Retrospective Study of Association between Displacement of Maxillary Canine and Tooth Agenesis

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Objective. *The purpose of this study was to investigate the interrelationships between displacement of maxillary canine and tooth agenesis in age from 10 to 19 years.* ***Study design.*** *The panoramic radiographs of 128 subjects with displacement of maxillary canine and 600 subjects without displacement of maxillary canine were examined. The panoramic radiographs taken between 2003 and 2013 were used for diagnosis other related dental anomalies, including permanent tooth agenesis and small maxillary lateral incisor.* ***Results.*** *Patients with maxillary canine displacement had a significantly higher prevalence rate of permanent tooth agenesis excluding of third molars ($p < 0.05$). Significant increase in occurrence of tooth agenesis of maxillary lateral incisor ($p < 0.05$), maxillary second premolar ($p < 0.05$) and small maxillary lateral incisor ($p < 0.05$). In contrast, the mandibular second premolar did not show any significant difference ($p > 0.05$).* ***Conclusion.*** *This study indicates that there is positive relationship between displacement of maxillary canine, small maxillary lateral incisor and permanent tooth agenesis. Especially, maxillary lateral incisor and maxillary second premolar have strong association with maxillary canine displacement. Consequently, permanent tooth agenesis and small maxillary lateral incisor can be a predictor of maxillary canine displacement.*

Key words. *Canine displacement, tooth agenesis, panoramic radiograph.*

INTRODUCTION

Maxillary canine displacement denotes a condition in which a maxillary canine does not follow its normal eruption path, and the treatment of this dental anomaly presents a great challenge to clinicians[1-3]. Oliver *et al* [4] noted that the positions of canine impaction differ from race to race, with Caucasians showing more palatal impaction than buccal impaction and Asians predominantly showing buccal impaction.

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Various diagnostic methods for maxillary canine displacement allow examination of the positional relationship between the maxillary canine cusp tip and adjacent lateral incisor and measurement of the angle formed by the long axis of the maxillary canine and the midline or the distance between the maxillary canine cusp tip and occlusal plane[5]. According to the study by Warford *et al* [6], which was conducted on 82 patients, the position of the different sectors is a better criterion than the angulation of the impacted tooth to the midline. Currently, the definition based on displaced sectors presented by Lindauer *et al* [7] is the most widely applied diagnostic criterion for determining canine displacement.

Two hypotheses have been proposed for the aetiology of maxillary canine displacement. The first hypothesis is that maxillary canine eruption cannot be guided to follow a normal path due to an abnormal maxillary lateral incisor[4,8]. However, Becker[9] argued that only about 20% of maxillary canine palatal displacement cases can be explained by this hypothesis. The second hypothesis states that abnormal maxillary canine eruption is genetically determined. Previous studies supported the genetic aetiology for abnormal canine eruption and other concomitant dental anomalies[10,11].

Nevertheless, the genes responsible for canine displacement have not yet been identified and no consensus has been reached among the related studies over the genetic association of dental anomalies. Moreover, only a very small number of studies focused on the race-specific relevance of maxillary canine displacement and tooth agenesis between Europeans and Asians. Against this

background, this study aimed to investigate the interrelationships among dental anomalies such as maxillary canine displacement, tooth agenesis, and small maxillary lateral incisor, as manifested in Koreans, and to determine the genetic association of these dental anomalies by determining whether they show distinctive genetic patterns.

MATERIALS AND METHOD

We pre-screened the panoramic radiographs of patients who presented to Wonkwang University Dental Hospital in South Korea from January 2003 to December 2013, and enrolled 187 cases of maxillary canine displacement in adolescents aged between 10 and 19 years (76 males and 111 females). As controls, we randomly chose 600 students (248 males and 352 females) with no evidence of maxillary canine displacement. The control group was age- and gender-matched to the study group.

