Original Article

Mesially Impacted Mandibular Second Molars and Adjacent First Molars: A Study of Occlusal Inclination and Root Curvature Via Panoramic Radiographs

Noppadol Chanpongsaeng[1], Soontra Panmekiate[2] and Udom Thongudomporn[3]

[1]Department of Dentistry, Lerdsin Hospital, Silom Road, Bangkok

[2]Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok

[3]Department of Preventive Dentistry, Faculty of Dentistry, Prince of Songkla University, Songkla

Abstract

There is very little available information on the root characteristics of mesially impacted mandibular second molars (7M). This study investigates occlusal inclination, root curvatures and calcification stage of unilateral 7M versus their normal counterparts (7N). Inclination and curvature of the mandibular first molars on the affected (6M) and control side (6N) were also assessed. Fifty-one digital panoramic radiographic images from study participants with unilateral 7M were examined with image J software. Occlusal inclination and degrees of root curvature at middle third and apical third level of mesial and distal root of 7M, 7N, 6M, 6N were measured and compared. Association between 7M occlusal inclination and degree of root curvature was tested. Calcification stage of 7M and 7N was evaluated by Demirjian Index. There were significant differences of occlusal inclination between 7M and 7N ($P<0.01$), and between 6M and 6N ($P<0.01$). In 7M, apical third of mesial root tended to curve mesially ($P<0.01$), whereas in 6M, apical third of both roots tended to curve distally ($P<0.01$) but the middle third of distal root tended to curve mesially ($P<0.05$). No association between the degree of root curvature and occlusal inclination was found for 7M. About one-quarter of 7M had delayed calcification compared to 7N. In conclusion, there were differences in root curvature between 7M and 7N, and 6M and 6N. 6M tended to be more upright than 6N. The degrees of root curvature and occlusal inclination of 7M were not related.

Keywords: Impaction, Mandibular second molars, Mandibular first molars, Occlusal inclination, Root curvature, Root development

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Correspondence to:

Udom Thongudomporn. Orthodontic Section, Department of Preventive Dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla, 90112. Thailand Tel: 074-429875 Fax: 074-429875 E-mail: tudom@yahoo.com

Introduction

A molar is impacted when it fails to emerge into the oral cavity after more than three quarters of its roots have formed.[1] Mesial impaction of the mandibular second molars (7M) is the most common form.[2] The tooth is mesially angulated and its mesial cusps are usually positioned against the undercut of the distal wall of the first molar and it is unable to emerge even though more than three quarters of its roots have been formed.[3] Leaving 7M untreated may lead to caries, periodontal problems and resorption of the adjacent teeth. The formation of cysts related to 7M has also been reported.[4,5] Other complications of 7M are shortening of the occlusal plane and a tendency for over-eruption of the opposing tooth.[6]

Possible etiologic factors for 7M include an abnormal tooth bud position for the 7M itself, and a lack of space between the first molar and the anterior margin of the mandibular ramus.[7] Abnormal root morphology, such as root deviation, a hooked shape and ankyloses, has also been related to the occurrence of 7M.[2] A high frequency of root deviation (31.5 %) among a group of patients with 7M has been reported.[8] However, there is a lack of information regarding the classification of 7M root deviation patterns. If an abnormal root pattern exists, such data may be a useful guide for the early detection and prevention of late complications associated with 7M.

It has been postulated that the abnormal eruption path of one tooth may be an aggravating factor that promotes the tilting or malalignment of neighboring teeth.[9] Consequently, it is possible that the abnormal eruption path of 7M may affect the inclination of the adjacent first molar (6M). A number of previous studies measured 7M inclination with reference to the axis of the 6M.[1,8,10] However, this method is unable to independently describe the degrees of inclination for the first and second molars, as an external reference line is necessary for this type of analysis.

Studies found symmetrical dental development of normally erupted left and right mandibular teeth.[11,12] In contrast, delay maturation of mandibular second molars with arrested eruption has been reported.[13] It has yet to be tested if the calcification stage of a 7M and its normal counterpart (7N) are equal.

This study had four aims: Firstly, to compare the occlusal inclination and root curvatures of 7M and 6M with their normal counterparts on the opposite side (7N and 6N). Secondly, to characterize the root curvature patterns of 7M and 6M. Thirdly, to determine the correlation between the occlusal inclination and the degrees of root curvature for 7M. And fourthly, to compare the calcification stages of 7M and 7N.

Materials and Methods

Study participants

This cross-sectional study protocol was approved by the ethics committee of the Faculty of Dentistry, Chulalongkorn University. Panoramic radiographs of patients who have a unilateral mesially impacted mandibular second molar were assessed. A mandibular second molar is considered to be mesially impacted when its mesial cusps are positioned against the undercut of the distal wall of the first molar and three quarter of its roots have formed.[3] Inclusion criteria were: the presence of all permanent teeth including mandibular third molars, absence of posterior dental crowding (overlapping of posterior teeth in the film must be less than 1/3 of mesio-distal width), formation of at least three quarters of the root of each mandibular second molar, no history of systemic disease or previous orthodontic treatment, and no facial asymmetry. The mandibular molar crowns and roots had to be clearly defined in the radiograph. Additionally, the difference between the mesio-distal crown width of the left and right mandibular first molars must not exceed 5 % to ensure a symmetrical head position during radiography. Exclusion criteria were abnormally sized or shaped teeth and single-rooted mandibular second molars. All radiographs were taken using the same machine (Kodak 8000c, Carestream Health INC., Rochester, NY, USA.) with a standardized method.

