Comparison of the dental anomalies found in maxillary canine-first premolar transposition cases with those in palatally displaced canine cases

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Summary

Aim: To compare the developmental dental anomalies associated with maxillary canine-first premolar (MxCP1) transposition and those of palatally displaced canine (PDC) with each other and with the background prevalence in the Maltese population in order to elucidate whether the two conditions have similar or differing genetic backgrounds.

Materials and methods: Dental records of 477 subjects with PDC, 57 subjects with MxCP1, and a control group of 500 subjects with no history of a PDC or tooth transposition were compared for canine eruption anomalies and hypodontia.

Results: A high frequency of bilateral occurrence was present for both canine malpositions and when unilateral, a trend to right-sided occurrence was evident. The occurrence of transpositions in the PDC group and of PDC in the MxCP1 group was higher than expected. The prevalence of incisor hypodontia was significantly higher in subjects with PDC and MxCP1, as compared to the control group.

Limitations: The size of the MxCP1 group is relatively small. The study population is a small isolated Caucasian population and the results may not be applicable to other populations.

Conclusions: There is no significant difference between the MxCP1 and PDC groups in the prevalence or distribution of hypodontia and each of these groups exhibits a higher prevalence of the other canine anomaly. These findings support the theory that PDC and MxCP1 form part of a group of interrelated dental anomalies that share a common genetic basis.

Introduction

Maxillary canines are the most commonly impacted teeth, apart from third molars (1, 2). Impaction generally occurs because of ectopic placement (Figures 1 and 2). Ectopic maxillary canines are usually palatally displaced; however, may also be buccally displaced or transposed. The maxillary canine-first premolar (MxCP1) transposition is the most frequently reported type of transposition (3). Many theories have been advanced to account for the aetiology of palatally displaced canine (PDC) and transposed canines; however, the weight of evidence favours a primarily genetic, multifactorial inheritance model (4–7).

Both PDC and MxCP1 are associated with other developmental dental anomalies, particularly hypodontia (4, 8). The suggestion has been advanced that the transcription factors MSX1 and PAX9 play a part in the aetiology of PDC but not MxCP1. This was based on a different pattern of tooth agenesis in samples of both anomalies, with an increased prevalence of third molar and mandibular...
second premolar agenesis associated with PDC, and an increased prevalence of the mandibular second premolar and maxillary lateral incisor agenesis in the MxCP1 sample (9). Another study found the prevalence and distribution of hypodontia to be similar to both canine anomalies. No differences in anterior and posterior hypodontia were noted (10). Furthermore, several studies have associated an increased prevalence of hypodontia with the occurrence of MxCP1 in individuals (4, 11, 12). Evidence against this association has been brought forward (5); however, it is possible that a difference may exist between the phenotypes of MxCP1 and PDC cases as regards hypodontia. This may be a reflection of differing genotypes.

The Maltese population has grown dramatically over the past 500 years, from 17,000 (13) in 1535 to over 400,000 (14) in the 21st century (National Statistics Office Malta, http://nso.gov.mt/en/Pages/NSO-Home.aspx). Immigration has been minimal and mixing with occupying powers chiefly limited to the harbour areas. Thus, the Maltese population is a young, homogenous Caucasian population most closely related to the Eastern Sicilians (15).

The aim of this study was to determine any differences in the distribution of hypodontia between MxCP1 and PDC, using large samples of both canine eruption anomalies, in an attempt to clarify whether these two canine malpositions are separate entities or whether they share a common aetiology. As the Maltese population is thought to have a high level of hypodontia (16), the data were compared to a population control sample and not figures taken from the published literature, wherever possible.

**Materials and methods**

This study was approved by the University of Malta Research Ethics Committee Ref No: 54/2011.

