Interrelationship between the position of impacted maxillary canines and the morphology of the maxilla

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Introduction: The aim of this study was to examine whether there is a relationship between the position of impacted maxillary canines and the morphology of the maxilla. Methods: The palatally impacted canine group included 18 boys and 27 girls with an average age of 12 years 9 months (±2 years 1 month). The buccally impacted canine group comprised 19 boys and 26 girls with an average age of 12 years 2 months (±1 year 4 months). Arch length/intermolar width × 100 was used as the value for comparison of maxillary arch shapes, and palatal vault depth/intermolar width × 100 was used to compare the shapes of palate between the 2 groups. Each category was directly measured from the diagnostic model. Results: Both the arch length/intermolar width × 100 and the palatal vault depth/intermolar width × 100 formulas showed statistically significant differences (P < 0.0001), indicating differences in the shape of maxillary arch and the palatal vault between the 2 groups. Conclusions: The shape of the maxillary arch was narrower and longer in the palatally impacted canine group compared with the buccally impacted canine group, and the palatally impacted canine group had a deeper palatal vault than did the buccally impacted canine group. (Am J Orthod Dentofacial Orthop 2012;141:556-62)

Eruption disturbance including impaction is a frequently observed problem in a series of processes that results in conversion from the deciduous to the permanent dentition. Every tooth can potentially experience such problems. In general, the maxillary canines, with the exception of the third molars,1-3 are the most susceptible, and the prevalence of maxillary canine impaction has been reported to be in the range of 1% to 5%.4-7

The definition of impaction varies among clinicians.1,2,8-10 By summing up the definition, in pathologic terms, impacted teeth can be defined as a state when a tooth remains embedded in the oral mucosa or bone past its normal eruption period. However, the clinical definition of impacted teeth can be broadened to include teeth that are predicted to undergo an abnormal eruption process or teeth that are causing root resorption of the adjacent teeth, even before the normal eruption period.

Many studies on maxillary canine impaction have been carried out. Therefore, it is known that maxillary canine impaction occurs 2 to 3 times more often in girls than in boys.11-14 In general, it has also been reported that palatal impaction of maxillary canines occurs 3 to 6 times more often than buccal impaction.15-17 However, most of these studies were with white subjects. Since Oliver et al13 suggested that the trend of maxillary canine impaction in Asians would differ from that of white people, the recent studies have reported that buccal impaction of maxillary canines occurs 2 to 3 times more often than palatal impactions in Asians of Korean and Chinese descent.18,19

Most maxillary canine impactions diverge from the normal eruptive site in either the buccal or the palatal direction. According to the studies thus far, the etiologies of these 2 phenomena appear to differ. Palatally impacted canines are related to excessive space in the dental arch. Jacoby,16 disclosing that 85% of palatal impactions have sufficient space for eruption and 83% of buccal impactions have insufficient space for eruption, was the first to propose that excessive space causes palatally impacted canines. Subsequent studies have discovered crowding only in a few subjects with palatally

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impacted canines and excessive space often observed. On the contrary, it has been reported that buccally impacted canines are closely related to crowding. The tooth germ of the maxillary canine lies buccally on the buds of the lateral incisor and the first premolar during the growth and development stage. Accordingly, if there is insufficient space for canine eruption due to crowding, it becomes difficult for the canine to erupt into its normal position, thereby forcing it to remain on the buccal side.

The relevance between the anomalies of lateral incisors and palatally impacted canines has been a well-known fact for a long time. Similarly, it has been reported that the mesiodistal dimensions of maxillary teeth including the incisors were reduced significantly in palatally impacted canines. On the contrary, the mesiodistal width of the maxillary incisors in buccally impacted canines cases tends to be larger than in patients with palatally impacted canines. Moreover, the development stage of the dentition is also related to the position of the impacted canines. Palatally impacted canines occur mainly in patients with a normal or belatedly developed dentition, and do not occur frequently in early developing dentitions.