For the evaluation of maxillary canine displacement, we adopted the sector analysis method proposed by Lindauer [7], with necessary adaptation. Each impacted maxillary canine was assigned to one of the four sectors depending on the location of the canine cusp tip: Sector I, the canine cusp tip was positioned distally to a line tangent to the distal side of the lateral incisor; Sector II, the canine cusp tip was more mesial than in sector I, but was distal to the long axis of the lateral incisor; Sector III, the canine cusp tip was mesial to the long axis of the lateral incisor, but was distal to a line tangent to the mesial side of the lateral incisor; and Sector IV, the canine cusp tip was mesial to a line tangent to the mesial side of the lateral incisor.

Warford *et al* [6] stated that the canine cusp tip positions assigned to Sectors III(87%) and IV(99%) would be impacted; therefore, we defined maxillary canine displacement as the canine cusp tip positioned in Sectors III and IV for the purpose of this study. We also included cases in which the canine cusp tip was distal to the long axis of the first premolar or in which transposition with the lateral incisor (mesial displacement) or first premolar (distal displacement) had occurred.

Additionally, we examined the number of occurrences of tooth agenesis, excluded the third molar from the count, and checked the agenesis of the maxillary lateral incisor and second premolar. The criterion for the definition of small maxillary lateral incisor was that the maximum mesiodistal distance of the crown of the maxillary lateral incisor was smaller than that of the opposite side mandibular lateral incisor. Cone-shaped lateral incisor and peg-shaped lateral incisor were also classified as small maxillary lateral incisor.

The panoramic radiographs were assessed and the observations was recorded by one investigator. The same investigator performed two additional examinations at one-week intervals.

Statistical analysis was performed electronically by using Window SPSS(ver.18, IBM, Chicago, USA). Statistical significance was accepted at 5% ($p < 0.05$).

RESULTS

The age and gender distribution are presented in Table 1. The prevalence rate of tooth agenesis, with the exception of the third molar, was significantly higher in the study group than in the control group. The permanent tooth most closely associated with canine displacement was the maxillary lateral incisor, which showed a substantial difference between the study and control groups (41 vs. 1). A significant difference was also observed in maxillary second premolar agenesis, whereas the mandibular second premolar did not show any significant difference (Table 2).

A significant intergroup difference was observed in the prevalence rate of small maxillary lateral incisor, with the study group demonstrating a higher prevalence rate of small lateral incisor than agenesis of the maxillary lateral incisor (Table 2).

Moreover, a higher prevalence rate of tooth agenesis was observed when canine displacement was bilateral compared to unilateral, but this difference was not statistically significant (Table 3).

Of the 187 students with canine displacement, girls showed a higher tendency towards canine displacement than boys (111 vs. 76). However, with the exception of the third molar, no significant gender-dependent differences were observed in tooth agenesis (Table 4).

DISCUSSION

Garn *et al*.[12,13] found a genetic association between palatal displacement of the maxillary canine and tooth agenesis, tooth size reduction, and abnormal tooth development. Furthermore, Peck *et al*.[14] reported a higher prevalence rate of tooth agenesis and peg-shaped lateral incisor in patients with transposition of the maxillary canine and maxillary first premolar. Baccetti[15] investigated the correlations among palatal displacement of the maxillary canine and tooth agenesis, infraocclusion of the primary teeth, amelogenesis imperfecta, and ectopic eruption of the first molar, and reported that genes control these pathological traits.

Much research has been undertaken to identify the causative genes associated with dental anomalies. In a study of four families, Svinhufvud *et al* [16] reported that palatal and buccal maxillary canine displacement and tooth agenesis were interrelated through autosomal dominant inheritance. Of the related genes, Peck *et al* [17] pinpointed *MSX1* and *PAX9*, which belong to the homeobox gene family, as the genes associated with palatal maxillary canine impaction, maxillary canine-lateral incisor transposition, and tooth agenesis of the premolar and molar teeth; however, this author proposed that the genes associated with maxillary canine displacement and agenesis of the anterior tooth have not yet been found.

