Submitted: 02 February, 2023 Accepted: 03 March, 2023 Published: 03 September, 2023 DOI:10.22514/jocpd.2023.063

Journal of Clinical Pediatric Dentistry

ORIGINAL RESEARCH

Association between the occurrence of buccally displaced canine and palatal and craniofacial morphology in adolescents

Yuhsin Choi[1], Shuting Zhang[1], Danni Shi[1], Muhsuan Liu[1], Wa Li[1], Pei Tang[1], Kokkun Choi[2], Xin Yang[1,*], Jianyong Wu[1,*]

[1]Department of Stomatology, XinHua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, 200092 Shanghai, China
[2]Centre for Gaming and Tourism Studies, Macao Polytechnic Institute, 999078 Macao, China

***Correspondence**
yangxin@xinhuamed.com.cn
(Xin Yang);
wujianyong@xinhuamed.com.cn
(Jianyong Wu)

Abstract

The main objective of the present research study is to evaluate the association between the occurrence of buccally displaced canine (BDC) and the palatal as well as the craniofacial morphology in adolescents in accordance at the early permanent dentition. As the experimental group, 100 adolescents of Chinese ethnicity (mean age 13.05 years) with crowding and buccally displaced canine (BDC-c) were selected in comparison with the same number of candidates (mean age 12.59 years) without BDC and crowding as control group. Digital dental casts and cephalograms were collected for three dimensional (3D) and cephalometric measurements. An independent sample T-test was used to compare the cephalometric values between the two groups. Logistic regression as commonly statistical methods used in empirical study including categorical dependent variables was used to identify the joint effects of the dental variables' 3D measurements. When comparing the groups with above analysis, patients with BDC showed a statistically significant narrower and higher palatal vault. For the cephalometric variables, the anterior cranial base length, sagittal position of the maxilla (SNA), sagittal position of the mandible (SNB), and skeletal relationship between maxilla and mandible (ANB) appeared to be smaller, whilst palatal plane angle (SN-PP), Frankfort-mandibular plane angle (FMA), anterior facial height, and lower facial height were larger in BDC-c control group ($p < 0.05$). A smaller inter-first premolar width was significant in the prediction model ($p = 0.002$). This study highlights that BDC-c participants in early permanent dentition exhibited a narrower dental arch and higher palatal vault, of which a smaller inter-first premolar width would significantly increase the occurrence of BDC.

Keywords

Cephalometry; Cuspid; Ectopic eruption; Maxillary morphology; Three-dimensional

1. Introduction

Maxillary canines play an important role in facial esthetics and maintain stability in guiding occlusion [1]. Canines usually erupt at the age of 13 years old for boys, and 12 years old for girls, respectively. The incidence of canine impaction occurs eight times more frequently than buccal canine impaction [2]. Maxillary canines are the most frequently impacted teeth in the dental arch after the third molars [3]. Buccally displaced canine (BDC) are more likely to erupt than palatally displaced canine (PDC) [4]. In this study, we compared BDC dentitions with no crowding (BDC-nc) and BDC dentitions with crowding (BDC-c).

BDC-nc is related to genetic factor—primary tooth bud displacement due to the abnormal genetic pattern. Whereas, BDC-c is caused by insufficient space of the dentition. The main contributing factors to crowding are the relatively larger tooth size and shorter dental arch, leading to eruption of BDC-c [5, 6]. An early loss of deciduous tooth and consequent mesial drift of 6, 5, 4 are also common cause of the canine becoming crowded out of the arch [7]. Various studies have found that larger tooth size is not responsible for the maxillary crowding in contrast to the smaller dental arch, providing evidence that smaller maxilla dimensions including arch lengths, widths, and perimeters are found along with asymmetric and irregular arch in the crowded arch [8]. Research study carried out by Suri *et al.* [9] revealed that racial and ethnic factors have both influence in eruption. The purpose of this study was to investigate the incidence of any association of buccally erupted canine in early permanent crowded dentition with palatal dimensions and craniofacial measurements in adolescents of Chinese ethnicity that may add clues of the racial and ethnic influence to the literature.

