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Cone-beam computed tomography analysis of the association between sella turcica bridging and palatally impacted canine

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ABSTRACT

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The aim of this study was to analyze the association between sella turcica bridging (STB) and palatally impacted canine and to investigate the correlation between the angular measurements of palatally impacted canine and STB using cone beam computed tomography (CBCT).

The impaction group included 36 subjects (16.97 ± 6.00 years) who had at least one palatally impacted canine and the control group consisted of 36 subjects (16.89 ± 3.52 years) who had normally erupted canines without any dental anomalies. Sella turcica and dental measurements were obtained from reconstructed CBCT images using OnDemand3D 1.0software. Sella turcica dimensions were compared between two groups, and the STB ratio, the proportion of interclinoid distance to diameter of sella turcica, were compared between the impacted and non-impacted sides. Correlation coefficients were calculated between the angular measurements of palatally impacted canine and STB ratio.

In the impaction group, interclinoid distance and STB ratio were significantly smaller than those of the control group ($p < 0.001$). The distribution of STB type II, partial calcification of intercliniod ligaments, was significantly higher in the impaction group than in the control group ($p < 0.05$). However, there was no significant difference of STB between the impacted and non-impacted sides ($p > 0.05$) in the unilateral impaction group. Further, STB ratio was negatively correlated with the mesiodistal angulation and the buccolingual inclination of the palatally impacted canine ($p < 0.05$).

The STB was more frequently found in patients with palatally impacted canine, and the degree of STB was significantly associated with the angular measurements of impacted canine.

Key words : CBCT, Sella turcica bridging, Palatally impacted canine

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I. Introduction

The maxillary canines are the most frequently impacted teeth following the third molars, and maxillary canine impactions are found in 1%-3% of the population[1]. The directions of the canine impaction are palatal or labial side, and the incidence of the former was two or three times higher than that of the latter[2]. Palatally impacted canines may cause clinical problems such as tooth malposition or root resorption of adjacent teeth, midline shift, and arch length discrepancy, etc[3]. Therefore early interceptive diagnosis and treatment are desirable to orthodontists[4,5].

The sella turcica is a saddle shaped depression of the sphenoid bone and serves as an important cephalometric landmark in orthodontics[6]. Some morphologic variations of sella turcica were reported by Axelsson et al[7]. Among them, one common morphologic variation is a sella turcica bridging (STB), definition of which is the calcification of the interclinoid ligament[8]. In general health population, the occurrence of STB ranges from 1.1 to 13%[6,9]. However, the prevalence of STB increases in patients with systematic developmental syndromes, craniofacial disproportion, and dental anomalies such as dental transposition, congenital missing tooth, and palatally impacted canine, etc[10~13].

One common etiology of palatally impacted canine is the genetic theory[14,15]. According to the genetic theory, palatally impacted canines are associated with other genetic abnormalities, and the STB is one of them. Several studies[16,17] have described the association between them. It has been estimated that sella turcica and dental epithelial progenitor cell share a common embryologic origin, specifically neural crest cells. In addition, some genetic mutations contained in neural crest cells, such as the homeobox gene expression, might disrupt the development of sella turcica, midface and teeth.

There were a few previous studies[11,13,18,19] to evaluate the association between STB and dental anomalies, especially palatally impacted canine. But most of those studies have been assessed by using two dimensional radiographs, lateral cephalograms. It has several limitations such as projection or identification errors and potential overlap of anatomical structures[20]. To overcome such limitations, the assessment of craniofacial structures by using cone beam computed tomography (CBCT) has been recently introduced[21]. Additionally, none of the previous studies compared the difference of STB between the impacted and non-impacted sides in the unilateral impaction group, or considerd correlation between STB and the degree of the palatally impacted canine.

Therefore, the purpose of this study was to analyze the association between STB and palatally impacted canine by using CBCT images, to compare the difference of STB between impacted and non-impacted sides in the unilateral impaction group, and to evaluate the correlation between STB ratio and the angular measurements of palatally impacted canine.