Many previous studies on the correlations among dental anomalies designated their respective control groups according to the existing prevalence rate and compared them in relation to their study groups. However, this method poses several problems. Above all, a reliable genetic association cannot be derived if racial differences exist between the study and control groups. Further, an accurate comparison between the two groups cannot be easily performed because such a control group provides information on the prevalence rate of tooth agenesis of certain teeth only. Finally, most data on the prevalence rate of tooth agenesis were obtained in subjects over 30 years of age; thus, these data may not be applicable for comparisons with the present-day prevalence rate for a study group. To address these issues, we designed the study and control groups from a contemporary same-race population.

Previous studies have provided widely varying opinions on the interrelation between maxillary canine displacement and tooth agenesis. While a general consensus has been reached in the finding that maxillary canine displacement increases overall tooth agenesis, except for the third molar, research regarding the agenesis of individual teeth remains quite controversial. For example, many studies on the correlation between the maxillary lateral incisor

Table 1. Age and gender distribution.

		Age									
		10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Study group N=187	Males N=76	14	13	16	11	5	6	6	1	3	1
	Females N=111	36	20	18	13	11	3	2	3	2	3
Control group N=600	Males N=248	44	41	50	35	17	20	20	5	11	5
	Females N=352	110	62	56	41	35	11	8	11	8	10

Table 2. Prevalence rate of tooth agenesis and small maxillary lateral incisor in subjects with maxillary canine displacement, compared with control group.

Tooth agenesis	**Study group(N=187)**		**Control group(N=600)**		***p*-value**	**Odds ratio**	**95% C.I. for odds ratio**
	N	**%**	**N**	**%**			
Any Tooth agenesis (Excluding M3)	59	31.6%	58	9.7%	.000*	4.30	2.86~6.49
Mx,I2 agenesis	41	21.9%	1	0.2%	.000*	168.21	22.94~1232.97
Mx.P2 agenesis	14	7.5%	14	2.3%	.001*	3.39	1.58~7.24
Mn.P2 agenesis	10	5.3%	26	4.3%	.562	1.25	0.60~2.64
Small Mx.I2	62	33.2%	19	3.2%	.000*	15.17	8.76~26.26

* p<0.05, Pearson chi-square test

Table 3. Distribution of tooth agenesis in bilaterally and unilaterally displaced canines.

	Bilateral(N=40)		**Unilateral(N=147)**		***p*-value**	**Odds ratio**	**95% C.I. for odds ratio**
	N	**%**	**N**	**%**			
Any Tooth agenesis (Excluding M3)	16	40.0%	44	29.9%	.227	1.56	0.76~3.22

* p<0.05, Pearson chi-square test

Table 4. Distribution of tooth agenesis according to gender.

	Male(N=76)		**Female(N=111)**		***p*-value**	**Odds ratio**	**95% C.I. for odds ratio**
	N	**%**	**N**	**%**			
Any Tooth agenesis (Excluding M3)	27	35.5%	32	28.8%	.333	1.36	0.73~2.54

* p<0.05, Pearson chi-square test

and premolar, two teeth that are prone to agenesis, reported that maxillary canine displacement and agenesis of the maxillary lateral incisor are significantly interrelated[18-20]. However, although Peck *et al*.[17] acknowledged a strong correlation between maxillary canine and premolar transposition and agenesis of the lateral incisor, the author pointed out that this correlation did not apply to a palatally impacted canine.

In our study, a significant correlation was demonstrated between maxillary canine displacement and agenesis of the maxillary lateral incisor, presumably because both a genetic association and guidance theory can be applied to canine displacement in the presence of agenesis of the maxillary lateral incisor. The reason for the discrepancies among studies may be ascribed to different methods for evaluating maxillary canine displacement. In our study, maxillary canine displacement included the erupted canines to the undeveloped maxillary lateral incisor position as well as maxillary canine-premolar transposition cases, which may explain the higher correlations compared to other studies. The discrepancies in the resulting values can also be attributed to the fact that our study considered both palatal and buccal maxillary canine displacements, while the existing studies mostly considered only cases of palatal displacement.

