Vertical Movements and Rotations of the Ectopic Mandibular Canine Registered in Cross-Sectional and Longitudinal Studies on Orthopantomograms from 54 Patients Diagnosed with Mandibular Canine Ectopia

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Abstract

Introduction: The hypothesis behind this study is that the ectopic mandibular canines move vertically in the mandibular bone during childhood and puberty. The aim was to evaluate interosseous vertical movements of the ectopic mandibular canines for improvement of diagnostic treatment and planning. Material and Methods: The study had two parts: a cross-sectional study and a longitudinal study. The cross-sectional study included orthopantomograms from 54 patients (ages 9 years and 6 months to 16 years) with ectopic mandibular canines. The longitudinal study included series of orthopantomograms from 14 out of the 54 patients. Two methods were involved in both studies. 1) The canine angle expressing the vertical position (angle between canine axis and the vertical line perpendicular to the occlusal plane) was registered. 2) The crown morphology indicating rotation of the canine, as well as the maturity of the canine (Nolla Score System), were registered. Results: The cross-sectional study demonstrated that the largest canine angles were observed in the most mature canines, often with the canine crown appearing in the lateral view. The longitudinal study demonstrated in 4 out of the 14 cases that the canines moved in the vertical plane towards a more upright position, resulting in a smaller angle, while the other ten cases moved during the observation period to a lower and more horizontal position, creating a larger angle. The crown morphology was unchanged in the uprighting cases, while rotation occurred in the ten cases undergoing increasing inclination. Maturity increased during all observation periods. Conclusions: This study is the first study which demonstrates and accordingly proves the hypothesis that the vertical movements and rotation of mandibular canines can occur in children and young adults diagnosed with ectopic mandibular canine eruption. These spatio-temporal movements are believed to be of importance for diagnostics and treatment planning of ectopic mandibular canines.

Keywords: Canine, dentition, human, mandible, radiography

INTRODUCTION

Mandibular canine ectopia is rare and often considered a mysterious dental phenomenon. The ectopic canines can be positioned differently in the mandibular bone, from a nearly normal vertical position to a horizontal position in the bone. Mupparapu¹ has suggested a subdivision of cases after the inclination of the canines. When the ectopic mandibular canine crosses the midline of the mandible the diagnosis transmigrated mandibular canine is a term often used.²,³

Due to the rare occurrence of this condition, exact information on the prevalence in different populations does not exist. Therefore, the aim of this study was to evaluate interosseous vertical movements of the ectopic mandibular canines for improvement of diagnostic treatment and planning.

Material and Methods:

The study had two parts: a cross-sectional study and a longitudinal study. The cross-sectional study included orthopantomograms from 54 patients (ages 9 years and 6 months to 16 years) with ectopic mandibular canines. The longitudinal study included series of orthopantomograms from 14 out of the 54 patients. Two methods were involved in both studies. 1) The canine angle expressing the vertical position (angle between canine axis and the vertical line perpendicular to the occlusal plane) was registered. 2) The crown morphology indicating rotation of the canine, as well as the maturity of the canine (Nolla Score System), were registered.

Results:

The cross-sectional study demonstrated that the largest canine angles were observed in the most mature canines, often with the canine crown appearing in the lateral view. The longitudinal study demonstrated in 4 out of the 14 cases that the canines moved in the vertical plane towards a more upright position, resulting in a smaller angle, while the other ten cases moved during the observation period to a lower and more horizontal position, creating a larger angle. The crown morphology was unchanged in the uprighting cases, while rotation occurred in the ten cases undergoing increasing inclination. Maturity increased during all observation periods.

