Original Article

Maxillary canine impaction in orthodontic patients with and without agenesis
A cross-sectional radiographic study

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ABSTRACT

Objective: To assess potential associations between maxillary canine impaction (MCI) and agenesis status as well as between MCI and gender.

Materials and Methods: The records of 182 orthodontic patients with agenesis (excluding the third molars) and 630 orthodontic patients without agenesis were examined. Diagnosis of MCI was based on pretreatment panoramic radiographs. Maxillary canines that had not erupted as a result of physical barrier or deflection in the eruption path at the dental age of at least 12 years were considered impacted. Logistic regression analysis was used to test for the associations of interest.

Results: MCI was detected in 5.6% (n = 35) of the nonagenesis group (28 female and 7 male participants) and in 18.1% (n = 33) of the agenesis group (20 female and 13 male participants). Bilateral impaction was detected in 12 patients (34.3%) of the nonagenesis group and in 11 patients (33.3%) of the agenesis group. There was evidence that maxillary lateral incisor agenesis (odds ratio = 5.1, 95% confidence interval [CI] 2.5–10.5, $P < .001$) and second premolar agenesis (odds ratio = 2.6, 95% CI 1.0–6.6, $P = .042$) were significant MCI predictors after adjusting for gender. The odds of MCI were 69% higher in female versus male subjects after adjusting for agenesis status (95% CI 0.97–2.92, $P = .063$).

Conclusions: This study indicates that there is evidence that agenesis status is a strong predictor of MCI, whereas gender is a weak predictor of MCI. Caution should be exercised in interpreting the results because of the observational nature of the present study. (*Angle Orthod.* 2014;84:11–17.)

KEY WORDS: Canine impaction; Agenesis; Cross-sectional study

INTRODUCTION

Maxillary canines are the teeth most likely to be impacted, after the third molars. The reported prevalence of impaction varies between 0.8% and 23.5%.[1–4] Maxillary impacted canines are more often located palatally than labially, with frequencies dependent on the imaging technique implemented.[5,6] The prevalence of impaction appears to be higher in females compared to males, with the reported ratio ranging from 1.3:1 to 3.2:1[7,8]; however, no evidence of an association between gender and canine location (labial/palatal) has been reported.[9]

Maxillary canine impaction (MCI) occurs frequently together with other dental anomalies, such as second premolar agenesis, microdontia of maxillary lateral incisors, enamel hypoplasia, and infraocclusion of deciduous molars.[10] Other dental anomalies associated with MCI are missing and/or peg-shaped maxillary lateral incisors,[11–14] third molar agenesis,[13] generalized or localized tooth-size reduction,[7,11,12,15] distoangulation of unerupted mandibular second premolars,[16,17] generalized or localized delayed tooth development and eruption,[17] and transpositions.[18–20]

These associations led to the hypothesis that concurrent dental anomalies share common etiology, and the term "patterns of dental anomalies" has been proposed.[21] Palatally displaced maxillary canines (PDCs) have been included in those anomalies. PDCs have been associated with missing and peg-shaped upper lateral incisors.[14] In contrast, Peck et al.[13] found

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a strong association of PDCs with third molar agenesis and second premolar agenesis, whereas the higher prevalence of upper lateral incisor agenesis did not differ significantly from that of the reference population surveyed.

The prevalence of PDCs ranges from 5.2% to 12.6% in the presence of at least one missing maxillary lateral incisor[22,23] and 8.1% in the presence of at least one missing second premolar.[24] In the aforementioned studies, the possible confounding impact of gender on the results was not examined. To our knowledge, no data are available about tooth agenesis concomitant to MCI in Greece. Additionally, the conflicting results make it difficult to draw solid conclusions about the prognostic value of agenesis status for MCI. It is therefore the purpose of this study to compare potential associations of MCI with tooth agenesis and gender in an orthodontic population treated in Greece.

MATERIALS AND METHODS

The study protocol was approved by the ethical committee of the School of Dentistry, University of Athens (189/01.11.12).

