I	2.48	1.98	2.00	1.50	0.6030	.7400
Class II	2.61	1.90	2.00	1.50		
Class III	2.43	1.49	2.50	1.38		
Loop						
Class I	2.15	1.93	2.00	1.00	5.2350	.0730
Class II	2.48	1.90	2.00	1.00		
Class III	2.17	1.80	2.00	1.00		
Symmetrical						
Class I	1.14	1.09	1.00	1.00	3.4280	.1800
Class II	0.95	1.01	1.00	0.50		
Class III	1.04	1.07	1.00	0.50		
Spiral						
Class I	2.16	1.71	2.00	1.00	1.7980	.4070
Class II	1.91	1.51	2.00	0.50		
Class III	2.07	1.60	2.00	0.50		
Double loop						
Class I	0.71	0.79	1.00	0.50	5.7750	.0500*
Class II	0.69	0.83	0.00	0.50		
Class III	0.96	0.94	1.00	1.00		

<sup>a</sup> SD, standard deviation; IQR, interquartile range.

\* *P* < .05.

Dermatoglyphic	Palatal Dimensions					
Pattern	IMD	ICD	PH	PA		
Simple arch	0.0613	0.0414	-0.1205*	0.0082		
Tented arch	0.0790	0.0222	0.0411	0.0429		
Loop	-0.1066*	-0.0477	-0.0290	-0.0426		
Symmetrical	-0.0292	-0.0061	-0.0606	-0.0034		
Spiral	-0.0420	-0.0372	0.0456	0.0204		
Double loop	0.0923	0.1249*	-0.0239	-0.0328		

<sup>a</sup> IMD, intermolar distance; ICD, intercanine distance; PH, palatal height; and PA, palatal area.

\* *P* < .05.

stay.<sup>12</sup> Many researchers have investigated DG in the fields of genetics, anthropology, and forensic medicine. In the literature, there have been reports on the presence of irregular fingerprints in patients with some congenital anomalies, such as trisomy-21, breast cancer,<sup>16</sup> autism,<sup>17</sup> and skeletal abnormalities,<sup>18</sup> which has stimulated considerable interest in the field of medical dermatoglyphics. The same embryonic tissues form epidermal ridges of the fingers and palms, as well as facial structures, during the same intrauterine time period. Thus, this might be indicative of an association between DG and facial skeletal disorders, such as malocclusions.<sup>19</sup> Ethnicity of an individual has also been shown<sup>8,15,20</sup> to be a determining factor for DG and palatal anatomic characteristics.

#### **Dermatoglyphics and Angle Malocclusions**

There exists extensive literature on the genetic determinant of fingerprint patterns in every individual. The gene responsible for formation of fingerprints is known to be the SMARCAD1 gene, located on 4q22.3 [long (q) arm of chromosome 4 at position 22.3]. The SMARCAD1 gene provides instructions for making a unique skin-specific isoform for each individual, which is expressed only in skin cells and appears to play a critical role in the formation of DG. These ridges are also present on the toes, the palms of the hands, and the soles of the feet. It develops before birth and remains the same throughout life.<sup>21</sup>

The gene strongly associated with malocclusion has been identified as the MSX1 gene. It is located on chromosome 4p16 and is expressed in cranial neural crest cells, thus influencing the development of the nasal processes, maxilla, and mandible.<sup>22,23</sup> Previous study<sup>24</sup> has confirmed an important correlation between the MSX1 gene and Class I and II malocclusions.

As a result of the close association of those two genes on the same chromosome, it can be hypothesized that malocclusion and fingerprint pattern have a relationship. It was observed that only the double loop characteristic showed a significant association with

Independent Variables	Estimates	Std. Err.	Z-Value	P-Value	95% CI
Simple arch	-0.24	0.13	-1.8000	.0730	-0.50-0.02
Tented arch	-0.23	0.12	-1.9300	.0500*	-0.46-0.00
Loop	-0.17	0.11	-1.5600	.1180	-0.37-0.04
Symmetrical	-0.32	0.14	-2.2500	.0240*	-0.60 to -0.04
Spiral	-0.26	0.12	-2.0600	.0390*	-0.50 to -0.01
IMD	0.01	0.03	0.1700	.8660	-0.05-0.07
ICD	0.04	0.04	1.0300	.3010	-0.03-0.11
PH	-0.03	0.03	-0.9900	.3220	-0.09-0.03
PA	0.00	0.00	2,1400	.0320*	0.00-0.00