Studies on the correlation between maxillary canine displacement and agenesis of the second premolar have yielded widely varying results. Lempesi *et al* [18], who studied 812 patients, reported that maxillary canine displacement is not significantly related to agenesis of the second premolar. However, the studies conducted by Baccetti[15] (1998) and Garib.[21] (2009) found a significant correlation between maxillary canine displacement and agenesis of the second premolar. In our study, maxillary canine displacement was significantly related to agenesis of the maxillary second premolar, but the correlation between maxillary canine displacement and agenesis of the mandibular second premolar did not reach statistical significance. Poler *et al* [22] performed a meta-analysis of 24 papers on the prevalence rate of genetically predisposed tooth agenesis, and noted that the prevalence rate of the mandibular second premolar is two-fold higher than that of the maxillary second premolar. From these results, it can be inferred that, while agenesis of the mandibular second premolar has a higher prevalence rate than agenesis of the maxillary second premolar, it is not significantly influenced by the genetic variation associated with maxillary canine displacement.

Several studies reported that maxillary canine displacement is more strongly related to the small maxillary lateral incisor than to agenesis of the maxillary lateral incisor[23,24]. These studies proposed that, if the maxillary lateral incisor is small, the guidance theory can be appropriately applied in relation to maxillary canine eruption, and that the canine and posterior teeth act as the same "field" of tooth germ differentiation. Nevertheless, these studies only investigated maxillary canine displacement independently of transposition with the adjacent teeth, without specifying the criteria for defining canine displacement; we propose that this explains why the results of these studies are different from those of our study.

We studied maxillary canine displacement by dichotomizing it into unilateral and bilateral incidence. The unilateral-to-bilateral ratio was 3.5:1. The bilateral incidence of maxillary canine displacement was a factor associated with increased tooth agenesis, but this was not statistically significant. This result is consistent with previous studies[20,25].

No gender differences were observed in tooth agenesis of the students with maxillary canine displacement in the group evaluated in this study, which is consistent with the results of other studies[18,26]. This indicates that the genes involved in maxillary canine displacement and tooth agenesis are not subject to sexual dimorphism.

The prevalence of impacted maxillary canines is two-fold higher among Europeans compared to Asians; specifically, palatal impaction occurs five times more frequently in Europeans than in Asians. No data are currently available concerning the correlations between maxillary canine displacement and other dental anomalies in Koreans. Most of the currently available studies on canine impaction were conducted in Europeans, with only a small number of studies being conducted in Asians; further, family research has never been conducted.

The results of the current study suggest that it is possible for clinicians to predict maxillary canine displacement before its onset. Maxillary canines usually erupt after the lateral incisors or the second premolars; therefore, if the maxillary lateral incisor or second premolar is still lacking after due time, the maxillary canine eruption path should be followed to allow a timely intervention by clinicians. Such follow-ups and the timely intervention of clinicians can reduce inevitable orthodontic treatment for maxillary canine impaction in later years and can prevent side effects, such as root resorption of the adjacent teeth. The early mixed dentition is considered to be the most appropriate period for examining the risk of maxillary canine displacement. If tooth agenesis is confirmed in this period, related dental anomalies can be detected at an adequately early stage. Detection of a small maxillary lateral incisor is also possible during this period. Therefore, check-up panoramic radiography is recommended during the period of early mixed dentition.

The majority of previous studies focused on palatal canine displacement, and differentiating between buccal or palatal displacement of the maxillary canines is difficult with panoramic radiographs alone. However, given our finding that maxillary canine displacement is interrelated with tooth agenesis irrespective of whether the displacement is buccal or palatal, panoramic radiography is considered sufficient for risk prediction; further, such panoramic radiography has the advantage of reducing the need for additional radiography.

One of the limitations of this study is insufficient research into the dental anomalies that share genetic traits with maxillary canine displacement, such as inclined mandibular molar or infraocclusion of the deciduous teeth. Further, family research would have contributed to elucidating the genetic influences on dental anomalies more clearly than randomized sampling. Therefore, studies that are more diverse must be conducted to clarify the genetic association of dental anomalies and to analyse the causative genes systematically.

ACKNOWLEDGMENTS

This research was supported by educational expenditures of Wonkwang University, 2015.

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