Ⅱ. Materials and Methods

1. Subjects

The palatally canine impaction group consisted of 36 subjects (16 males and 20 females; mean age, 16.97 years; range, 11-28 years) and they were sampled from patients who had CBCT images taken for orthodontic diagnosis at Wonkwang University Dental Hospital (Iksan and Daejeon, South Korea) from August 2009 to August 2018. To be included in the impaction group, the subjects needed to have at least 1 palatally impacted canine with any depth, direction, or severity. Of the 36 subjects, 30 had unilaterally impacted canine (Right side, 13; Left side; 17) and 6 had bilaterally impacted canines.

Other 36 subjects (16 males and 20 females; mean age, 16.89; range, 11-26 years) of the control group were randomly selected from patients who had CBCT images taken for orthodontic diagnosis at Wonkwang University Dental Hospital (Iksan and Daejeon, South Korea) from August 2014 to August 2018. For the control group, the inclusion criteria were normally erupted canines without any dental anomalies.

Both groups had (1) good quality standardized CBCT with clear reproduction of sella turcica, (2) no history of orthodontic treatment, (3) no craniofacial anomalies, (4) no systemic diseases or history of trauma, and (5) no missing teeth other than third molars or supernumerary teeth. This study was approved by the institutional review board of Wonkwang University dental hospital in Iksan (WKDIRB201810-03) and Daejeon (W1810/004-001).

2. CBCT imaging and 3D image reconstruction

CBCT images were obtained with an Alphard VEGA scanner (Asahi Roentgen Ind. Co., Ltd., Kyoto, Japan; field of view, 200 × 179 mm; 80 kV; 5.00 mA; exposure time, 17 s; voxel size, 0.39 mm; and slice thickness, 1.00 mm). After the images taken, all CBCT data were exported to a Digital Imaging and Communications in Medicine (DICOM) files with INFINITT PACS software program (INFINITT healthcare Co., Ltd, Seoul, Korea). The DICOM files were imported into 3D images by using OnDemand3D 1.0 software (Cybermed, Seoul, Korea). With this software, the reconstructed 3D images were reoriented according to Frankfort horizontal plane (FH plane) constructed by right orbitale and both sides of porion and midsagittal plane perpendicular to FH plane passing through nasion and basion.

3. Measurements

The landmarks and reference planes in this study were detailed in Fig. 1 and Table 1. The reference planes in maxilla were defined as suggested by Park et al.[22] and these reference planes were used to project dimensions and measurements from 3D image to 2D image. Angular measurements were measured in palatally impacted canine by using a projected line of impacted canine axis on other

Table 1. Landmarks for measurements

Landmarks	Definition
N (nasion)	Point of contact between frontal bone and suture between two halves of nasal bones
Ba (basion)	Midpoint on anterior margin of foramen magnum
Po (porion)	Most superior point of external auditory meatus
Or (orbitale)	Lowest point on infraorbital margin of each orbit
ANS (anterior nasal spine)	Tip of anterior nasal spine of palatal bone
PNS (posterior nasal spine)	Tip of posterior nasal spine of palatal bone
Mx (maxillare)	Zygomaticoalveolar crest, points show maximum concavity on contour of maxilla around molars and lower contour of maxillozygomatic process
ACP (anterior clinoid process)	Tip of anterior clinoid process
PCP (posterior clinoid process)	Tip of posterior clinoid process
DS (dorsum sellae)	Most posterior point of the contour of the sella turcica
U3C	Cusp tip of maxillary canine
U3R	Root apex of maxillary canine

Landmarks and reference planes used for the evaluation of the association between sella turcica bridging and palatally impacted canine.

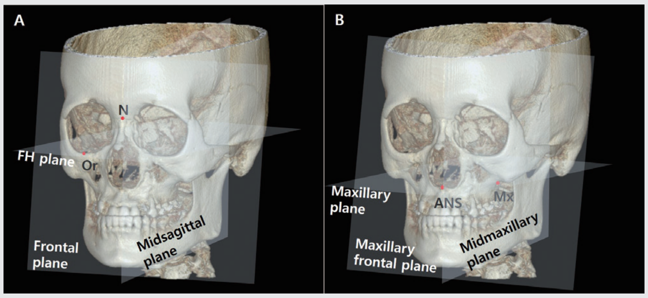

Fig. 1. Landmarks and references planes. A, Reference planes for sella turcica dimensions. B, Maxillary reference planes.

planes. The maxillary plane was made by the right and left maxillares and anterior nasal spine (ANS). The midmaxillary plane was defined as perpendicular to the maxillary plane passing through ANS and posterior nasal spine. The maxillary frontal plane was defined as perpendicular to the maxillary plane and midmaxillary plane passing through right maxillare.

