Acta Odontologica Scandinavica. 2015; 73: 375–379

informa healthcare

ORIGINAL ARTICLE

Changes in the location of the human mandibular foramen as a function of growth and vertical facial type

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Abstract

Objective. A previous cross-sectional investigation showed that the mandibular foramen location depends on the age and the vertical facial pattern of growing individuals. The aim of the present longitudinal study was to explain how these factors influence the distance between the foramen and the occlusal plane. It is known that a certain distance is necessary for a successful inferior alveolar nerve block in clinical dentistry. ***Materials and methods.*** This distance, as well as another four cephalometric variables, were measured on both pre-treatment and 10-year post-treatment lateral cephalometric radiographs collected from 50 patients who underwent orthodontic treatment. The changes between these two sets of measurements were also calculated. ***Results.*** A multiple regression analysis was performed using the pre-treatment age, the pre-treatment inter-maxillary angle, the rotation of the occlusal plane and the change in mandibular ramus height as independent variables and the change of foramen-occlusal plane distance as a dependent variable. The independent variables under investigation were found to account for more than half of the variability of the foramen-occlusal plane distance ($r = 0.732$; $p < 0.001$). ***Conclusion.*** In very young individuals the mandibular foramen is located approximately at the level of the occlusal plane. With age it moves upwards relative to the occlusal plane and more so for those individuals with a low anterior facial height (short-face vertical facial type). These observations are, at least, partially explained by the differential growth of the various elements of the maxillo-mandibular complex and the change of the inclination of the occlusal plane.

Key Words: *anesthesia, facial morphology, inferior alveolar nerve block, lateral cephalometric radiograph, occlusal plane*

Introduction

Knowledge of the location of the mandibular foramen is necessary for a successful inferior alveolar nerve block anesthesia. This anesthesia, one of the most commonly used in clinical dentistry, has a failure rate of ~ 10% [1]. It is obtained by inserting the needle at the inner surface of the ramus, 6–10 mm above and parallel to the mandibular occlusal plane [2–5]. In a previous study [6], the distance between the foramen and the occlusal plane in growing children was measured in order to determine whether it was constant for every patient. This was found not to be the case and that two main factors seem to influence this distance: (1) the age of the patient and (2) the vertical facial morphology. The distance between the foramen and the occlusal plane was significantly (positively) correlated to the patient's age: the older the growing individual the higher the foramen was relative to the occlusal plane. This distance was also significantly (negatively) correlated with one of the skeletal variables depicting the vertical facial morphology: the inter-maxillary angle. This first cross-sectional study has raised a lot of questions concerning the mechanism behind these changes in the position of the foramen in relation to the occlusal plane.

The mandibular foramen is located at approximately the level of the occlusal plane in very young individuals. With growth, the increase of the alveolar height moves the occlusal plane away from the body of the mandible. If drifting of the mandibular foramen did not occur, one would expect its location to be below the occlusal plane in older individuals. However, this drift systematically occurs in line with growth and the foramen is located above the occlusal plane in adult subjects. In order to explain this observation, we have formulated two hypotheses.

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(Received 11 April 2014; accepted 4 September 2014)

ISSN 0001-6357 print/ISSN 1502-3850 online © 2015 Informa Healthcare
DOI: 10.3109/00016357.2014.968871

The first one is that the foramen, through remodeling, is displaced upwards in comparison to the occlusal plane during growth. The second hypothesis is that the occlusal plane rotates during growth in a counter-clockwise fashion, which, purely geometrically, creates the change in relative position between the two landmarks. It is already known that the inclination of the occlusal plane depends on the vertical facial growth pattern [7,8].

The aim of this longitudinal study was to investigate the observed changes in the location of the mandibular foramen as a function of growth and vertical facial types.