Some authors stated that BDC is associated with a narrower

This is an open access article under the CC BY 4.0 license (https://creativecommons.org/licenses/by/4.0/).
 ©2023 The Author(s). Published by MRE Press.

and higher palatal vault [10]. However, studies assessing the relationship of BDC with palatal and craniofacial morphology have conveyed inconsistent results, while to evaluate the palatal morphology of BDC by using 3D measurement method are even fewer [1, 11, 12]. To the best of our knowledge, the only research trails so far are primarily in the study of morphology in the mixed and permanent dentition [12, 13], and adolescents with early permanent dentition have yet to be explored. In addition, there are fewer research studies which had investigated the association of craniofacial morphology with BDC [11, 12].

Given the lack of solid evidence of BDC-c in adolescent stage of Chinese, this study aimed to investigate whether the palatal dimensions discrepancy and craniofacial abnormity is associated with the occurrence of BDC in crowded early permanent dentition. The null hypothesis is that any experimentally observed differences in adolescents of Chinese ethnicity with BDC-c in the early permanent dentition will exhibit similar palatal and craniofacial morphology to those without BDC and crowding in the comparison group.

2. Materials and methods

2.1 Setting and study procedures

Of all the untreated patients enrolled for orthodontic treatment during January 2017 to April 2021 in Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, 635 adolescents of Chinese ethnicity were selected. After checking the selection criteria through patients' medical journal and cone-beam computed tomography (CBCT), and eliminating the unqualified dental casts and cephalograms, 100 eligible patients diagnosed with moderate crowding in the early permanent dentition phase from their records were selected as the BDC-c study group, while another 100 adolescents with no BDC, PDC and crowding were selected as the control group (Table 1).

TABLE 1. Characteristics of participants (n = 200).

Characteristic	BDC-c group (n = 100)	Control group (n = 100)
Gender		
Male	41	37
Female	59	63
Age		
Mean (SD)	13.05 yr (SD 1.29)	12.59 yr (SD 1.17)
Range	12–14	12–14
Angle's Class		
Class I	38	47
Class II	50	43
Class III	12	10

BDC-c, buccally displaced canine with crowding; SD, standard deviation.

2.2 Inclusion criteria

The inclusion criteria for the study group were designed as shown below:

1. Either maxillary unilateral or bilateral BDC with crowding and insufficient space for maxillary canine to occupy.
2. Early permanent dentition with completely erupted canines.
3. Adolescents of Chinese ethnicity age between 12 and 16 years old.
4. No premature loss of any primary tooth (information assessed from patients' medical journal).
5. No retained primary teeth or impacted tooth.
6. No abnormal tooth including fused tooth, germinated tooth, concrescence of tooth, hypodontia, hyperdontia (*e.g.*, supernumerary teeth), *etc.*
7. No previous orthodontic treatment.
8. No congenital diseases or anomalies such as cleft lip and palate.

2.3 3D measurement method variables

Within this study, the variables are comprised of both 3D model measurements of the dental casts and 2D lateral cephalometric measurements for all participants. For 3D measurements, inter-canine (W3), inter-first premolar (W4), inter-second premolar (W5), and inter-molar (W6) transverse widths at the buccal cusps were chosen for further evaluations. Depths at the buccal cusps levels of canine (D3), first premolar (D4), second premolar (D5), and first molar (D6) as well as the palatal surface area (SA) and volume (VOL) were measured. To identify dental variables which is served to distinguish BDC-c patients from control group, W3 and D3 were particularly included in the logistic regression model due to the salient feature from the control group (*i.e.*, buccally displaced reference point for the BDC-c patients versus the non-displaced point for the control) in order to understand if it can capture the effect of other dental variables. As for 2D lateral cephalometric measurements, 17 cephalometric measurements were recorded.

2.4 3D measurement method

A 3D scanner (3 Shape 3D Scanner, D800, 3Shape A/S, Copenhagen, Denmark) was used to analyse the dental casts. Collected data further were exported to the Geomagic Wrap 2015 software (Geomagic, Research Triangle Park, NC, USA) for manual processing. Following the detailed study by our group, three planes were set up by using customised method which is described here. The gingival plane was created by connecting the midpoints (the lowest points) of the dentogingival junction of all permanent teeth. The distal plane was set up through two points at the distal surface of the first molar perpendicular to the gingival plane. Both the gingival plane and distal plane were defined as the boundaries of the palate such that the surface area and volume can be easily measured. The sagittal plane was created by passing through the frontmost anterior point of the incisive papilla which is considered to be stable point. The three planes were chosen to be perpendicular to each other as much as possible (Fig. 1A–C). The palatal surface area and volume were calculated by software analysis. The transverse widths were measured directly between the buccal cusps of contralateral teeth, while the depths of the palate vault were measured as the vertical distances from the palate vault to the connecting lines between the contralateral buccal cusps (Fig. 1D–G) [13–15]. All lateral cephalogram (LC) data were imported to the Dolphin Imaging software (Dolphin Imaging 11.95 Premium, Patterson Dental Supply Inc., Chatsworth, CA, USA) and orientated at the Frankfort-horizontal plane. 20 landmarks were then marked later to obtain 17 skeletal cephalometric measurements (Fig. 2).