A different etiology was discussed by McConnell et al, who implicated a deficiency in maxillary width as a local mechanical cause for palatally impacted canines. They also concluded that maxillary orthopedic expansion would be an interceptive modality in treating patients with palatally impacted canines. Schindel and Duffy also stated that maxillary transverse discrepancies increase the possibility of canine impaction. However, Langberg and Peck observed no statistically significant difference in the anterior and posterior maxillary arch widths between subjects with palatally impacted canines and the control samples. Moreover, Al-Nimri and Gharaihe even reported that patients with palatally impacted canines have greater maxillary transverse arch dimensions. Therefore, more studies should be carried out on how the morphology of the maxilla affects canine impaction.

The specific mechanism underlying maxillary canine displacement has not been identified yet. Two general theories have been proposed to explain the phenomena of maxillary canine impaction. The first is the guidance theory. As evident from the title, this theory asserts that the displacement of a maxillary canine can occur when the guiding function of the lateral incisor is lost. However, it is difficult to expand this theory for patients with buccally impacted canines, and it is more likely that buccally impacted canines are caused by an abnormal genetic pattern. The second theory is the genetic theory, which asserts that the location of canine eruption is determined by deciduous tooth germ displacement. Moreover, this theory is supported by several studies that have proven that palatally impacted canines are significantly associated with other dental anomalies. Nonetheless, it is still difficult to explain impaction of maxillary canines with only 1 mechanism.

The purpose of this study was to examine whether there is a relationship between the position of impacted maxillary canines and the morphology of the maxilla.

MATERIAL AND METHODS

This study was approved by the institutional review board at the School of Dentistry of Seoul National University in Korea (S-D20100003). Patients who received orthodontic diagnoses at the Dental Hospital of Seoul National University for treatment of impacted maxillary canines between 2005 and 2010 were enrolled. These patients were clearly diagnosed with maxillary canine impactions. To make an exact diagnosis, data including computed tomography images were collected. Diagnosis criteria of the evident maxillary canine impaction were as follows: (1) eruption difference of more than 1 year compared with the canine on the opposite side, (2) unerupted canine more than 1 year after all permanent teeth had erupted, and (3) root resorption of the adjacent tooth caused by the canine. In addition, the exclusion criteria were as follows: (1) patients whose canine was distally impacted toward the first premolar, (2) patients with definitive obstructions (eg, odontoma or supernumerary teeth), (3) patients with a systemic disease, (4) patients with craniofacial anomalies (eg, cleft lip or palate), and (5) patients with several impacted teeth or congenitally missing teeth. The ages of the subjects who satisfied these criteria were between 10 and 18 years.

The bucco-palatal position of the impacted canine was determined on the computed tomography image with the lateral incisor root as the reference. Palatal impaction was defined as the canine crown tip more palatally positioned than the root of the lateral incisor, and the opposite was defined as buccal impaction. The initial subjects included 123 patients with buccally impacted canines and 46 patients with palatally impacted canines; 29 patients had bilateral maxillary canine impactions. Patients with bilateral impaction were included if the position of impaction was the same on both sides, but those with opposite impaction positions were excluded. There was 1 such subject in this study. Thus, 28 bilateral impaction subjects were included in this study. They were divided into 2 groups, palatally impacted canine and buccally impacted canine groups. The palatally impacted canine group comprised 45 subjects, 18 boys and 27 girls,
with an average age of 12 years 9 months ($\pm$ 2 years 1 month). Forty-five subjects were selected randomly for the buccally impacted canine group to ensure a sample distribution (age and sex ratio) similar to that of the palatally impacted canine group. As a result, the buccally impacted canine group included 19 boys and 26 girls with an average age of 12 years 2 months ($\pm$ 1 year 4 months).