Materials and methods

Material

In this retrospective longitudinal investigation we used the diagnostic records of growing patients who underwent orthodontic treatment in the department of orthodontics at the University of Geneva dental school. Cases with complete pre-treatment and 10-year post-treatment records were collected. The following exclusion criteria were then applied:

(1) radiographic records of insufficient quality,
(2) patients with obvious asymmetry (more than 5 mm at the lower border of the ramus), with syndromes or history of maxillofacial injury,
(3) non-Caucasian patients (in order to have a more homogenous population sample), and
(4) patients older than 12 years old at the initial radiographic examination. This exclusion was performed in the attempt to include only patients who were likely to undergo a significant amount of growth during the observation period.

This investigation was submitted and received the approval of the Research Ethics Committee of the University of Geneva.

All radiographs were taken with the same radiological equipment. The lateral cephalometric radiographs were taken using a Cranex3+ Ceph (Soredex, Tuusula, Finland) with Konica X-ray 24 × 30 cm films (Konica Minolta Medical & Graphic Inc., Tokyo, Japan). For the panoramic radiographs, Scanora was used (Soredex, Tuusula, Finland) with Kodak X-ray 15 × 30 cm films (Carestream Health Inc., Bagnolet, France). All radiographs were digitized (300 dpi, grayscale mode) using a flatbed scanner (Epson Expression 1600Pro; Seiko Epson Corp., Nagano, Japan) and stored in a jpeg format. The cephalometric radiographs were finally traced on screen using a cephalometric program (Viewbox3.0, DHal, Kifisia, Greece) and a custom-made analysis was created in order to measure sets of pre-defined variables.

Methods

In the context of this investigation, the mandibular foramen had to be located on the cephalometric radiographs. This was particularly difficult in some cases due to double structure superimposition and/or image blurring. In these cases, the foramen was first located on the corresponding panoramic radiograph and then transferred on the cephalometric radiograph. This transfer of foramen position between radiographs has been shown to be valid by a previous study [6] because the proportional vertical position of the foramen does not change when comparisons are made between panoramic and cephalometric radiographs.

Figure 1 shows the cephalometric landmarks employed to calculate the location of the foramen as a function of its distance to the functional occlusal plane (*Foramen–occlusal plane distance, Mf–Mf′*) in addition to the other variables being studied. A previous study found that the foramen–occlusal plane distance was not constant between subjects [6]. Therefore, four variables were selected for the investigation of the variability of this distance: the age of the patient, the *Condyle-Gonion distance* (Co-Go), the *Inter-maxillary angle* (Ans-Pns/ Go-Me) and the *Angulation of the occlusal plane* (S-N/ occlusal plane). These measurements were taken from both the initial and 10-year post-treatment radiographs. The differences between these two sets of measurements were calculated as well.

Method's error and statistical analysis

The Shapiro-Wilk test revealed that all variables were normally distributed. Differences after the follow-up period were tested using a paired Student's *t*-test. A multiple regression analysis was performed using the following variables: the pre-treatment age, the pre-treatment inter-maxillary angle, the change in angulation of the occlusal plane (= *rotation of the occlusal plane*) and the change in height of the mandibular ramus as independent variables. The dependent variable was the change in the distance between the foramen and the occlusal plane.

The significance level was set at $p < 0.05$ (two-tailed). The Statistical Package for Social Sciences for Windows, version 20.0, (SPSS Inc., Chicago, IL) was used to perform all statistical evaluations.

In order to evaluate the systematic error of the vertical position of the foramen, the cephalometric radiographs of 15 subjects were randomly selected and analyzed 4 weeks later by the same operator (JFE). No differences were detected at a significance level of 0.05 ($p = 0.21$, Pearson's correlation = 0.99). Dahlberg's formula [9] was used to calculate the coefficient of reliability (CR), which was excellent (CR = 0.996).