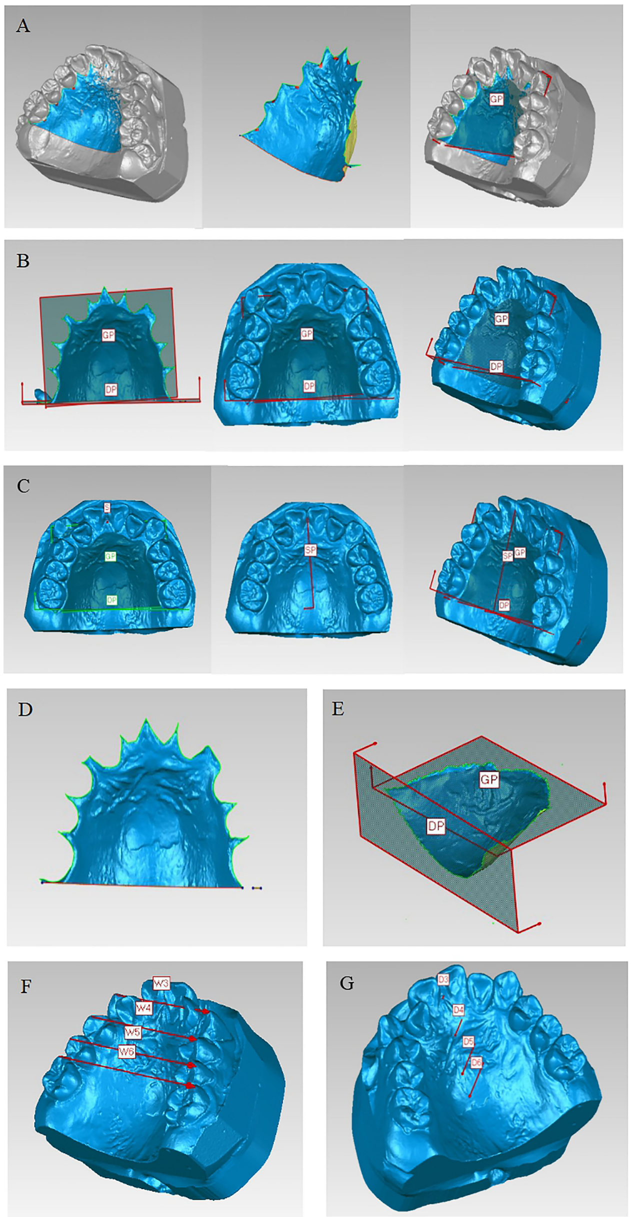

FIGURE 1. The customised method of setting up three planes and 3D measurements. A. Gingival plane (GP). B. Distal plane (DP). C. Sagittal plane (SP). D. Palatal surface area. E. Palatal volume. F. Transverse widths between inter-canines (W3), inter-first premolars (W4), inter-second premolars (W5), and inter-molars (W6) respectively. G. Depths between inter-canines (W3), inter-first premolars (W4), inter-second premolars (W5), and inter-molars (W6), respectively.