The agenesis (OA) group (n = 182) was part of the sample of another ongoing study about phenotype and genetic considerations of tooth agenesis in a Greek orthodontic population. The initial sample comprised 294 patients with at least one missing tooth (excluding the third molars) treated in the Postgraduate Clinic, Orthodontic Department, School of Dentistry, University of Athens, Greece, between 1994 and 2010 and two private orthodontic offices in Athens. Those with craniofacial deformities and syndromes were excluded from participation. The diagnosis of tooth agenesis had been based on dental history and pretreatment panoramic tomograms (DPTs). Availability of good-quality pretreatment DPTs and dental age ≥12 years were required for inclusion in the study. Exclusion criteria were bilateral agenesis of the maxillary canines and teeth that were missing because of previous extractions or traumas.

A control sample of 630 nonsyndromic subjects without agenesis (ONA) (excluding the third molars), treated between 1994 and 2010, was selected from the archives of the Postgraduate Clinic, Orthodontic Department, School of Dentistry, University of Athens, Greece. Inclusion criteria were availability of good-quality pretreatment DPTs and dental age ≥12 years. All radiographs were examined by a single person (EL) on a transparency projector under constant lighting conditions. The impaction criteria were based on the definition of impacted teeth proposed by Thilander and Myrberg.[25] The 12-year age cut-off criterion was used to reduce the probability of MCI misclassification. In a

Greek population, mean canine eruption time was 11.2 years for girls and 11.6 for boys.[26] Thus, maxillary canines that remained unerupted because of a physical barrier or deflection along the eruption path at the dental age of at least 12 years were considered impacted. For the assessment of dental age, the method described by Becker and Chaushu was used.[27]

The intraexaminer reliability of the method of MCI diagnosis and the method of dental age determination were assessed by reexamining 30 randomly selected DPTs 3 weeks after the initial screening. For measurement of random error, the Dahlberg formula was used[28]: $\tau = SD/\sqrt{2}$, where SD is the standard deviation of the differences between repeated measurements. The systematic error between measurements was evaluated with the paired t-test.

Statistical analysis was performed at the patient level. The diagnosis of both dental anomalies studied was considered as a single statistical unit, even for bilateral MCI or tooth agenesis. Descriptive statistical analysis for age was performed and frequency tables were created with respect to MCI presence or absence. The data were analyzed using logistic regression to determine the effect of gender and type of agenesis on MCI (dependent variable). Agenesis status was classified into four categories: agenesis of at least one maxillary lateral incisor (UI2), agenesis of at least one second premolar (P2), other types of agenesis and concomitant maxillary lateral incisor and second premolar agenesis (UI2+P2), and no agenesis. The model fit was examined using the Hosmer-Lemeshow test for goodness of fit. The level of significance was set at alpha = .05. All analyses were conducted with STATA 12.1 (StataCorp LP, College Station, Tex).

RESULTS

The intraexaminer reproducibility of the method of MCI diagnosis was excellent (93.3%). The random error in measurement of dental age was $\tau = -0.02$, and the systematic error was not significant ($P = .71$).

The patient flowchart is shown in Figure 1. The OA group comprised 112 females (61.5%) with a mean dental age of 15.4 years (SD 2.2) and 70 males (38.5%) with a mean dental age of 14.8 years (SD 2.2). The ONA group included 366 females (58.1%) with a mean dental age of 15.7 years (SD 2.3) and 264 males (41.9%) with a mean dental age of 15.4 years (SD 2.3) (Table 1).