All subjects with MxCP1 or PDC were identified from a register of ectopic canine cases kept at the Orthodontic Department, Mater Dei Hospital, Tal-Qroqq, Malta and from an Orthodontic Private Practice in Sliema, Malta. The control group consisted of the pre-treatment records of 500 consecutive subjects referred for orthodontic treatment at the Orthodontic Department, Mater Dei Hospital, Tal-Qroqq, Malta. Inclusion criteria for the study groups were: Maltese citizenship (defined as in possession of a Maltese Identity Card); age between 11 and 20 years inclusive and presentation with a PDC or MxCP1. The lower end of the range was chosen as the average age of formation of third molars (Demirjian stage A) (17) in Maltese is 10.31 years [95 per cent confidence interval (CI): 9.57–11.07; unpublished data]

**Figure 1.** (A) A palatally displaced canine can be seen on the left, together with developmentally missing second premolars and retained deciduous teeth. The lower primary molars are submerging. (B) A maxillary canine-first premolar transposition is on the right, together with developmentally missing upper lateral incisors, lower first premolars, both upper third molars, and the lower right third molar.

**Figure 2.** Two cases of maxillary canine-first premolar transposition with a contralateral palatally displaced canine. (A and B) The right canine shows the canine crown moving apically relative to the lateral incisor root on the standard occlusal view. The lower canines had also erupted lingually. (C–E) The left canine crown shifts distally with the tube. The position of the canines in both cases was confirmed during surgical exposure.
and the upper end so that third molar extractions would be kept to a minimum.

The criteria for definition of a PDC were the positioning of the canine crown palatal to the roots of the adjacent teeth or erupted palatally to the line of the arch. This was determined by inspection, radiography, and additionally, where available, surgical records.

The criterion for transposition was that the crown and root of the canine would be both simultaneously displaced mesial or distal to their normal position, leading to an interchange in position.

Exclusion criteria for the MxCP1 and PDC groups were: subjects presenting with a pseudotransposition; a history of dentofacial trauma; any craniofacial malformation, including cleft lip/palate; or if records were incomplete or of poor diagnostic quality. The criteria for the control group were similar, but with the exclusion criterion of history of a PDC or any type of tooth transposition, in order to evaluate the background prevalence of associated dental anomalies in the unaffected general population.

The MxCP1 group consisted of 59 subjects. One of the subjects had cleidocranial dysplasia and another patient did not have a dental panoramic tomogram. These were excluded from the study, reducing the group to 57 subjects.

The PDC group consisted of 487 subjects. In total, 10 subjects were excluded from the study; 5 with cleft lip and/or palate, 1 with cerebral palsy, 3 with missing radiographs, and 1 with bilateral transposition of the upper lateral incisor and canine. The PDC study group therefore consisted of 477 subjects.

The control group consisted of 500 subjects consistent with the inclusion and exclusion criteria. The study was projected to take 3 years.

Procedure
The records and radiographs of the subjects in the PDC and MxCP1 groups were examined. The location of the PDC was confirmed from the dental panoramic tomogram and standard maxillary occlusal or periapical radiograph and from existing operative records. The presence of a true transposition was confirmed from the dental panoramic tomogram.

The following data were registered for each patient with a PDC/ MxCP1:

1. Age when the PDC/MxCP1 was diagnosed.
2. Gender.
3. Distribution of the PDC/MxCP1: left, right, and bilateral.
4. Developmentally absent lateral incisors, second premolars, and third molars.
5. Peg-shaped/small maxillary lateral incisors—a small maxillary lateral incisor was diagnosed when the mesiodistal width of the crown was reduced compared to the contralateral tooth; a peg-shaped maxillary lateral incisor was diagnosed when the crown was reduced in size and had a conical shape (18).

The data collection procedure for the control group was identical to that used for the study groups. One author (ESS) carried out the examination.

The sample size calculation was carried out using Piface1.72 (www.stat.uiowa.edu/~rlenth). The data were analysed with the IBM SPSS Statistics 19.0 package (SPSS Inc., Chicago, Illinois, USA).

Intrarater reliability was assessed by re-examining 25 PDC cases, randomly selected from the PDC database, 1 month after the initial examination, using the Spearman correlation coefficient. The Pearson chi-square test or the Fisher exact test was used to investigate:

1. Any difference in the prevalence of third molar formation between the under-14 group and the over-14 group.
2. The prevalence of PDC and MxCP1 in males and females.
3. The frequency of PDC and MxCP1 occurring on the left side and on the right side.
4. The prevalence of incisor-premolar-third molar hypodontia in the PDC group with the prevalence of the same dental anomalies in the general population.
5. The prevalence of incisor-premolar-third molar hypodontia in the MxCP1 group with the prevalence of the same dental anomalies in the general population.
6. The prevalence of incisor-premolar-third molar hypodontia in the PDC group with the prevalence of the same dental anomalies in the MxCP1 group.
7. The total number of missing incisors, premolars, and third molars in bilateral MxCP1 and PDC cases as compared to unilateral cases.