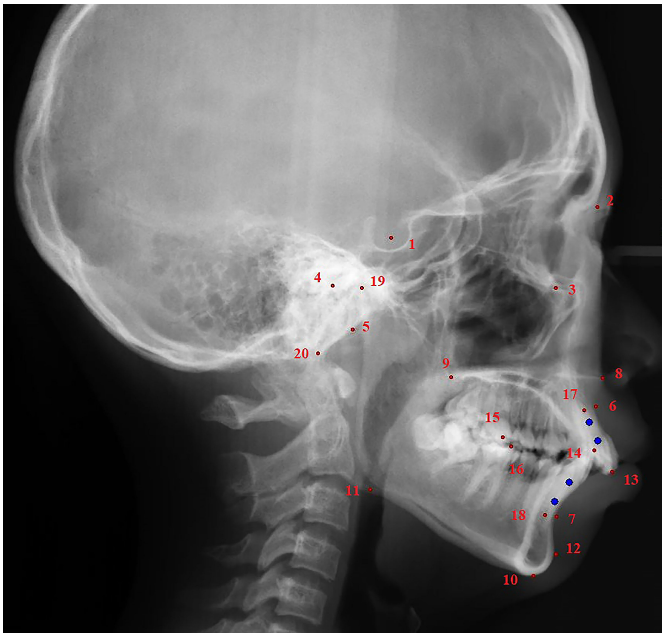

FIGURE 2. The cephalometric landmarks. 1. Sella, S. 2. Nasion, Na. 3. Orbitale, Or. 4. Porion, Po. 5. Articular, Ar. 6. Point A, A. 7. Point B, B. 8. Anterior nasal spine, ANS. 9. Posterior nasal spine, PNS. 10. Menton, Me. 11. Gonion, Go. 12. Pogonion, Pog. 13. Upper central incisor cusp tip, U1. 14. Lower central incisor cusp tip, L1. 15. Upper first molar buccal-mesial cusp, U6M. 16. Lower first molar buccal-mesial cusp, L6M. 17. Upper central incisor root, U1R. 18. Lower central incisor root, L1R. 19. Condyloid process, Co. 20. Basion, Ba.

2.5 Statistical analysis

The effects of the research variables were analysed by using SPSS 24.0 (SPSS Inc., Chicago, IL, USA). All 3D model measurements and cephalometric measurements were performed three times independently by the same practitioner with an interval of one week for three consecutive weeks to ensure the data were measured accurately and consistently. Single rater measurement error is assessed with an ICC (Intraclass correlation coefficient) Index by use of absolute agreement between repeated measurement definition to confirm the reliability of measurements.

Independent-samples *T* tests were conducted to evaluate any dental and cephalometric variable's differences between BDC-c and control groups. For 3D models, multiple binary logistic regression models were employed to evaluate any of the above predictor's effects on the odds of predicting the BDC-c study group, using 0.5 as the endpoint of cut-off from the default control group.

Logistic Regression analysis was used to identify the joint effects of the dental variables' 3D measurements; however, the sample size of the current study precluded the inclusion of the 17 cephalometric variables into the model. Various assumptions of logistic regression were tested. Spearman's rho was used to identify issue of multi-collinearity, and any predictor pair with correlation coefficient of over 0.8 would signal the need to drop either one of the pair from the model.

Box-Tidwell transformation technique was applied to identify nonlinearity of the independent variables, and both VOL and SA were therefore excluded from the model. Outlier detection was performed by comparing the Mahalanobis distance with a critical value of χ^2 (Chi-Square) distribution. Any value less than 0.001 would suggest an outlier and to be examined. Only one BDC-c case had a *p*-value (0.0004) due to its large Mahalanobis distance. Further inspection of the participant's dental variables did not show any special differences from all other cases. Hence it was decided not to exclude it.

3. Results

A large number of clinical research studies (200 subjects) are conducted, including BDC-c group with a mean age of 13.05 $\pm$ 1.29 years and control group with mean age of 12.59 $\pm$ 1.17 years. Angle classification for BDC-c group had more Class II patients (50), followed by Class I (38), and Class III (12), while control group had more Class I patients (47), followed by Class II (43) and Class III (10) (Table 1).

The correlations for all the weekly measurements for dental and cephalometric variables had well exceeded the respective lowest of 0.94 and 0.8 from ICC, suggesting reliability of the repeated measurements.

Using independent samples *T*-test, VOL, SA, W4, W5, W6, D3 and D4 of BDC-c group were significantly smaller, while W3 and D6 were larger than those of control group ($p < 0.05$). As for the cephalometric variables, SN, SNA, SNB, and ANB of BDC-c group were significantly smaller, while the SN-PP, FMA, N-Me and ANS-Me were larger than those of control group ($p < 0.05$) (Table 2).

The binary logistic regression analysis revealed that D3, W3, W4 and W6 were all significant in predicting the odds of having a BDC-c. Specifically, while keeping other predictors unchanged, for every 1 mm increase would lower the odds of being BDC-c by 0.30 times for D3 and 0.45 times for W4; and therefore, it would raise the odds by 2.19 times for W3 and 1.35 times for W6, respectively (Table 3).