The female-to-male ratio was 1.5:1 for patients with agenesis and impactions and 4:1 for patients with impactions but without agenesis (Figure 2). Bilateral impaction was detected in 12 patients (34.3%) of the ONA group and in 11 patients (33.3%) of the OA
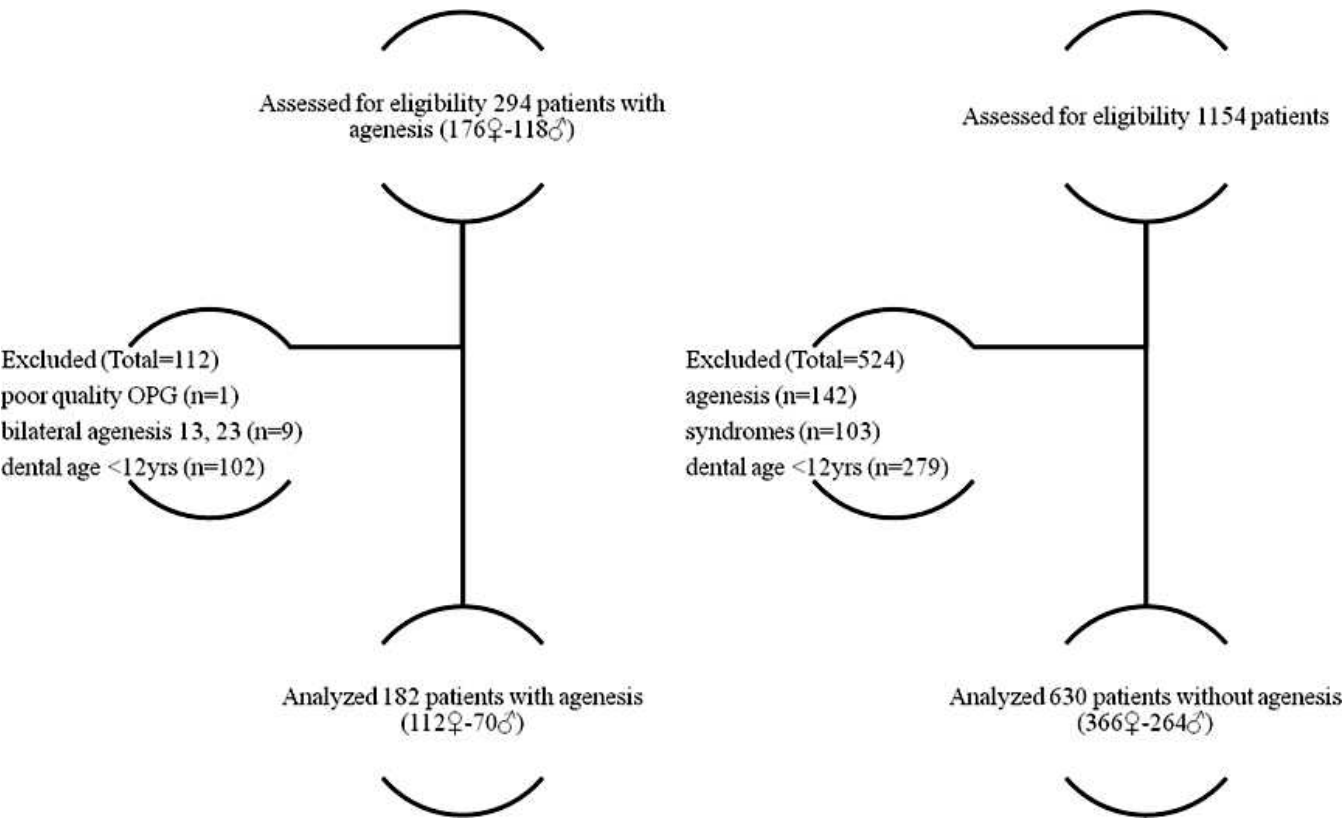
Figure 1. Patient flow chart.

group. Localizations of impacted canines for both groups are given in Figure 3.

The distribution of MCI according to agenesis status is shown in Table 2. Among the 182 OA with agenesis, 55 (30.2%) were classified as UI2. For that group, bilateral impaction was recorded in 7 of 13 subjects (53.8%). In the impaction group, the frequency of unilateral (n = 7, 53.8%) and bilateral agenesis (n = 6, 46.2%) was similar. Fourteen of 20 maxillary impacted canines were found on the same quadrant with UI2 agenesis. The odds of MCI were 5.1 times higher in the UI2 agenesis group compared to the nonagenesis group after adjusting for gender (95% CI 2.5–10.5, $P <$ .001) (Table 3), indicating strong evidence of an association between UI2 agenesis and MCI.