The significance level was set at \( P = 0.05 \).

Results
The Spearman correlation coefficient was 0.7, considered to be substantial intrarater agreement.

There was no significant difference between the number of third molars in the under-14 group as compared to the over-14 group, \( P = 0.16 \).

PDC and MxCP1 were found with a male to female ratio of 1:1.9 and 1:1.7, respectively. A ratio of 1:1.8 was found in the control group. There was no statistically significant difference in the male to female ratio between the three groups, \( P = 0.918 \) (Table 1).

PDC and MxCP1 were found to occur more frequently on the right side; however, there was no significant difference between the groups. A high prevalence of bilateral occurrence of both PDC (25.58 per cent) and MxCP1 (21.05 per cent) was evident (Table 2).

The prevalence of PDC in the MxCP1 group was 10.5 per cent and the prevalence of transpositions in the PDC group was 1.9 per cent.

Lateral incisor agenesis and diminutive or peg lateral formation was found in 20.1 and 29.8 per cent of the subjects in the PDC and MxCP1 groups, respectively. The difference between these two groups was not significant but both prevalences were significantly higher than the control group (9 per cent; Table 3).

Premolar agenesis was not statistically significant between any of the groups; however, the percentage of missing teeth here was higher for both PDC and MxCP1 groups over the control.

Third molar agenesis was significantly higher in the PDC group than the control. There was no difference between the MxCP1 group and the control group or between the PDC and MxCP1 groups (Table 3).

There was no difference in the total number of missing or diminutive/peg incisors, premolars, and third molars between unilateral and bilateral PDC and MxCP1 cases.

Discussion
All subjects in both the PDC and MxCP1 groups and in the control group were Maltese Caucasians. Previous studies grouped subjects from different centres or populations or different types of transpositions to make up sufficient numbers and results may have been confounded by racial or ethnic or phenotypic differences. In this case, all subjects were taken from one homogenous population, with a
similar phenotype. As the Maltese population has a high prevalence of ectopic canines and lateral incisor hypodontia (16), comparison to a control group taken from the general population would give a more accurate result than comparison to figures from the published literature.

The 14-year-old threshold is often quoted as the cut-off age below which third molar formation cannot be predicted with accuracy (19). However, this arbitrary cut-off does not take into account the improvement in imaging techniques since publication and the wide range in physiological and ethnic variation in dental age. Chronological age is a poor predictor of third molar formation (20) and it seemed better to use the population-specific data available. The mean age at which third molars reach Demirjian stage A in Maltese is 10.31 years (95 per cent CI: 9.57–11.07; unpublished data). As no difference was seen in the prevalence of third molar agenesis between the under-14 and the over-14 age groups, the use of 11 years as the minimum age for establishment of third molar formation may be justified.

The finding in this study that PDC and MxCP1 occurred more frequently in females than in males with a male to female ratio of 1:1.9 and 1:1.7, respectively, is in agreement with several other studies (3, 4, 18, 21–23). The control group revealed a male to female ratio of 1:1.8 and it seemed better to use the population-specific data available. The mean age at which third molars reach Demirjian stage A in Maltese is 10.31 years (95 per cent CI: 9.57–11.07; unpublished data). As no difference was seen in the prevalence of third molar agenesis between the under-14 and the over-14 age groups, the use of 11 years as the minimum age for establishment of third molar formation may be justified.

The findings are equivocal for both malpositions (3, 4, 6, 12, 18). Unilateral occurrence of PDC and MxCP1 was the most common finding; however, bilateral occurrence accounted for a quarter of the sample for PDC and one-fifth of the MxCP1 cases. This result is in accordance with results obtained in previous studies (4, 18, 22, 24–26).