4. Discussion

4.1 3D analysis of the maxilla abnormality with BDC-c

Larsen *et al*. [12] described that transverse distance between molars was significantly larger in both BDC and PDC group of subjects around 13 years old. Meanwhile, Ikoma and Aria [11] did not find any significant differences in the inter-canine transverse widths in adults with BDC. In the present study, we focused on the early permanent dentition and found that in participants with BDC-c, W3 was greater while W4, W5 and W6 were smaller. Our finding clearly suggests that participants with BDCs have a narrower posterior dental arch than those in control group.

Bizzarro *et al*. [13]'s observation in children with BDC by using cusps of primary canines as reference points revealed that the anterior depths increased slightly whilst posterior depths decreased insignificantly in comparison with control group. In contrast, Ikoma and Aria [11] stated that women with BDC had smaller anterior depths, which agrees with the current results that the anterior vertical depths were smaller and posterior vertical depths were larger in BDC-c group. The reference points selected in previous studies were the cusps of the ectopic permanent canine, and hence it was referred as landmarks in our study, hinting that the smaller anterior depths can be due to the eruption height of the ectopic permanent canines at the transition stage and affected by the participants' ethnicity, races, growth or tooth sizes, and thus, more stable landmarks for measuring ectopic permanent canines still need to be evaluated. Seto *et al*. [16] revealed that palatal height itself is not a reliable indicator of maxillary constriction and that the width must also be taken into account when assessing constriction. To avoid the confusion of the contradictory results, SA and VOL were introduced in our study to avoid biases caused by tooth position and angulation. Moreover, these two 3D measurements have been previously verified as reliable indicators of palatal and maxillary arch growth [14]. Meanwhile, adolescents with BDC-c were found to establish a smaller palatal volume and surface area than control group, suggesting that crowding due to smaller palatal vault in all three-dimensions might attribute to BDC-c. Furthermore, logistic regression model was used to investigate whether BDC-c is the result of the deviated growth of the maxillary complex or whether deviation in eruption is independent from morphology of the maxillary complex. Besides, it also suggested that these variables should be considered simultaneously as a whole. The need for 3D measurement is justified by statistical outcome of the model, which had a high correct prediction rate of 91%. As implied from the statistical outcome, reduced W4 and D3 with greater W3 and W6 together tend to relate to the occurrence of BDC-c, suggesting that BDC-c would more likely to appear with a narrower dental arch at corresponding first premolar region. Such phenomenon could possibly be caused by earlier eruption of premolar, leaving insufficient space for the canine, and resulting in a higher and/or more buccal positioned canine, thus a shorter D3 and wider W3. Growth in widths of dental arches tends to be completed before adolescent growth spurt, and therefore it is affected minimally even if there is growth change in which inter-canine width also seems to decrease after age 12 [17]. At the same time, most canines have erupted by age 12–13. In this way, the arch width not only provides little space for canine, but also it might attribute to a future chance of ectopic position. Consequently, smaller D3 and larger W3 can be speculated as a result instead of the causes of BDC-c.

Dimensions of the palate can provide clinical signs and it determines degrees of crowding, since earlier research had shown that children with BDC demonstrated a smaller palatal VOL and SA compared with non-BDC [13]. Most research suggests that a larger tooth size is not responsible for maxillary crowding and that smaller dental arch could be the main factor, providing evidence that smaller maxilla dimensions including arch lengths, widths, and perimeters are found along with asymmetric and irregular arch in the crowded arch [8]. In the present study, adolescents with BDC-c also had a smaller palatal volume and surface area, suggesting that crowding due to smaller palatal dimensions can be the main factor to BDC-c. Thus, according to the results of this study, if signs of a narrower W4 and palatal dimensions are identified clinically

TABLE 2. Comparison of dental and cephalometric variables between the BDC-c and control groups.