Conclusions:

This study is the first to demonstrate and accordingly prove the hypothesis that the vertical movements and rotation of mandibular canines can occur in children and young adults diagnosed with ectopic mandibular canine eruption. These spatio-temporal movements are believed to be of importance for diagnostics and treatment planning of ectopic mandibular canines.
not exist. In a Greek population the prevalence was estimated to be 0.17%\textsuperscript{[3]} and in a Turkish population the prevalence was registered to be 0.34%\textsuperscript{[4]} In a systematic review compiling results from 13 articles published from 2001 to 2015 the prevalence of transmigrated canines occurred in 0.1 to 031% of the published cases.\textsuperscript{[5-7]}

Significant gender differences in the rare observation of ectopic mandibular canines was not reported\textsuperscript{[5]} but it is generally believed that females are more affected than males.\textsuperscript{[8]}

A few cases with bilateral ectopic mandibular canines have been described.\textsuperscript{[9,10]} Also, the association between eruption time of mandibular canines is well known.\textsuperscript{[11]} The interrelationship between ectopic mandibular canines and ectopic maxillary canines have been highlighted.\textsuperscript{[12]}

The exact etiology behind ectopia of the mandibular canine is not known. Some suggestions have been forwarded. An early embryological error in the tooth bud has been suggested as a causative factor\textsuperscript{[13,14]} and a genetic etiology behind the abnormal dental deviation has been suggested.\textsuperscript{[15,16]} Associations with regional odontomes, cysts and lateral incisor anomalies have also been suggested as playing a role.\textsuperscript{[7,17]} A scientific proof for these suggestions concerning etiology does not exist.

In the scientific literature on ectopic mandibular canines, several case reports exist with or without thorough literature review.\textsuperscript{[1,3,6,7,9,10,16,18-22]}

Also few investigations performed on larger materials exist.\textsuperscript{[8,17,23-25]}

In the existing literature focus has especially been on the location of the ectopic canines and on resorptions of the primary mandibular canine localized where the permanent canine should have erupted.\textsuperscript{[1,25]} Other phenotypic characteristics described are the craniofacial profile and the occlusion and space in the dental arches.\textsuperscript{[6,25]} Plakwicz \textit{et al.}\textsuperscript{[25]} described normal craniofacial relationships, while Holla \textit{et al.}\textsuperscript{[6]} described deep bite and deep curve of Spee and low anterior face height as characteristic for the patients with ectopic mandibular canines.

In the existing literature, only sporadic descriptions occurred on deviation in the permanent dentition in ectopic mandibular canine cases. Thus Camilleri and Sceri\textsuperscript{[16]} and Mazinios \textit{et al.}\textsuperscript{[3]} and Plakwicz \textit{et al.}\textsuperscript{[25]} described agenesis and other eruption deviations in the dentition.

In the cases where specific focus is on the ectopic mandibular canines, the crown follicles of the ectopic canines have also been described.\textsuperscript{[16]} It is also mentioned that the eruption direction of the mandibular canines could depend on the follicles. Sporadic mentioning of the maturity of the mandibular canine is also found in newer literature.\textsuperscript{[25]}

In a recent pilot study, longitudinal orthopantomograms from 4 patients have been published by Svanholt \textit{et al.}\textsuperscript{[26]} In the early orthopantomograms of these 4 patients, bilateral ectopic mandibular canines were diagnosed. Each patient was followed several years with orthopantomograms. In each of these four patients, only one ectopic mandibular canine occurred at the time when the last orthopantomogram was taken. This canine was the one which inclined most in the vertical plane initially. The contralateral mandibular canine erupted to a normal position in the dental arch.\textsuperscript{[26]}

This published longitudinal pilot study\textsuperscript{[26]} gave inspiration to the hypothesis behind the present study which is that the ectopic mandibular canines move vertically within the mandibular bone during childhood and puberty. The present study represents a more comprehensive investigation not only on the canine inclination but also on the vertical intra-jaw movements of the mandibular ectopic canine, which seemingly has never been described.

Only very few studies exist focusing on the morphology of the ectopic mandibular canine.\textsuperscript{[1,6,16,20]} In these studies, the ectopic mandibular canines are illustrated in the different inclined positions within the jaw as having the same standard morphology seen in the crown and demonstrated in the facial aspect.

Apparently no studies exist illustrating the vertical movements of the canine within the mandibular bone. Also the evaluation of the canine morphology from the facial and lateral aspects in relation to the canine’s inclination and dental maturity have seemingly never been reported.

The overall purpose in this study was to evaluate interosseous vertical movements of the ectopic mandibular canines for improvement of diagnostic treatment and planning.

The first aim was to categorize the material according to the canine inclination.

The second aim was to perform a cross-sectional study of the complete material according to the morphology and maturity of the canine in different inclined positions in the mandible.