First, the ratio of arch length to intermolar width was the value used to compare the maxillary arch shapes between the 2 groups. This ratio was computed by arch length/intermolar width $\times$ 100 (Fig 1, A). Arch length was defined as the distance from the incisal edge of the maxillary central incisors to the line that links the distal ends of the right and left first molars. Intermolar width was defined as the distance between the mesiobuccal cusp tips of the first molars. If the anteroposterior position of the left and right maxillary central incisors differed for reasons including crowding, the values on the right and left were measured, and the average value was used. In case of difficulties in determining the location of the incisal edge of the central incisors for reasons such as rotation, the measurement was taken from the most labial side. All values were measured to an accuracy of 0.01 mm with a digimatic digital caliper (Absolute; Mitutoyo, Kawasaki, Japan).

Second, the ratio of palatal vault depth to intermolar width was used to compare the shape of the palate between the 2 groups. This ratio was computed by palatal vault depth/intermolar width $\times$ 100 (Fig 1, B). The depth of the palatal vault was defined as the vertical distance from the contact line between the mesiopalatal cusp tips of the right and left first molars to the palatal vault. This distance was measured by using a Bernklau plate (Kwangmyung Dacom, Seoul, Korea) and the digimatic digital caliper.

Third, the value resulting from the following equation was used to determine whether there was insufficient eruption space for the maxillary permanent dentition: sum of the widths of the 4 maxillary incisors/available arch space $\times$ 100 (Fig 1, C). This parameter can be used in patients with both permanent and mixed dentitions, who were included as subjects in this study. Available arch space was defined as the space measured through the points of contact between adjoining teeth from the mesial surfaces of the right to the left first molars.

All parameters were measured directly on the diagnostic models. Each parameter was measured twice, and the average was used for analysis.

Examination of the dissected skull of an 8-year-old girl showed that the maxillary canine is surrounded by the nasal cavity, orbit, and anterior wall of the maxillary sinus. Accordingly, the widths of the nasal cavity and the nostrils were measured on computed tomography.

Fig 1. A, Measurements for the comparison of maxillary arch shape: arch length/intermolar width $\times$ 100; B, measurements for the comparison of palatal vault shape: palatal vault depth/intermolar width $\times$ 100; C, measurements to predict the eruption space for the maxillary permanent dentition: sum of the widths of the 4 maxillary incisors/available arch space $\times$ 100.
images to determine whether there was a relationship between nasal cavity width and impacted canine position in our subjects. Computerized tomographic imaging was performed for each subject by using SOMATOM Sensation 10 (Siemens AG, Erlangen, Germany) with a slice thickness of 0.75 mm. The width of the nasal cavity was measured at the widest part of the lower third of the nasal cavity closest to the maxilla in the coronal section (Fig 2, A). The width of the nostrils was measured at the widest region in the horizontal section (Fig 2, B).

### Statistical analysis

An independent 2-sample t test was carried out to compare the 2 groups. Statistical analysis was performed by using SPSS for Windows software (version 12.0; SPSS, Chicago, Ill). The level of statistical significance was set at 5%.

### RESULTS

To measure intraexaminer agreement, 10 randomly selected subjects from each group were reevaluated 2 weeks later. No significant intraexaminer differences were noted, with a Cohen’s kappa coefficient of 0.833.

The average values and standard deviations for each item in the 2 groups are given in the Table. Both the arch length/intermolar width × 100 and the palatal vault depth/intermolar width × 100 formulas showed statistically significant differences (P <0.0001), indicating differences in the shapes of the maxillary arch and the palatal vault between the 2 groups. Moreover, the depth of the palatal vault showed highly significant differences between the 2 groups with an absolute distance. However, the inclination of the maxillary central incisors can affect the measurement of the arch length. Therefore, the angles between the maxillary central incisor and the sella-nasion plane were measured and found to be 106.6° ± 5.4° in the buccally impacted canine group and 103.5° ± 10.3° in the palatally impacted canine group, and the difference was not statistically significant (P = 0.203). It can be concluded that the inclination of the maxillary central incisors had no effect on the comparison of maxillary arch shape.