Of the 182 OA subjects, 81 (44.5%) presented agenesis of at least one P2. Bilateral impaction involved 2 of 14 subjects (14.3%). In the impaction

group, 4 of 14 patients (28.6%) had agenesis of all four second premolars. The odds of MCI were 2.6 times higher in the P2 agenesis group compared to the nonagenesis group after adjusting for gender (95% CI 1.0–6.6, $P =$ .042), indicating a weak association between P2 agenesis and MCI.

No interaction between gender and agenesis status was found. The odds of MCI were 1.69 times higher in females than in males after adjusting for agenesis status (95% CI 0.97–2.92, $P =$ .063). The probability of impaction was higher in females compared to males across all types of agenesis and no agenesis; however, this difference was not statistically significant (Figure 4).

DISCUSSION

The aim of this cross-sectional study was to assess possible associations between tooth agenesis and

Table 1. Gender and Age (Means and SDs) of Patients in Agenesis and Nonagenesis Groups

	Agenesis Group (n = 182)			Nonagenesis Group (n = 630)		
	N	%	Age (y)[a]	N	%	Age (y)[a]
Males	70	38.5%	14.8 ± 2.2	264	41.9%	15.4 ± 2.3
Females	112	61.5%	15.4 ± 2.2	366	58.1%	15.7 ± 2.3

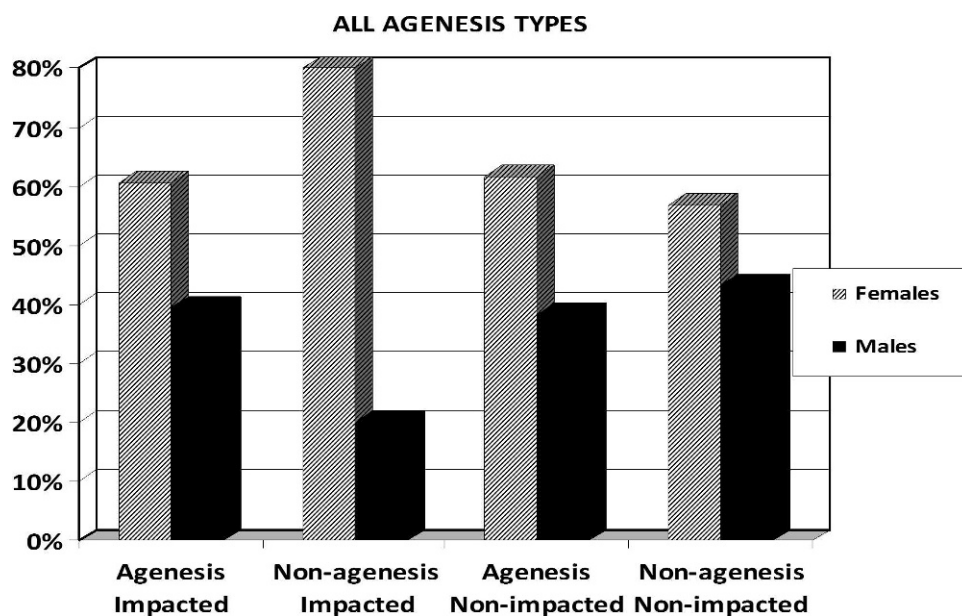[a] Dental age.

ALL AGENESIS TYPES

Figure 2. Sex ratio percentage of each group with regard to MCI presence and agenesis status for all agenesis types.

MCI in a Greek orthodontic population, using orthodontic patients without agenesis as a control group. Overall, after adjusting for gender, MCI was strongly associated with agenesis of all types. In addition, it was found that the probability of MCI was higher in females compared to males across all types of agenesis and no agenesis; however, this female predominance did not reach statistical significance.

No study has yet been conducted in Greece to investigate tooth agenesis along with MCI, such that any speculations about these phenomena would be based solely on study samples of different ethnicities. However, an ethnicity-dependent variation for both dental anomalies has been reported,[29,30] and consequently the generalizability of the results of those studies is uncertain.