Table 4. Ordered Logistic Regression (LR) of Status of Malocclusion Classes by Dermatoglyphic Pattern and Palatal Dimensions<sup>a</sup>

LR Chi-square (with df = 9) = 13.83, P = .1285

<sup>a</sup> Std. Err., standard error; CI, confidence interval; IMD, intermolar distance; ICD, intercanine distance; PH, palatal height; and PA, palatal area. \* P < .05.

malocclusion (Table 2). This was similar to the results of Tikare et al.<sup>12</sup> They believed that sample size variations and an unclear protocol for fingerprint recording could contribute to varied results. An amalgamation of hereditary and environmental factors influences the abnormalities of fingerprint patterns. It was also proposed<sup>25</sup> that the underlying mechanism of variability in the DG pattern could result from factors such as inadequate oxygen supply, unusual distribution of sweat glands, and alterations of epithelial growth during intrauterine development. Another observation that the authors of this study came across was a common observation of heterogeneity of fingerprints in Class III malocclusion. This, by itself, may be a determinant factor in the development of malocclusion. It can be hypothesized that this variation in individual fingerprints may be an ultimate effect of an unknown stress during fetal development. Hence, DG may be a useful tool in trying to understand how genetic vulnerability interacts with the growth of Class III malocclusion.

In this study, an increased frequency of tented arch in all three malocclusion groups was found, which is consistent with observations by Reddy et al.<sup>26</sup> Their results showed Class II and Class III malocclusions to be associated with a high number of arches and loops. In addition, the current study results were consistent with those of Trehan et al.<sup>27</sup> They observed that Class II malocclusion was significantly associated with an increased frequency of arches. Thus, the association between malocclusion and DG pattern has been documented by only a few studies.<sup>25,26,28</sup>

# **Palatal Dimensions**

There has been no reported literature on the association of DG parameters with PD. Hence, the current study explored this novel idea of correlation to help predict patients' palatal dimensional characteristics using DG pattern. The classification used in DG

analysis may further be utilized as a reliable criterion for correlating PDs.

The association of malocclusion and PD has been studied previously8 comparing normal occlusion with open and deep bite,<sup>29</sup> Class I and II malocclusions,<sup>30</sup> and Class I and III malocclusions.<sup>31</sup> A study by Al-Sayagh<sup>20</sup> compared PD in four classes of malocclusion based on Angle classification in an Iragi population. Malocclusion and PD were assessed in ethnically different populations by multiple authors<sup>12,15,20,29,32</sup> who have documented varied results, thereby confirming the influence of ethnicity. The current study aimed at correlating PD and DG pattern in malocclusion classes. It was observed that there were no significant differences between any of the palatal anatomic parameters and Angle malocclusion groups except PA. This finding was in contrast with the previous literature.<sup>20,32,33</sup> Variations in sample size and absence of clear protocol in most previous studies might have contributed to contradictory results. A combination of hereditary, environmental, and local factors influences palatal anatomy. The variations would occur only when the combined factors exceed a certain threshold level.<sup>26</sup> Hence, the factors that are responsible for PD and malocclusion might not cross this threshold level for the clinical manifestation to occur. The current study was unique because it employed measurements on a 3D image rather than using a two-dimensional analysis.

The tendency toward decreased maxillary palatal area in Class I malocclusion (Table 1) was compatible with a multifactorial determination or gene/environment interaction. It can also be said that certain environmental factors may affect some genetically determined craniofacial phenotypes. This tendency could be explained, at least in part, by the interracial mixing of different populations, which is a feature of 'globalization.' There is indisputable evidence for a significant genetic influence in many dental and occlusal variables, while phenotype is the result of both genetic and environmental factors.<sup>1</sup>

# CONCLUSIONS

- This study used a novel method of correlating heterogeneity of DG pattern and PD in Angle malocclusions.
- A few of the fingerprint and palatal characteristics correlated strongly.
- However, only some of them can significantly predict Angle malocclusions.
- Further studies to assess longitudinal growth characteristics of the palate and to correlate them with DG pattern could be promising in predicting future occurrence of malocclusion.

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#### Disclosure

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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