Diminutive and peg-shaped maxillary lateral incisors are thought to be a variant of developmentally missing lateral incisors (26, 27) and may be included in the assessment of lateral incisor hypodontia. In agreement with the literature, a statistically highly significant association was found between the two canine malpositions under investigation and maxillary lateral incisor agenesis. The percentage of these anomalies in the PDC group was twice that of the control group and threefold in the MxCP1 group. This is consistent with the findings in previous studies of an increased prevalence of premolar agenesis with both groups (4, 5, 18, 26, 29–32). In addition, the prevalence rates for lateral incisor anomalies reported in the two study groups were not statistically different from each other pointing to a genetic similarity between the two varieties of ectopic canine.

The prevalence of second premolar agenesis was statistically similar for all three groups. This is not in accordance with previous investigations, which found an increased prevalence of premolar agenesis with both groups (9, 10). However, as the population prevalence of hypodontia is high, this may have masked any significant difference between the groups.

Third molar agenesis was found to be significantly higher in the PDC group compared to the control sample. Although the MxCP1 group had a higher percentage of third molar agenesis, the difference with the population control was not statistically significant. This is in accordance with a previous study where an increased association of developmentally missing third molars was seen in association with PDC but not with MxCP1 (9). However, no significant difference
was seen between the PDC and MxCP1 groups either, so it is not possible to draw any definite conclusion as to differences between the groups in this respect and there is no evidence from this study that there is any difference in the antero-posterior distribution of hypodontia between the two groups. Most likely PDC and MxCP1 are different phenotypes of a trait well known for its diversity of expression.

The substantial dissimilarity in the size of the MxCP1 group as compared to the PDC and control groups may have contributed to the lack of statistical significance in some instances. This was inevitable due to the rarity of transpositions; any further investigation will have to await the incorporation of more transposition cases.

There was no difference in the number of missing lateral incisors, premolars, or third molars between the bilateral and unilateral PDC/MxCP1 cases. This is surprising as it would be expected that the more severe canine anomaly would be reflected in the number of missing teeth. It may suggest that the genetic variants coding for canine anomalies are linked with but not identical to those coding for tooth agenesis. Alternatively, the variants may be similar, but the effects on different tissues may vary. The aetiology of canine eruption anomalies is complex. There is evidence for the effect of a major gene or genes, most likely with the added effect of minor genes and an environmental or epigenetic overlay (7). This is largely consistent with an oligogenic model, which would help explain both the variable expression and penetrance. Different combinations of nucleotide variants and epigenetic or environmental mechanisms may result in phenotypes of varying severity.

As regards the distribution of developmentally missing teeth, the phenotypes of both canine anomalies were similar. The pattern of tooth agenesis and peg laterals, the most prevalent associated anomalies, was consistent with that of incisor-premolar hypodontia, with no difference in the prevalence or the distribution of any of the anomalies under study. There was a high prevalence of PDC (10.5 per cent) in the MxCP1 group and a high prevalence of transpositions (1.9 per cent) in the PDC group, consistent with previous findings (7). The prevalence of PDC in the Maltese population is 5.5 per cent (10) and while no local figure for transpositions is available, the published prevalence is 0.33 per cent (24). This would indicate that the two canine anomalies share similar genetic variants. The evidence supports the theory that PDC and MxCP1 form part of the group of interrelated dental anomalies that share a common, as yet undefined, genetic basis.

Despite the overall lack of statistical difference between the two groups, the percentage of all three anomalies under study is far higher in the MxCP1 group than the PDC group. A feature of all family-based studies into these anomalies is the highly variable expression and penetrance of the trait. It seems here that MxCP1 may be the result of a more severe mode of expression, both as regards displacement of the canine and number of missing teeth.

As an extreme phenotype, molecular investigations may be directed at MxCP1 cases, as the phenotype is unequivocal and the causative genetic variants rarer and therefore may be easier to distinguish.

Conclusions

The findings in this study show:

1. Both PDC and MxCP1 cases show a significantly higher prevalence of lateral incisor hypodontia compared to the population prevalence.
2. The prevalence and distribution of developmental dental anomalies is similar in both cases, there is no evidence of any difference in the genetic basis of MxCP1 and PDC.
3. There is no difference in the prevalence of hypodontia between unilateral and bilateral MxCP1 and PDC cases.

References