In general, studies that focus on tooth agenesis concomitant to MCI can be divided into two categories based on the methodology followed: (1) those examining patients that were diagnosed with impaction and then seeking for concomitant agenesis among those patients and (2) those examining subjects diagnosed with tooth agenesis and then seeking out concomitant impaction among those patients. In an orthodontic sample of PDCs, agenesis (excluding the third molars) was found in 36% of patients.[14] Mercuri et al.[9] examined PDC separately from labially displaced canines and found associations with agenesis for both impaction types. Peck et al.[13,31] found that PDCs are associated with (1) small but not with missing U12 and with (2) agenesis of third molar and mandibular second molars.[31] Most studies have focused on maxillary lateral
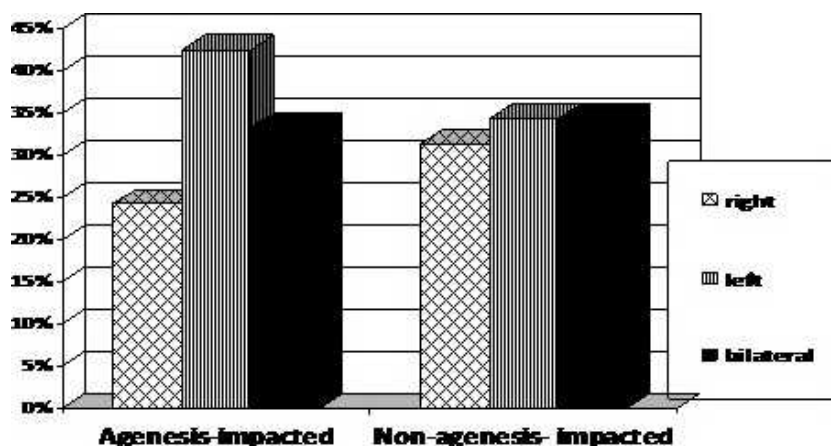

Figure 3. Distribution and relative frequency of MCI according to localization in the agenesis and control (nonagenesis) groups.

Table 2. Distribution of Maxillary Canine Impaction According to Agenesis Status

	Agenesis Status				
Impaction Status	Nonagenesis (%)	Upper Lateral Incisor (UI2) (%)	Second Premolar (P2) (%)	Other (%)	Total (%)
Nonimpaction	595 (94.4)	42 (76.4)	67 (82.7)	40 (87.0)	744 (91.6)
Impaction	35 (5.6)	13 (23.6)	14 (17.3)	6 (13.0)	68 (8.4)
Total	630 (100)	55 (100)	81 (100)	46 (100)	812 (100)

incisor (UI2) agenesis, with conflicting results. UI2 were missing in 5.5% of a PDC orthodontic sample[11] and in 4% of the general population of children.[32]

Studies that began with an agenesis sample found PDC prevalences of 5.2%–12.6% in the presence of at least one UI2 agenesis[22,23] and 8.1% in the presence of at least one P2 agenesis.[24] All the aforementioned studies do not account for the potential confounding impact of gender. In contrast, the present study examined gender separately and found no interaction between gender and agenesis status. In our study, for the purpose of statistical analysis, agenesis status was set as a four-way categorical variable. A larger sample would be advantageous in detecting a significant difference, when it exists, but disadvantageous in detecting specific trends of certain types of agenesis. Since all agenesis types do not share the same genetic profile,[33] the most frequent agenesis types—UI2 and P2—were analyzed separately. The prevalence of MCI in the UI2 agenesis group was 23.6%, almost five times higher than MCI in the control group. In addition, a prevalence of 17.3% was seen for MCI in the P2 agenesis group, which is 2.6 times higher than that of the control group.

According to the present findings, despite female predominance, there is evidence that gender is a weak predictor of MCI. The odds of MCI were 69% in females versus males after adjusting for agenesis status. This finding, combined with the results of other studies showing greater female prevalence,[8,12,34,35] cannot support the hypothesis of a strong sex heritability pattern in impaction.