The third aim was to perform a longitudinal study based on several orthopantomograms from the same patients diagnosed with an ectopic mandibular canine and describe the canine morphology and maturity in comparison to the canine inclination during the observation period. The morphology of the mandibular canine and the maturity of the canine should be compared to the inclination of the canine.

\textbf{Material and methods}

\textbf{Material}

The material in this study is orthopantomograms collected since 2001 from 54 patients predominantly from the authors, PS and MS. In addition, a few orthopantomograms are included from other specialists in orthodontics working in the community dental clinics in Denmark. The orthopantomograms are all taken due to orthodontic
diagnostics and treatment planning. The radiograph materials were forwarded to author IK at the Dental School of Copenhagen for consultations.

In most cases, information on age and gender was given. The orthopantomograms not anonymized were from patients aged 9 years and 6 months to 16 years. Information on gender was available in 39 cases with male/female ratio = 20/19.

Regarding two of the patients who had their orthopantomograms taken, cone beam computed tomography (CBCT) scans were included in the provided material. Both CBCT scans had been taken for planning the surgical movement of the ectopic canine. The CBCT scans are demonstrated in this report but not specifically evaluated.

The orthopantomograms were analyzed in two types of investigations.

The cross-sectional study
Orthopantomograms from all 54 patients were analyzed. Among these, the last orthopantomogram from each patient in the different series belonging to the longitudinal study was included.

The longitudinal study
In the longitudinal study, several orthopantomograms from 14 patients taken during the individually different observation periods were analyzed from each patient.

Methods
The following methods were used in the cross-sectional as well as in the longitudinal study.

Inclination of the canine
The total material is subgrouped according to the inclination of the canines in three groups. The method used for measuring the inclination is demonstrated in Figure 1. The longitudinal axis of the canine is measured compared to the vertical line perpendicular to the occlusal plane (OL) through the mental spine (ms). OL: the line connecting the mesial cusps of the right and left lower first molar (27).

Morphology of the canine
The morphology of the crown of the canine was evaluated from drawings demonstrated in Figure 2. The crown observed in the facial view is designated FAC and in the lateral view, LAT [Figure 2].
In the two patients where orthopantomograms as well as CBCT exposures existed, the canine crown morphology FAC is illustrated in Figures 3A and the canine crown LAT is illustrated in Figure 3B.

There is no distinction observed between mediolateral and distolateral crown morphology. The FAC morphology is interrelated with a narrow root while the LAT morphology is interrelated with a broad root. Only the crown morphology received specific attention in the present study.

If the morphological contour of the crown is not a FAC contour or a LAT contour it is designated ROT as an abbreviation for rotation.

Maturity of the canine

The maturity according to age and gender of the ectopic canine was registered as demonstrated by Svanholt and Kjær.[29]

In the present report the canine maturity index is evaluated after the Nolla Score System[30] accordingly: index 7 = 1/3 root completed. Index 8 = 2/3 root completed. Index 9 = root almost completed with open apex. Index 10 = root apex completed.

RESULTS

Cross-sectional investigation

Material subgrouped

The material was divided in groups according to the inclination of the mandibular canines. Material with a canine inclination less than 25° was omitted from analysis.

Three different groups were defined.

Group 1: Orthopantomograms with an inclination of the ectopic canine between 25° and 50°, 13 cases.

Group 2: Orthopantomograms with an inclination of the ectopic canine between 50° and 75°, 25 cases.

Group 3: Orthopantomograms with an inclination higher than 75°, 16 cases.

The distribution of the orthopantomograms according to these groups and the ages at which the orthopantomograms were taken appear in Table 1.

Morphology of the canine crown

Group 1: In eight cases the ectopic mandibular canine had the crown morphology FAC.

In two cases, the morphology ROT and in three cases, the morphology LAT.

Group 2: In five cases the ectopic mandibular canine had the morphology FAC. In 15 cases, the morphology ROT and in four cases, the morphology LAT.

Group 3: In 3 cases the ectopic mandibular canine had the morphology FAC. In one case, the morphology ROT and in 12 cases, the morphology LAT.

Maturity of the ectopic canine

Group 1: Maturity indexes 7 (3 cases), 8 (4 cases), 9 (1 case), 10 (5 cases).