Dental and cephalometric Variables	BDC-c group (n = 100)		Control group (n = 100)		*p*-value
	Mean	SD	Mean	SD	
VOL (mm^3)	5998	1151	6300	944	0.044
SA (mm^2)	1371	152	1458.28	121	<0.001
Transverse dental features					
W3, inter-canine width (mm)	37.2	2.5	35.6	1.9	<0.001
W4, inter-first premolar width (mm)	40.8	3.1	42.9	2.4	<0.001
W5, inter-second premolar width (mm)	46.5	3.8	49.0	2.9	<0.001
W6, inter-first molar width (mm)	52.3	3.0	53.5	3.0	0.009
Vertical dental features					
D3, depth at canine (mm)	2.2	1.5	4.8	1.2	<0.001
D4, depth at inter-first premolar (mm)	8.7	2.1	10.1	1.8	<0.001
D5, depth at inter-second premolar (mm)	14.8	2.2	14.8	2.0	0.955
D6, depth at the first molar (mm)	17.2	2.1	16.5	1.8	0.013
Cranial base					
Ar-S-N (°)	126.2	4.1	125.1	4.6	0.099
S-N (mm)	63.3	3.0	64.2	3.1	0.029
S-Ar (mm)	43.9	4.0	43.9	2.7	0.994
N-Ar (mm)	98.7	5.0	99.2	4.4	0.473
Maxilla					
SNA (°)	79.5	3.0	81.4	3.5	<0.001
ANS-PNS (mm)	47.3	2.5	48.0	2.4	0.053
FH-N-A (°)	88.9	3.0	89.5	2.7	0.126
SN-PP (°)	10.6	3.2	9.5	2.8	0.009
Mandible					
SNB (°)	76.1	3.5	77.4	3.5	0.010
Ar-Pog (mm)	97.1	6.0	97.3	5.5	0.802
FH-N-Pog (°)	85.8	3.1	85.9	3.2	0.931
Inter-maxillary relationship					
ANB (°)	3.3	2.2	4.0	2.3	0.030
FMA (°)	28.3	4.6	26.4	5.3	0.006
Facial Height					
N-Me (mm)	126.4	7.1	124.1	7.1	0.018
N-ANS (mm)	52.3	2.9	52.0	2.9	0.402
ANS-Me (mm)	63.9	4.7	62.2	4.9	0.015
S-Go (mm)	76.1	5.3	76.5	5.2	0.520

BDC-c, buccally displaced canine with crowding; VOL, volume; SA, surface area; W3, inter-canine width; W4, inter-first premolar width; W5, inter-second premolar width; W6, inter-first molar width; D3, depth at canine; D4, depth at inter-first premolar; D5, depth at inter-second premolar; D6, depth at the first molar; Ar-S-N, cranial base angle; S-N, anterior cranial base length; S-Ar, posterior cranial base length; N-Ar, total cranial base length; SNA, sagittal position of the maxilla; ANS-PNS, maxillary length; FH-N-A, maxillary depth angle; SN-PP, palatal plane angle; SNB, sagittal position of the mandible; Ar-Pog, mandibular length; FH-N-Pog, facial angle; ANB, skeletal relationship between maxilla and mandible; FMA, Frankfort-mandibular plane angle; N-Me, anterior facial height; N-ANS, upper facial height; ANS-Me, lower facial height; S-Go, posterior facial height; SD, standard deviation.

TABLE 3. Results of logistic regression.

Parameter	Beta (β)	df	Wald	Odd Ratio	95% confidence interval for EXP (B)		p-value
					Lower	Upper	
D3, depth at canine (mm)	−1.21	1	14.03	0.30	0.16	0.56	<0.001
D4, depth at inter-first premolar (mm)	−0.12	1	0.14	0.89	0.49	1.63	0.707
D5, depth at inter-second premolar (mm)	−0.21	1	0.29	0.81	0.38	1.73	0.590
D6, depth at the first molar (mm)	0.46	1	2.43	1.58	0.89	2.81	0.119
W3, inter-canine width (mm)	0.78	1	15.33	2.19	1.48	3.23	<0.001
W4, inter-first premolar width (mm)	−0.79	1	9.67	0.45	0.28	0.75	0.002
W5, inter-second premolar width (mm)	−0.30	1	3.26	0.74	0.53	1.03	0.071
W6, inter-first molar width (mm)	0.30	1	3.92	1.35	1.00	1.82	0.048
Constant	4.25	1	0.62	69.92			0.431

D3, depth at canine; D4, depth at inter-first premolar; D5, depth at inter-second premolar; D6, depth at the first molar; W3, inter-canine width; W4, inter-first premolar width; W5, inter-second premolar width; W6, inter-first molar width; β, beta; df, degrees of freedom; Wald, Wald statistic; EXP (B), Odds Ratio.

in the mixed dentition, early intervention such as maxillary expansion, may be recommended to increase the palatal surface area and volume to encourage normal canine eruption.