The impacted side of sella turcica was defined as the side where the impacted canine was placed whether left or right side. Non-impacted side was defined as the other side.

1) Sella turcica dimensions

Sella turcica dimensions were interclinoid distance, anterior clinoid distance, posterior clinoid distance, and diameter of sella turcica. Definitions of the sella turcica dimensions are described at Fig. 2.

To evaluate and quantify the STB, the standard scoring scale suggested by Leonardi et al.[23] was used. The STB was classified into 2 types by the STB ratio, the proportion of interclinoid distance to diameter of sella turcica: no calcification (type I); the ratio was equal to or greater than 75%, partial calcification (type II); the ratio was less than 75%.

2) Dental measurements

Dental measurements were the mesiodistal angulation and buccolingual inclination of the palatally impacted canine published in a previous study of Naoumova et al[24]. Definitions of dental measurements are described at Fig. 3.

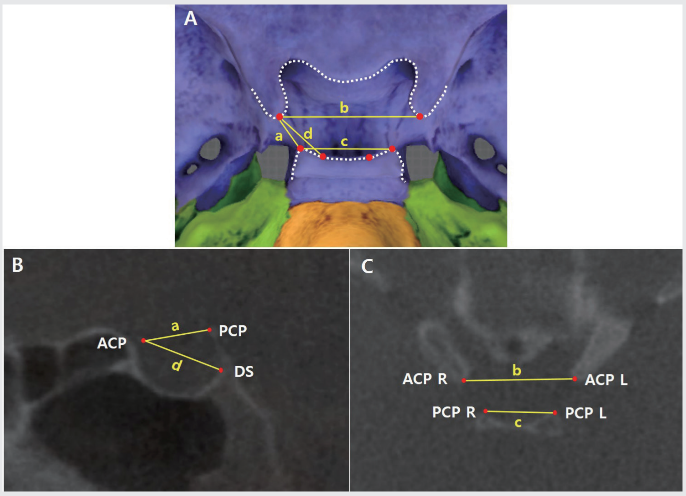

Fig. 2. Sella turcica dimensions. A, Sella turcica landmarks and dimensions; B, Sella turcica dimensions projected on midsagittal plane; C, Sella turcica dimensions projected on Frankfort horizontal plane; a, Interclinoid distance, distance from anterior clinoid process and posterior clinoid process; b, Anterior clinoid distance, distance from right and left side of anterior clinoid process; c, Posterior clinoid distance, distance from right and left side of posterior clinoid process; d, Diameter of sella turcica, distance from anterior clinoid process and dorsum sellae. ACP, anterior clinoid process; PCP, posterior clinoid process; D, dorsum sellae; ACP R, right side of ACP; ACP L, left side of ACP; PCP R, right side of PCP; PCP L, left side of PCP; STB ratio, the proportion of interclinoid distance(a) to diameter of sella turcica(d).

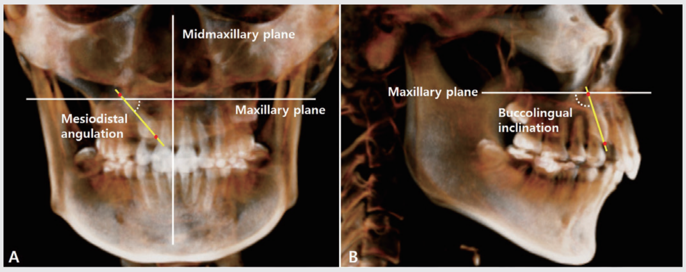

Fig. 3. Dental (angular) measurements. Angular measurements were measured in palatally impacted canine by using a projected line of impacted canine axis on other planes. A, Mesio-distal angulation, angle between the maxillary plane and the projected line connecting cusp tip and root apex of maxillary canine on maxillary frontal plane; B, Buccolingual inclination, angle between the maxillary plane and the projected line connecting cusp tip and root apex of maxillary canine on mid maxillary plane.