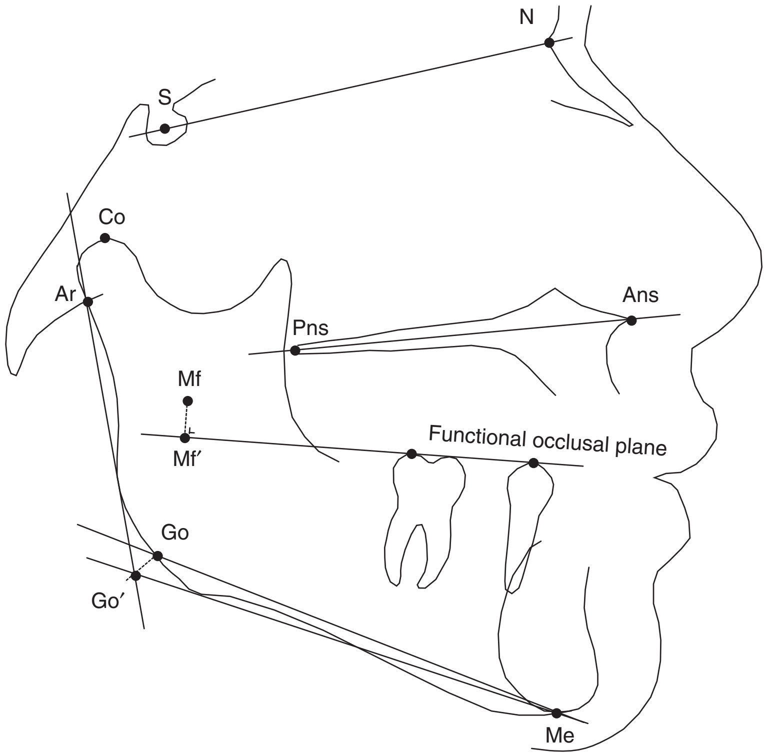

Figure 1. Cephalometric landmarks used in the variables under study. Ans (Anterior nasal spine), apex of the anterior nasal spine; Pns (Posterior nasal spine), intersection point of soft palate, hard palate and pterygopalatinal fissure; Ar (Articulare), radiographic intersection of the posterior margin of the ramus with the basion; N (Nasion), anterior limit of the nasofrontal suture; S (Sella), center of sella turcica; Co (Condyle), top of the condyle; Me (Menton), lowest point of the symphysis; Go' (Gonion marked), intersection of the tangents to the mandible, through Ar and Me; Go (Gonion), point on the contour of the mandible obtained by bisecting the angle Ar-Go'-Me; Mf, mandibular foramen; Mf', projection of Mf on the occlusal plane; Functional occlusal plane, line through the cusp of the first mandibular premolar and through the distal cusp of the first mandibular molar.

Results

Fifty patients (29 females and 21 males) fulfilled our inclusion criteria.

Descriptive statistics

Pre-treatment records. The average age before treatment was 9.5 ± 1.4 years (range = 6.3–11.8 years). The foramen–occlusal plane distance was 2.9 ± 2.4 mm (range = −3.7 to +6.8 mm). A positive value indicates that the foramen is above the occlusal plane, whereas a negative value shows that the foramen is below it. The Condyle-Gonion distance was 49.0 ± 4.6 mm (range = 37.7–59.2 mm). The mean inter-maxillary angle was 28.3 ± 4.7° (range = 14.0–37.9°). The angulation of the occlusal plane in respect to the S-N line was 20.0 ± 4.4° (range = 10.2–28.8°).

10-year post-treatment records. The average age was 24.2 ± 1.6 years (range = 20.1–27.8). The foramen–occlusal plane distance was 5.5 ± 2.2 mm (range = 0.0–9.9 mm). The Condyle-Gonion distance was 64.1 ± 7.4 mm (range = 47.7–81.5 mm). The mean inter-maxillary angle was 24.6 ± 6.0° (range = 13.2–35.7°). The angulation of the occlusal plane in respect to the S-N line was 17.4 ± 5.3° (range = 8.3–28.5°).