Group 2: Maturity indexes 7 (6 case), 8 (8 cases), 9 (6 cases), 10 (5 cases).
Table 1: Orthopantomograms sorted after canine angulation

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(Continued)
Group 3: Maturity indexes 7 (1 case), 8 (1 case), 9 (2 cases), 10 (12 cases).

Conclusion
This cross-sectional study demonstrates that the ectopic canines with the smallest angle in the vertical plane (upright position) had a FAC crown morphology in 8 cases out of 13 cases and a LAT morphology in only 3 cases out of 13 cases. The canines more tilted in the vertical plane (Group 2 and 3) appeared more often with a ROT or a LAT crown morphology.

In group 3, 3 cases had a FAC morphology out of 16 cases while a LAT morphology was observed in 12 cases and a ROT morphology only in 1 case out of 16 cases. In group 2, 13 cases out of 25 cases demonstrated a ROT morphology [Table 2].

The study also demonstrated that the most mature ectopic canines appeared in group 3 with the largest angle in the vertical plane.

As a conclusion of the cross-sectional evaluation, an association between the inclination of the mandibular ectopic canines and the canine morphology was noticed on orthopantomograms. It was also observed that the more mature canines predominantly were found in group 3 with a LAT crown morphology.

**LONGITUDINAL INVESTIGATIONS**

**Material categorized**
From the total material it was possible to investigate 14 patient cases longitudinally. Each of the 14 patients was radiographed from 2-5 times with intervals of 2-3 years.

An overview of the longitudinal material appears in Table 3. 10 persons had 2 orthopantomograms taken. 5 persons had 3 orthopantomograms taken. 1 person had 4 orthopantomograms taken, and 1 person had 5 orthopantomograms taken.

**Inclination of the canine**
Out of 14 patients observed longitudinally, 4 ectopic canines changed inclination to a more upright position (inclination angle diminished) while 10 ectopic canines changed position to a more horizontal position with an enlarged canine angle.

**Morphology of the canine crown**
In the cases where the inclination diminished, the crowns appeared with the same morphology during the observation period, either from FAC to FAC, from ROT to ROT or from LAT to LAT [Table 3].

In the cases where the inclination enlarged during the observation period, the crown appeared with the same morphology, FAC to FAC or LAT to LAT in 3 patients while the morphology changed in 7 patients from FAC to ROT or from FAC to LAT or from ROT to LAT [Table 3 and Figures 4].

**Maturity of the ectopic canine**
In all cases there was a change from less mature to more mature during the observation period. In the initial stages, the ectopic canine had not fully matured.

In the final stage of observation the ectopic canines were fully formed – Index 10, in 8 cases.
CONCLUSION

The results from the longitudinal study were that the mandibular ectopic canine changed to a more upright position in 4 cases without change in crown morphology while in 10 cases the canine changed to a more horizontal position often with a simultaneous change in crown morphology.

CONCLUSION AND EVALUATION OF THE HYPOTHESIS

The studies performed demonstrate that the ectopic mandibular canines to a great extent change position in the vertical plane during childhood and puberty development.

Some of the mandibular canines change to a more upright position while others move vertically to a deeper horizontal position in the mandibular jaw bone.

In the cases where the canines change vertical position to a deeper horizontally oriented position, a rotation of the canine along the length axis also occurred.

The study also demonstrates that the most mature canines, presumedly from older individuals, are the ones with the deep and horizontally orientated jaw position.

In summary, a spatio-temporal interaction occurs in the vertical plane of the ectopic mandibular canine within the mandibular bone in children and young adults.

DISCUSSION

This present study focuses on the change in localization of the ectopic mandibular canine studied in the vertical plane on orthopantomograms. In addition, rotation of the canine during development is highlighted. These two different types of movements have not previously been described longitudinally in ectopic mandibular canine cases.

Often described in the literature is the sagittal movement of the ectopic mandibular canine, including the transmigration movement crossing the mid-axis in the region of the symphysis. The transmigration of the canine has resulted in discussion of the eruption forces which cause this sagittal movement. This particular subject has not been discussed in this report.