The value of the sum of the widths of the 4 maxillary incisors/available arch space × 100 used to determine eruption space was not significantly different between the 2 groups. This result was different from previous studies in which deficient or excessive eruption space was found to affect the position of impacted maxillary canines.16,20-22 However, anomalies of the lateral incisors were more commonly found in the palatally impacted canine group (13 subjects, or 29%) compared with the buccally impacted canine group (5 subjects, or 11%); this was similar to previous studies.12,23-26 In addition, there were no statistically

### Table. Results of statistical comparisons between the groups with an independent 2-sample t test

<table>
<thead>
<tr>
<th></th>
<th>Bucally impacted canine group</th>
<th>Palatally impacted canine group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL (mm)</td>
<td>39.76 ± 2.65</td>
<td>40.80 ± 2.17</td>
<td>0.042</td>
</tr>
<tr>
<td>PVD (mm)</td>
<td>15.81 ± 1.45</td>
<td>18.09 ± 1.66</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>IMW (mm)</td>
<td>54.06 ± 2.87</td>
<td>52.16 ± 2.89</td>
<td>0.003</td>
</tr>
<tr>
<td>SWI (mm)</td>
<td>31.97 ± 2.39</td>
<td>31.25 ± 2.21</td>
<td>0.167</td>
</tr>
<tr>
<td>AAS (mm)</td>
<td>75.12 ± 5.78</td>
<td>74.05 ± 4.13</td>
<td>0.372</td>
</tr>
<tr>
<td>AL/IMW × 100</td>
<td>73.39 ± 4.47</td>
<td>78.46 ± 4.60</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PVD/IMW × 100</td>
<td>29.28 ± 2.61</td>
<td>34.81 ± 4.30</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SWI/AAS × 100</td>
<td>42.80 ± 4.26</td>
<td>42.29 ± 3.40</td>
<td>0.563</td>
</tr>
<tr>
<td>Width of NC (mm)</td>
<td>24.95 ± 1.87</td>
<td>24.60 ± 1.83</td>
<td>0.401</td>
</tr>
<tr>
<td>Width of nostrils (mm)</td>
<td>23.92 ± 1.65</td>
<td>24.11 ± 2.24</td>
<td>0.684</td>
</tr>
</tbody>
</table>

AL, Arch length; PVD, palatal vault depth; IMW, intermolar width; SWI, sum of the widths of the 4 maxillary incisors; AAS, available arch space; NC, nasal cavity.
significant differences in the widths of the nasal cavity and the nostrils between the 2 groups.

**DISCUSSION**

According to previous studies, there has been a dispute about whether the maxillary transverse arch width is an etiologic factor for maxillary canine impaction. Some authors have stated that the transverse discrepancy of the maxilla increases the possibility of impaction.\(^{30,31}\) Others have found no correlation between them or that a large transverse arch dimension actually increases the possibility of canine impaction.\(^{32,33}\) All those studies examined the features of the maxillary occlusal surface, and these parameters were absolute distances. However, a relative ratio seems to be more suitable than an absolute value when comparing the shape. That is why the relative ratio was used in this study to compare the morphology of the maxilla. A t test comparison of parameters corresponding to the shape of maxillary arch (arch length/intermolar width \(\times 100\)) between the 2 groups showed a statistically significant difference (\(P <0.0001\)), indicating that the maxillary arch of the palatally impacted canine group was narrower and more elongated than that of the buccally impacted canine group. Moreover, as shown in the Table, the intermolar width of the palatally impacted canine group was significantly lower than that of the buccally impacted canine group (\(P = 0.003\)). Therefore, in this study, we can state that there is a difference in the morphology of the maxilla between the 2 groups, and the palatally impacted canine group showed a transverse discrepancy compared with the buccally impacted canine group.