4. Statistical analysis

The G*Power 3.1.9.2 (Franz Faul, Universität Kiel, Germany) was used to determine the sample size required for this study. More than 28 subjects for each group were needed to acquire a significant difference when the program set the α value at 0.05 and the power (1-β) at 0.8 with a typical two-tailed statistical analysis.

All measurements were performed by 1 examiner (G.S.M). For evaluation of the intraobserver reliability, the same examiner remeasured 10 patients randomly selected from impacted canine and control groups after 2-week interval. The intraclass correlation coefficients (0.821 - 0.996) indicated excellent reproducibility of the measurements.

The independent t-test was used to compare the values of sella turcica dimensions between the impaction and control groups. The Chi-square test was performed to compare the STB ratio types in both groups. The paired t-test was performed to determine difference of STB between the impacted side and non-impacted sides in the unilateral impaction group. The Pearson correlation coefficient was calculated in the impaction group to investigate the correlation between STB ratio and the angular measurements of impacted canine. All data were statistically analyzed using Statistical Package for the Social Sciences (SPSS) software, version 12.0 (SPSS Inc, Chicago, IL, USA), and a 95% confidence level ($P < 0.05$) was considered statistically significant.

III. Results

1. Comparison of sella turcica dimensions between the impaction and control groups

Interclinoid distance in right and left side (p 〈

0.001), diameter of sella turcica in right side ($p < 0.05$) and STB ratio in right and left side ($p < 0.001$) on the impaction group were significantly smaller than those on the control group. However, there were no significant differences of anterior clinoid distance, posterior clinoid distance, and diameter of sella turcica in left side between both groups (Table 2).

2. Comparison of the STB ratio types between the impaction and control groups

On the right side, 83.3% of the impaction group had STB type II which means partial calcification of interclinoid ligaments and 55.6% of the control group. The difference between both groups on the right side was statistically significant by chi-square test ($p < 0.05$). On the left side, 75.0% of the impaction group had STB type II and did 44.4% of the control group. There was significant difference between both groups ($p < 0.01$) on the left side. In other words, the STB ratio types were significantly associated with presence of palatally impacted canine (Table 3).

3. Comparison of interclinoid distance and STB ratio between the impacted and non-impacted sides in the unilateral impaction group

In comparison of interclinoid distance and STB ratio between the impacted and non-impacted sides in the unilateral impaction group, there were no significant differences between both sides ($p > 0.05$) (Table 4).

4. Correlations between STB ratio and angular measurements of impacted canine

To assess correlations between STB ratio and angulation of the palatally impacted canine, we pooled 42 impacted canines in the unilateral impaction group (n = 30) and bilateral impaction group (n = 6). The STB ratio of impacted side showed significantly negative correlations with the mesiodistal angulation ($r = -0.321$, $p < 0.05$) and buccolingual inclination ($r = -0.316$, $p < 0.05$) of the palatally impacted canine (Table 5).

IV. Discussion

In this study, we focused on the association STB in palatally impacted canine group versus control group. Some previous studies[16,17] have described the reason of the association between STB and dental anomalies. As far as etiology is concerned, sella turcica and dental epithelial progenitor cell share a common embryologic origin, specifically neural crest cells. In addition, some genetic mutations contained in neural crest cells, such as the homeobox gene expression, might disrupt the development of sella turcica, midface and tooth. The pituitary gland originated in the embryo as a result of interaction between neural ectoderm and oral ectoderm, and the former developed into the posterior part and the latter gave rise to the anterior part[25]. The pituitary fossa was situated in the sphenoid bone and differentiated from the hypophyseal cartilage

Table 2. Comparison of sella turcica measurements between the impaction and control groups