Changes during the follow-up period

The changes that occurred during the follow-up period were evaluated using the Student's *t*-test for each variable under investigation. The foramen–occlusal plane increased by 2.6 ± 3.2 mm on average between the pre-treatment records and the 10-year post-treatment follow-up ($p < 0.001$). There was a mean increase of 15.0 ± 6.0 mm of the Condyle-Gonion distance during the observation period ($p < 0.001$) and the inter-maxillary angle decreased by −3.3 ± 3.6° ($p < 0.001$). There was an anterior rotation of the occlusal plane between the pre-treatment and 10-year post-treatment measurements. The mean difference was −2.6 ± 3.8° ($p < 0.001$) (Table I). It appears that the changes of these two last angles are inter-dependent: the anterior rotation of the occlusal plane is in harmony with the change of the inter-maxillary angle ($r = 0.408$; $p = 0.003$).

Gender was not found to influence the change of the foramen–occlusal plane distance during the follow-up period ($p = 0.513$).

A multiple linear regression analysis was conducted using as the dependent variable the change of

Table I. Changes to the variables under investigation during the 10-year follow-up period (paired t-test).

			95 % CI		
Variable	Mean	SD	Superior	Inferior	p-value
Foramen-Occlusal plane distance (mm)	2.6	3.2	1.7	3.5	< 0.001
Gonion-Condyle distance (mm)	15.0	6.0	13.3	16.7	< 0.001
Inter-maxillary angle (°)	−3.3	3.6	−4.3	−2.2	< 0.001
Rotation of the occlusal plane (°)	−2.6	3.8	−3.7	−1.6	< 0.001

foramen–occlusal plane distance (10-year post-treatment to initial) and as independent variables: (a) the initial age, (b) the initial inter-maxillary angle, (c) the rotation of the occlusal plane and (d) the change to the Condyle-Gonion distance. The independent variables under investigation were found to account for more than half of the variability of the foramen–occlusal plane distance change ($r = 0.732$; $p < 0.001$) (Table II). Evidently, this distance increases of course with age, but the magnitude of this increase seems to be influenced by the following:

(1) *The initial age*: a reduction to the difference measured of 0.337 ± 0.244 mm for each additional year of age ($p = 0.003$);
(2) *The initial inter-maxillary angle*: a reduction to the difference measured of 0.218 ± 0.077 mm for each additional degree ($p = 0.048$);
(3) *The rotation of the occlusal plane*: a reduction to the difference measured of 0.410 ± 0.091 mm for each additional degree ($p < 0.001$); and
(4) *The change to the Condyle-Gonion distance*: an increase to the difference measured of 0.301 ± 0.059 mm for each millimeter ($p = 0.009$).

Table II. Multiple regression analysis using as the dependent variable the change of foramen–occlusal plane distance ($R = 0.732$, $p < 0.001$) and as independent variables the initial age, the initial inter-maxillary angle, the rotation of the occlusal plane and the change to the Condyle-Gonion distance ($n = 50$, df = 49). Y = 10.630 + $b_1$initial age + $b_2$initial inter-maxillary angle + $b_3$rotation of the occlusal plane + $b_4$change in Condyle-Gonion distance.

Independent variables	Coefficient β	SE	p-value
Initial age	-0.337	0.244	= 0.003
Initial inter-maxillary angle	-0.218	0.073	= 0.048
Rotation of the occlusal plane	-0.410	0.091	< 0.001
Change of the Condyle-Gonion distance	0.301	0.059	= 0.009

Discussion

This study confirmed that the foramen–occlusal plane distance increases with growth. The change was shown to be influenced by the vertical facial growth pattern. This distance increases to a greater extent for short-face individuals when compared to long-face individuals. Four cephalometric variables were found to partially explain these changes and a multiple regression analysis model was proposed.

The mean foramen–occlusal plane distance was 2.9 ± 2.4 mm (range = −3.7 to +6.8 mm) before orthodontic treatment and 5.5 ± 2.2 mm (range = 0.0–9.9 mm) 10-years after completion of treatment. The difference recorded correlates to the initial age of the patients. Hwang et al. [10] also described an increase to the foramen–occlusal plane distance with age, but did not associate this change with the growth pattern of the individual. They ascertained that the foramen is at the level of the occlusal plane level by the age of 9 and that it moves upwards from the occlusal plane after this point. To our knowledge, no other longitudinal study has been performed on this subject of the change to the foramen–occlusal plane distance and the contributing factors.