In addition, our results indicated that participants with a BDC-c have some level of phenomenon similar to that of mouth-breathers. As reported by Lione *et al*. [18], greater narrowing and higher depths at the level of posterior teeth and smaller palatal VOL and SA were found in mouth-breathers. Thus, oral breathing might be related to BDC-c, and therefore further research can be considered, as mouth-breathers were not specified in the present study.

4.2 Cephalometric characteristics of BDC-c dentition

The present results clearly indicate that participants with a BDC-c demonstrate a significantly smaller SN, SNA, SNB, and ANB, implying that the maxilla of participants with a BDC were more underdeveloped or retrusive than those observed in control group, agreeing with the previous studies that BDCs featured with a shorter maxilla sagittally [11, 12]. Other clinical research has suggested that cranial base length and angle are main factors leading to retrusive maxilla because cranial base offers a central supportive structure for craniofacial region [19]. Hence, shorter anterior cranial base can lead to a retrusive maxilla and is interrelated to a smaller palatal volume and surface area. Chang *et al*. [20] concluded that retrusion of nasomaxillary complex could cause facial flatness and anterior displacement of temporomandibularjoint.

On the other hand, we found that the FMA, anterior facial height, and lower facial height were larger with a retrusive and narrower maxilla in the BDC-c, supporting the conclusion that hyperdivergent skeletal pattern is highly correlated with a smaller maxilla in the sagittal and transverse dimensions, thereby with less increase in inter-molar width [11]. We also found that larger SN-PP angle was a factor to imply the maxilla rotated downward and backward more as ANS moved more inferiorly than the PNS. This might be the reason why larger SN-PP angle usually associates with longer lower facial height [21]. In addition, it has been reported that a greater obtuse cranial base angle and shorter posterior cranial base length can lead to a higher positioned glenoid fossa and condyle, causing a backward rotation of the mandible and thus resulting in a hyperdivergent-angled face [22]. These all serve to add clues to the existence of racial/ethnic influence on facial structure. Nevertheless, there were no significant differences in both cranial base angle and posterior cranial base length between the BDC-c group and control group in the present study.

4.3 Limitations

The sample size of the studying subjects should be increased in order to elaborate on the outcomes of the BDC. The observational study only described a correlation between BDC and craniofacial morphology and further study is needed for analysing why and how it occurred.

5. Conclusions

Participants with BDC-c in early permanent dentition exhibited a narrower dental arch and higher palatal vault compared with control group, of which a narrower arch width at the corresponding first premolar region would increase the occurrence of BDC, resulting in a shallower D3 and wider W3.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

YC—designed the research study. YC, SZ, DS, ML, WL and PT—performed the research. YC and KC—analyzed the data. YC, XY and JW—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted at the Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai, China. The study was approved by Ethical Committee of Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine (Approval No. XHEC-D-2020-184). The study protocol followed the Declaration of Helsinki ethical standards for research involving human subjects and the STROBE guidelines. Informed consent was obtained from all participants and their parents before enrolment.

ACKNOWLEDGMENT

We thank all the staff of the Department of Stomatology, Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine for their cooperation.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Mucedero M, Ricchiuti MR, Cozza P, Baccetti T. Prevalence rate and dentoskeletal features associated with buccally displaced maxillary canines. The European Journal of Orthodontics. 2013; 35: 305–309.

[2] Litsas G, Acar A. A review of early displaced maxillary canines: etiology, diagnosis and interceptive treatment. The Open Dentistry Journal. 2011; 5: 39–47.

[3] Juvvadi S, Manne R, Gandikota C, Medapati Rama HR, Anche S. Impacted canines: etiology, diagnosis, and orthodontic management. Journal of Pharmacy and Bioallied Sciences. 2012; 4: S234–S238.

[4] Peck S, Peck L, Kataja M. Concomitant occurrence of canine malposition and tooth agenesis: evidence of orofacial genetic fields. American Journal of Orthodontics and Dentofacial Orthopedics. 2002; 122: 657–660.