Concerning eruption theory, it is well known that the tissue in the apical root membrane is richly innervated and that this specific tissue layer initiates the eruption movement. Meanwhile, the eruption process is also dependent on the crown follicle and of the adaptive processes in the periodontal membrane.

It could be very interesting to focus on the crown follicle in a malpositioned mandibular canine for a better understanding of the role of the follicle in path-finding and on the possible influence of the direction in which the canine moves.

Eruption is a three-dimensional process which makes it difficult to analyze on a two planes radiograph, like the orthopantomogram. It is believed that the actual eruption process of the ectopic canine could have been more precisely documented if viewed on CBCT. Meanwhile, in the cases studied where CBCT was available it was confirmed that orthopantomograms were useable as demonstrated in the present analysis. In the present study, orthopantomograms...
have been collected from references received for consultations during 17 years. The ages where ectopic mandibular canines were first observed and noted in the orthopantomograms varied from 9 years and 6 months to 16 years, Table 1. Therefore the chronological age was replaced by the evaluation of canine maturity as a more correct parameter for development.

In the referred cases, longitudinal orthopantomograms were rarely included. The very low prevalence of these dental eruption deviations makes it difficult to study larger populations and longitudinal studies specifically are extremely difficult to obtain due to requirements and regulations for radiographic exposure.

**Figure 4**: Examples of the first (left) and last (right) radiographs in three series (upper, middle, lower) from the longitudinal study of ectopic mandibular canines. The upper row illustrates radiographs from a male, 9 years old (left) and 12 years old (right). Left: Both mandibular canines have a FAC morphology. Right: The same patient observed 3 years later. The right mandibular canine shifted upright and preserved the crown morphology while the left tilted down and rotated as observed in the lateral LAT crown morphology. The middle row illustrates radiographs from a female, 10 years old (left) and 12 years old (right). Left: the canine crown had the crown morphology FAC. Right: 2 years later the same patient is observed in the right figure. The original FAC morphology of the right canine crown has changed to a ROT morphology during development. This indicates that the canine has not only tilted downwards but also rotated. The lower row illustrates radiographs from a female, 9 years old (left) and 12 years old (right). Left: the canine crown has a crown morphology named ROT (rotation). Right: 3 years later the radiographs to the right illustrates the situation where the mandibular canine has tilted and attained a lateral morphology LAT.
In future studies it could be recommended to include CBCT in the study of vertical and rotation movements of the ectopic canine. In this present study, the exact crown orientation of the canines was difficult to register. Specifically the rotation was difficult to graduate exactly. Therefore the evaluation of the rotation has only three stages, facial FAC, rotation ROT and lateral view LAT. The classification of rotation accordingly includes a minimal rotation or a more extended rotation close to the LAT stage. These uncertainties make statistical analysis worthless. How and why the mandibular canine is tilted during rotation and what initiates this process are conditions which ought to be studied if possible.

Also the histological explanation of the vertical movements during eruption described need a more profound analysis. This process could possibly be explained as a traditional tooth movement as observed during orthodontic treatment.

The fact that the primary dentition can undergo more or less resorption without pressure from the permanent dentition is well known but still not explained.[33]

In future studies on the intra-osseous movements of the ectopic mandibular canines, radiographs in three planes should be coordinated with tooth maturation and patient ages. In this spatio-temporal perspective, the cephalometric registered growth pattern of the jaws and the general body growth evaluated from hand x-rays should preferably be included. If this could be possible in an extended study with more material, then the pattern and intensity in the abnormal canine movement process could be a valuable contribution to elucidating the etiology behind this complicated dental deviation.

A study like this one is of importance for establishing preliminary guidelines for treatment of ectopic canines in the mandible. Guidelines have been severely needed but not yet established.[17,22]

One perspective is focused on possibilities for interceptive treatment and for planning orthodontic and surgery treatment.[22,24,34,35]

The present study is considered a new input in a complicated puzzle which needs more information. It is a difficult puzzle where diagnostics concerning an ectopic mandibular canine creates a clinical and treatment problem.

The ectopic mandibular canine is still a mystery, which first of all creates challenges because of the fundamental lack of understanding the etiology and the basal biological processes behind this severe dental deviation.

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Conflicts of Interest

None to declare. The corresponding author has editorial involvement with Dental Hypothesis.

References