Vertical facial growth patterns are cephalometrically evaluated commonly by examination of the angle formed by the maxillary and the mandibular planes (inter-maxillary angle). In long-face individuals this angle is increased, while in short-face individuals it is decreased. These opposing vertical facial types are determined mainly by the structures located below the palatal plane [11,12]. In the present study the pre-treatment inter-maxillary angle was examined in relation to the foramen–occlusal plane distance.

The change to the foramen–occlusal plane distance during the follow-up period was also examined in relation to the rotation of the occlusal plane and the change to the Condyle-Gonion distance. For subjects exhibiting a short-face growth pattern the occlusal plane rotates anteriorly, while for long-face individuals it rotates posteriorly during growth. The Condyle-Gonion distance increases to a greater extent during growth for subjects with a short-face type than for long-face individuals. The craniofacial morphology has been found to be influenced by the functional capacity of the masticatory muscles [13]. Long-face individuals have thinner masticatory muscles, often with reduced muscular activity. Their mandibular bone is also affected [14]: the ramus is shorter, the angle formed by the ramus and the corpus of the mandible (gonial angle) is larger and the alveolar process is longer due to the over-eruption of the posterior teeth [7,12,15]. These changes directly affect the occlusal plane, causing it to rotate posteriorly (becoming steeper). This increased posterior rotation in long-face individuals influences the distance between the occlusal plane and the foramen, causing it to be shorter.

It may be suggested that caution should be exercised before extrapolating the results of this study to the whole population. The sample used in the present study comprises exclusively individuals who received an orthodontic treatment. It could be argued that the relationship between the foramen and the occlusal plane was influenced by the orthodontic treatment itself. Ideally, this study would have been performed on individuals who did not receive orthodontic treatment. However, taking cephalometric radiographs for no other purpose than for a research study would pose serious ethical questions. Therefore, the decision was made to evaluate longitudinal changes in individuals who had undergone standard fixed orthodontic treatment in the orthodontic clinic of our university department. These patients were treated for various types of malocclusion, the majority of them being a Class I malocclusion with space problems or a Class II malocclusion. Although orthodontic appliances can cause moderate changes to the occlusal plane cant, there is anecdotal evidence that these changes are only temporary [16]. In a previous investigation on the stability of the occlusal plane following orthodontic treatment, it was concluded that the greater the change to the occlusal plane during orthodontic treatment, the greater the risk of relapse after the completion of treatment [17].

The sample used in the present study consisted exclusively of Caucasian individuals. This decision was taken in order to have a more homogeneous population sample. It is possible that our results are not fully applicable to non-Caucasian individuals as many structures of the lower face vary according to ethnic group.

The study was performed retrospectively using longitudinal observations measured from cephalometric radiographs. The results of this study are in-line with a previous cross-sectional study by the same research group, which showed that the foramen–occlusal plane distance is influenced by the age and facial growth pattern of the patient. The clinical relevance of this study relates to the positioning and insertion of needles during inferior alveolar nerve blocks, particularly in patients with extreme short or long facial types. Although the present findings may help clinicians to perform safe and successful inferior alveolar nerve blocks, the usefulness of this information would need to be confirmed in a clinical context.

Conclusions

- The foramen–occlusal plane distance increases with age. In our sample with age range 6.3–11.8 years, this distance varies from −3.7 to +6.8 mm before orthodontic treatment, while variation of this distance 10-years after completion of treatment was 0.0–9.9 mm.
- This increase varies between individuals and this variation is, at least partially, explained by the vertical facial growth pattern. For short-face individuals this change is more significant than for long-face ones.
- The vertical facial growth pattern influences both the inter-maxillary angle and the rotation of the occlusal plane. These two last mentioned parameters seem to be important determinants for the observed changes in the distance from the mandibular foramen to the occlusal plane.

***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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