[5] Chaushu S, Bongart M, Aksoy A, Ben-Bassat Y, Becker A. Buccal ectopia of maxillary canines with no crowding. American Journal of Orthodontics and Dentofacial Orthopedics. 2009; 136: 218–223.

[6] Schindel RH, Duffy SL. Maxillary transverse discrepancies and potentially impacted maxillary canines in mixed-dentition patients. The Angle Orthodontist. 2007; 77: 430–435.

[7] Bhujel N, Duggal M, Munyombwe T, Godson J, Day P. The effect of premature extraction of primary teeth on the subsequent need for orthodontic treatment. European Archives of Paediatric Dentistry. 2014; 15: 393–400.

[8] Radnzic D. Dental crowding and its relationship to mesiodistal crown diameters and arch dimensions. American Journal of Orthodontics and Dentofacial Orthopedics. 1988; 94: 50–56.

[9] Suri L, Gagari E, Vastardis H. Delayed tooth eruption: pathogenesis, diagnosis, and treatment. a literature review. American Journal of Orthodontics and Dentofacial Orthopedics. 2004; 126: 432–445.

[10] Mucedero M, Rozzi M, Di Fusco G, Danesi C, Cozza P. Morphometric analysis of the palatal shape and arch dimension in subjects with buccally displaced canine. European Journal of Orthodontics. 2020; 42: 544–550.

[11] Ikoma M, Arai K. Craniofacial morphology in women with class I occlusion and severe maxillary anterior crowding. American Journal of Orthodontics and Dentofacial Orthopedics. 2018; 153: 36–45.

[12] Larsen HJ, Sørensen HB, Artmann L, Christensen IJ, Kjaer I. Sagittal, vertical and transversal dimensions of the maxillary complex in patients with ectopic maxillary canines. Orthodontics & Craniofacial Research. 2010; 13: 34–39.

[13] Bizzarro M, Generali C, Maietta S, Martorelli M, Ferrillo M, Flores-Mir C, *et al*. Association between 3D palatal morphology and upper arch dimensions in buccally displaced maxillary canines early in mixed dentition. European Journal of Orthodontics. 2018; 40: 592–596.

[14] Primožič J, Perinetti G, Richmond S, Ovsenik M. Three-dimensional longitudinal evaluation of palatal vault changes in growing subjects. The Angle Orthodontist. 2012; 82: 632–636.

[15] Generali C, Primozic J, Richmond S, Bizzarro M, Flores-Mir C, Ovsenik M, *et al*. Three-dimensional evaluation of the maxillary arch and palate in unilateral cleft lip and palate subjects using digital dental casts. European Journal of Orthodontics. 2017; 39: 641–645.

[16] Seto BH. Maxillary morphology in obstructive sleep apnoea syndrome. The European Journal of Orthodontics. 2001; 23: 703–714.

[17] Nanda R, Snodell SF, Bollu P. Transverse growth of maxilla and mandible. Seminars in Orthodontics. 2012; 18: 100–117.

[18] Lione R, Buongiorno M, Franchi L, Cozza P. Evaluation of maxillary arch dimensions and palatal morphology in mouth-breathing children by using digital dental casts. International Journal of Pediatric Otorhinolaryngology. 2014; 78: 91–95.

[19] Ma W, Lozanoff S. Spatial and temporal distribution of cellular proliferation in the cranial base of normal and midfacially retrusive mice. Clinical Anatomy. 1999; 12: 315–325.

[20] Chang H, Liu P, Tseng Y, Yang Y, Pan C, Chou S. Morphometric analysis of the cranial base in Asians. Odontology. 2014; 102: 81–88.

[21] Oz U, Rubenduz M. Craniofacial differences between skeletal Class II and skeletal Class I malocclusions according to vertical classification. International Journal of Stomatology & Occlusion Medicine. 2011; 4: 105–111.

[22] Andria LM, Leite LP, Prevatte TM, King LB. Correlation of the cranial base angle and its components with other dental/skeletal variables and treatment time. The Angle Orthodontist. 2004; 74: 361–366.

How to cite this article: Yuhsin Choi, Shuting Zhang, Danni Shi, Muhsuan Liu, Wa Li, Pei Tang, *et al*. Association between the occurrence of buccally displaced canine and palatal and craniofacial morphology in adolescents. Journal of Clinical Pediatric Dentistry. 2023; 47(5): 138-144. doi: 10.22514/jocpd.2023.063.