Variable	Impaction group	Control group	*p*-value
Interclinoid distance, right	7.02 ± 2.45	9.30 ± 1.73	0.000**
Interclinoid distance, left	7.41 ± 2.43	9.65 ± 1.87	0.000**
Anterior clinoid distance	25.18 ± 2.54	25.83 ± 4.29	0.434
Posterior clinoid distance	15.68 ± 2.34	15.31 ± 4.50	0.509
Diameter of sella turcica, right	11.46 ± 1.71	12.54 ± 1.69	0.009*
Diameter of sella turcica, left	11.94 ± 1.86	12.89 ± 1.80	0.296
STB ratio, right	0.60 ± 0.17	0.74 ± 0.10	0.000**
STB ratio, left	0.61 ± 0.17	0.78 ± 0.12	0.000**

Values are presented as mean ± standard deviation.
Independent *t*-test was performed for comparison of the mean differences of sella turcica measurements between impaction and control groups.
STB ratio, the proportion of interclinoid distance to diameter of sella turcica.
*$p < 0.01$; **$p < 0.001$.

Table 3. Comparison of the STB ratio types between the impaction and control groups

Variable		n(%)			p-value
		Impaction group	Control group	Total	
STB ratio, right	Type I	6(16.7)	16(44.4)	22(30.6)	0.011*
	Type II	30(83.3)	20(55.6)	50(69.4)	
	Total	36(100)	36(100)	72(100)	
STB ratio, left	Type I	9(25.0)	20(55.6)	29(40.3)	0.008**
	Type II	27(75.0)	16(44.4)	43(59.7)	
	Total	36(100)	36(100)	72(100)	

Chi-square test was performed for comparison of the STB ratio types between the impaction and control groups.
STB ratio, the proportion of interclinoid distance to diameter of sella turcica; Type I, no calcification; Type II, partial calcification.
*$p < 0.05$; **$p < 0.01$.

Table 4. Comparison of interclinoid distance and STB ratio between the impacted and non-impacted sides in the unilateral impaction group

Variable	Impacted side	Non-impacted side	p-value
Interclinoid distance	7.15 ± 2.99	7.10 ± 2.14	0.911
STB ratio	0.59 ± 0.20	0.60 ± 0.16	0.490

Values are presented as mean ± standard deviation.
The paired t-test was used to determine significant differences of interclinoid distance and STB ratio between the impacted and non-impacted sides in the unilateral impaction group.
STB ratio, the proportion of interclinoid distance to diameter of sella turcica.

Table 5. Correlations between the STB ratio and the angular measurements of palatally impacted canine

Variable	STB ratio of impacted side	U3 to MxP, mesiodistal angulation	U3 to MxP, buccolingual inclination
STB ratio of impacted side	-	-0.321* (P = 0.038)	-0.316* (P = 0.041)
U3 to MxP, mesiodistal angulation		-	0.217
U3 to MxP, buccolingual inclination			-

Pearson correlation coefficient was calculated in the impaction group to assess correlations between the STB ratio and the angular measurements of palatally impacted canine.
STB ratio, the proportion of interclinoid distance to diameter of sella turcica; U3, maxillary canine; MxP, maxillary plane.
*$p < 0.05$.

which was derived from cranial neural crest cells[26]. By interaction between the oral epithelium cells and neural crest cells, teeth developed in the frontonasal process, the maxillary process, and the mandibular process. The establishment of dental axis was decided in very early developmental stage, and domains of homeobox gene expression established in neural crest cells by signaling from the epithelium[27]. During the early stages of pituitary and dental or skull development, similar molecular pathways such as signaling mediated through bone morphogenetic proteins, fibroblast growth factors, and hedgehog proteins were involved[28]. If this signaling pathways disrupted, some genetic syndromic conditions, craniofacial disproportion, and dental anomalies such as nevoid basal cell carcinoma syndrome (NBCCS) or Gorlin-Goltz syndrome, cleft lip and palate, and calcification of sella turcica, STB, as part of the clinical spectrum of the disease[10~13].

In addition to the molecular biological mechanisms mentioned above, it could be thought of as the influence of the pituitary gland. According to Kosowicz et al.[29], pituitary dwarfism caused a decrease in growth hormone, delaying jaw development and permanent teeth eruption. That was, due to the decrease in the volume of sella turcica by STB, the size of the pituitary gland located inside sella turcica decreased, causing hypopituitarism. And this delayed jaw development and permanent teeth eruption, consequently affecting canine eruption abnormalities, such as canine impaction.