It has been reported that hypo-development of the lateral incisors\(^{12,23-26}\) stimulated their eruption,\(^{16}\) and a late developing dentition are factors related to palatally impacted canines.\(^{20,29}\) Based on the guidance theory concept, the commonality in these 3 factors is that each points to the lack of guidance provided by the lateral incisor along the erupting path of the maxillary canine. It is apparent that a hypo-developed lateral incisor could not sufficiently fulfill the role of guidance. Additionally, when a lateral incisor erupts early, the possibility that it will act as a guide for the maxillary canine is reduced because of widening of the distance between the root of the lateral incisor and the tooth germ of the canine; a late developing dentition results in the same phenomenon. As the 4 maxillary front teeth erupt, the canine germ must immediately adjust its position appropriately. If it fails to do so and delays moving, the distance between the canine and the root of the lateral incisor might be too far from the lateral incisor to act as a guide for canine eruption.

The value corresponding to the shape of the palatal vault (palatal vault depth/intermolar width \(\times 100\)) was also significantly different between the 2 groups (\(P <0.0001\)). This signifies that the palatal vault of the palatally impacted canine group was narrower and deeper compared with the buccally impacted canine group. This result is believed to have the same significance as the causal factors mentioned above. A deep palatal vault can indicate a long vertical length of the maxilla, meaning that there might be a vertically widened space between the tooth germs in the arrangement of the permanent teeth in the bone. Therefore, in the palatally impacted canine group with a deeper palatal vault, the distance between the root of the lateral incisor and the canine tooth germ might be greater than that in the buccally impacted canine group. This assumption can explain the potential for palatal impaction with a deep palatal vault under the same principle as the early eruption of the lateral incisor or the delayed movement of the canine.

The lack of eruption space is the main cause of buccally impacted canines,\(^{2,16,22}\) whereas excessive space is related to palatally impacted canines.\(^{16,20,21}\) In this study, the estimated eruption space (sum of the widths of the 4 maxillary incisors/available arch space \(\times 100\)) was not significantly different between the 2 groups (\(P = 0.161\)). Moreover, unlike previous studies that asserted a significant difference between the size of the maxillary teeth in patients with palatally impacted canines compared with those with buccally impacted canines, a difference of the widths of the maxillary incisors was not found in this study.\(^{26-28}\) The fact that no differences were found in the mesiodistal widths of the maxillary incisors between the 2 groups is an opposite result from the previous studies. Sex and age could not have been the causes, since they were set to have no differences from the beginning. The difference of this study from the previous studies is that we focused only on Koreans. Therefore, further studies on whether a tooth size difference exists between races should be carried out. However, this also means that tooth size or crowding has no effect when comparing the morphology of the maxilla between the 2 groups. Therefore, this result supports the possibility that the morphology of the maxilla can be an important etiologic factor for maxillary canine impaction.

According to the genetic theory, the position of the maxillary canine is determined by the location at which the deciduous tooth germ is placed in the jaw. In general, the maxillary canine tooth germ is generated from the outer aspect of the nasal cavity, which is at a higher location than the germs of other teeth.\(^{14,16,17}\) Consequently, we expected that there would be
a difference in the widths of the nasal cavity and the nostrils between the 2 groups. However, the results were quite different from our preconception. That is, the hypothesis that the width of the nasal cavity would be wider in the buccally impacted canine group and narrower in the palatally impacted canine group was not proven. As a result, the width of the nasal cavity might have an effect on the position of the maxillary canine tooth germ, but it is not enough to state that this can affect the position of the maxillary canines.

CONCLUSIONS

In this study, we examined whether the position of impacted maxillary canines is related to the morphology of the maxilla. The conclusions are as follows.

1. The shape of the maxillary arch was narrower and longer in the palatally impacted canine group compared with the buccally impacted canine group (\( P < 0.0001 \)).
2. The palatally impacted canine group had a deeper palatal vault than did the buccally impacted canine group (\( P < 0.0001 \)).
3. There were no statistically significant differences in tooth size (\( P = 0.167 \)) and eruption space (\( P = 0.563 \)) between the 2 groups.
4. There were no statistically significant differences in the widths of the nasal cavity and the nostrils between the 2 groups (\( P = 0.401 \) and \( P = 0.684 \), respectively).

REFERENCES