For comparison purposes, previous studies used samples from other studies. However, such comparisons can be problematic, as control groups were drawn from different populations. Additionally, different methodologies might have been used, and differences

resulting from time-related trends might have ensued. In the present study, the agenesis and control groups were derived from an orthodontic population living in Greece during the same time period with similar characteristics. Additionally, one investigator assessed all individuals at the same point in time. The criteria for MCI diagnosis were identical for the two groups. One issue when conducting a cross-sectional study is establishing that the exposure preceded the disease; however, this was not a problem in this study, as tooth agenesis is usually evident earlier than MCI. The second premolar may present with wide variations in the time of mineralization[36]; as a consequence, an early diagnosis of P2 agenesis may lead to false-positive results. The path of eruption of the maxillary canine cannot be evaluated radiographically any earlier than the age of 10 years,[37] and after this, there is still a chance of self-correction.[37,38] Therefore, the critical age of 12 years was considered as an appropriate cut-off age to diagnose both MCI and tooth agenesis with the goal of minimizing information bias. In addition, the chance of recollection bias (patients or parents not remembering previous extractions/traumas) can be considered low as a result of the youth of the patients. However, the impact of endocrine status and gender on the eruption time of teeth was not considered.

One limitation of this study was the risk of ascertainment bias. Potential MCI was detected based on radiographic criteria only. This may lead to potential false-positive results, as in the case of ectopically erupted canines overlapping adjacent teeth. No studies have measured the reliability of DPTs in assessing impactions. To ensure more accurate diagnosis of MCI, additional clinical data from digital palpation and epithelial status would be more informative.

Table 3. Results of Logistic Regression Analysis

Predictor	Category	OR[a]	95% CI[a]	P Value
Agenesis status	Nonagenesis	Reference	Baseline	
	Agenesis UI2 only	5.1	2.5–10.5	< .001
	Agenesis P2 only	2.6	1.0–6.6	.042
	Other type of agenesis or combined UI2+P2 agenesis	3.5	1.8–6.8	< .001
Gender	Male	Reference		
	Female	1.69	0.97–2.92	.063

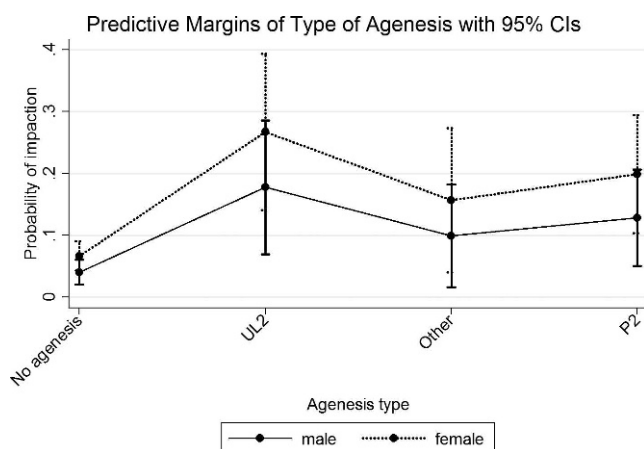[a] OR indicates odds ratio; CI, confidence interval.

Figure 4. Graph showing the probability of impactions for males/females at different levels of agenesis status (no agenesis, UI2, P2, other).

In the present study, PDCs and buccally impacted canines (BDCs) were combined into one group. Despite the unclear etiology of MCI, there is evidence that PDCs and BDCs are characterized by different etiopathogenesis.[27,29] Consequently, comparison with other studies and any speculations on a genetic origin should be made with caution. An investigation of the associated dental anomalies of the two types of impaction showed that both PDCs and BDCs were associated only with tooth agenesis.[9] Among BDCs, only those related to noncrowding have been associated with anomalous lateral incisors.[39] These findings may imply that, although PDCs and BDCs differ in their etiologic background, in the case of concurrent agenesis, some similarities can be expected. However, the confounding impact of crowding was not examined in the present study.

CONCLUSIONS

- In a combined sample of palatally and buccally impacted canines, agenesis status was a strong predictor of maxillary canine impaction.
- In this sample, despite a female predominance across all agenesis types, gender was a weak predictor of MCI.
- The results of this study should be interpreted with caution, given its cross-sectional design.

ACKNOWLEDGMENT

The authors are grateful to Dr Heleni Vastardis for her interest and advice.

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