There were a few previous studies[11,13,18,19,30] to evaluate the association between STB and dental anomalies, especially palatally impacted canine. Leonardi et al.[11] reported increased incidence of STB with palatally displaced canines. Similarly, Ali et al.[13] suggested that occurrence of STB in patients with palatally impacted canine was higher than that of control group. Also, Najim et al.[18] found result as same as above the two studies that increased prevalence of STB was showed in impaction group. However, almost all those previous studies have been assessed by using two dimensional radiographs, lateral cephalograms. Moreover, none of those studies compared the difference of STB between the impacted and non-impacted sides in the unilateral impaction group, or considered correlation between STB and the degree of the palatally impacted canine.

Therefore, the objective of this study was to analyze the association between STB and palatally impacted canine by using CBCT images. We also compared the difference of STB between the impacted and non-impacted sides in the unilateral impaction group. Further, we investigated the correlation between the STB ratio and the angular measurements of palatally impacted canine.

In comparison of sella turcica dimensions (Table 2), interclinoid distance and STB ratio in both sides were significantly reduced in the patients with palatally impacted canine. Whereas anterior clinoid distance and posterior clinoid distance showed no significant differences between the impaction and control groups. These results agreed with previous studies[13,18,19], however, diameter of sella turcica were differed from previous studies. Ali et al.[13] showed that the diameter of sella turcica was not significantly differ between two groups. But in this study, there was significantly smaller in impaction group only on the right side, not on the left side. This could be explained by the difference of the definition of diameter of sella turcica. In the previous studies, they defined the diameter of sella turcica as the distance from the tip of tuberculum sella to the dorsum sella, however, in this study, we defined as the distance from the anterior clinoid process to the dorsum sella, separated by left and right sides.

To compare the STB ratio types between the impaction and control groups, Chi-square test was performed (Table 3). Regardless right or left sides, the STB type II indicating partial calcification was increased in patients with palatally impacted canine. On the right side, 83.3% subjects were partial calcification in impaction group and 55.6% were in control group. Similarly, on the left side, 75.0% were partial calcification in impaction group and 44.4% were in control group. This result was similar to previous studies13,18,19,30), therefore the STB ratio types were significantly associated with presence of palatally impacted canine.

As shown above results, almost significant differences of sella turcica dimension between impaction and control group were on both right and left sides. Most of the previous studies[13,18,19,30] were evaluated by lateral cephalogram, they could not analyze separately in impacted and non-impacted side. In present study using CBCT images, we compared the interclinoid distance and STB ratio between the impacted and non-impacted sides in the unilateral impaction group (Table 4). There were no significant differences between the both sides.

It was clear that there was significant association between STB and palatally impacted canine. However, none of the previous studies considered the correlation between STB and the degree of the palatally impacted canine. Regarding correlation with them, negative correlations were observed in the mesiodistal angulation and buccolingual inclination of the palatally impacted canine (Table 5). It could be interpreted that as the STB ratio decreased, the degree to which the impacted canine deviated from normal increased. However, since it was just a statistical correlation comparison, there were some limits to the conclusion.

Our findings supported a genetic theory that a palatally impacted canine related to a simultaneous embryogenesis of some craniofacial structures, such as STB. The results of this study suggested that subjects with STB might have a potential risk of palatally impacted canine, and the STB could be used as a diagnostic marker to alert clinicians of the potential presence of palatally impacted canine.

This study had some limitations. According to a review of the literature, the occurrence of STB might be greater in females[19] and in skeletal Class III patients[31]. But the age was not related with the STB, because the STB was laid down in cartilage at an early stage of development and ossified in early child hood[32]. However, in this study subjects with palatally impacted canine were not controlled by sex, skeletal patterns and age. And, further studies with a large sample size would need to improve the reliability of the findings. Moreover, longitudinal studies would help to analyze the correlation between the STB and degree of the impacted canine, more accurately.

V. Conclusion

In subjects with palatally impacted canine, STB ratio was significantly reduced. However, there were no significant differences of STB between the impacted and non-impacted sides in subjects with unilaterally palatally impacted canine. Further, mesiodistal angulation and buccolingual inclination of the palatally impacted canine were negatively correlated with STB ratio.

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