A total of 35, 840 panoramic radiographs taken at the Radiology Clinic, Faculty of Dentistry, Chulalongkorn University during 2006-2013, were screened. According to the inclusion and exclusion criteria, 51 radiographs were selected from 25 males and 26 females patients who were between the ages of 11-34 years old.

Measurements

All panoramic image files were transferred to ImageJ software (www.rsb.info.nih.gov/ij/). A horizontal (H) line parallel to the horizontal border of the image was drawn (Fig 1). This line was formed on the image from thousands of tiny pixels connected together; to ensure true parallelism, the line of pixels must be linear without “stepping”. As each patient’s head was symmetrically positioned and fixed using the chin and temporal supports of the machine during radiography, the H line was determined to be a repeatable external reference line for occlusal inclination measurements. The occlusal inclination of each mandibular molar was defined as the angle between the line connecting the mesio-buccal and disto-buccal cusps of the tooth and the H line (Fig 1). Acute angle means the tooth is mesially inclined and distally inclined vice versa.

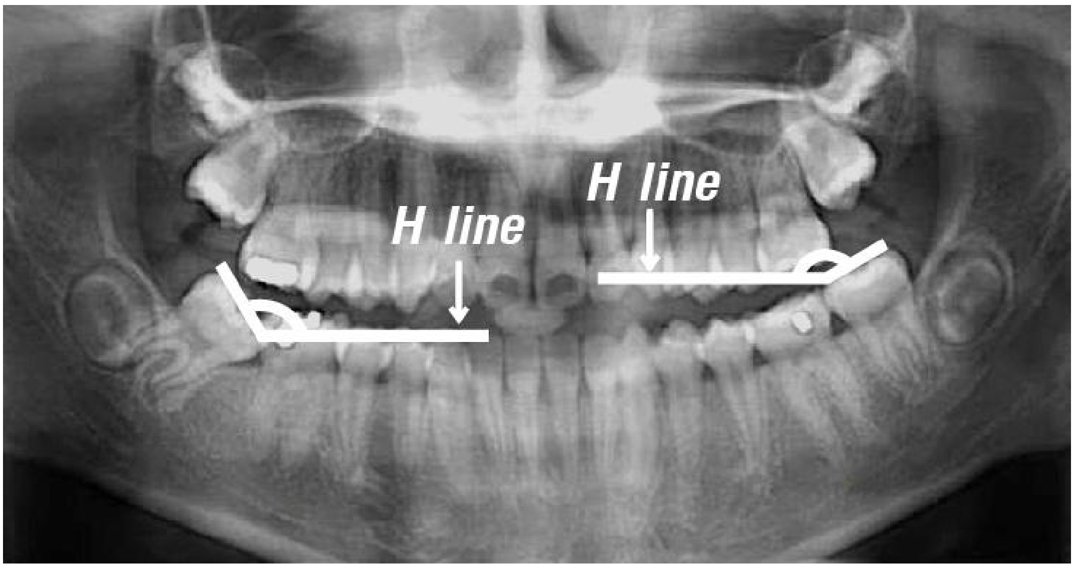

Figure 1 *Occlusal inclination measurement from a panoramic radiograph. (H line = Horizontal reference line)*

The root curvature of both the mesial and the distal roots of each molar was assessed. The middle third root curvature was defined as the angle formed by the intra-coronal root canal axis passing the canal orifice and the intra root canal axis immediately below the curve of the canal (Fig 2). The apical third root curvature was defined as the angle formed by the intra-apical root canal axis passing the apical foramen and the intra root canal axis immediately above the curve of the canal (Fig 3). The angles formed at the distal side of the bisecting axis were measured; an angle < 180 degree indicated that part of the root was distally curved; otherwise, mesially curved. For teeth with incomplete root formation, only the curvature of the middle third root was measured.

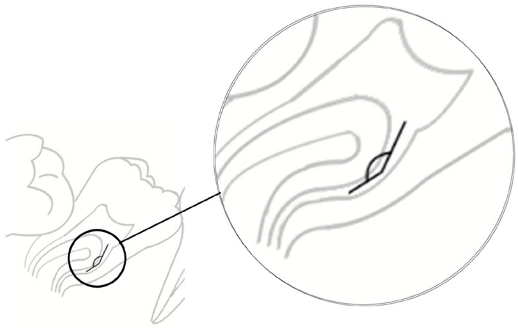

Figure 2 Illustration of degree of root curvature measurement at the middle third level

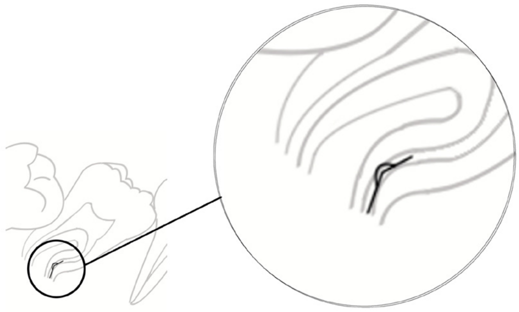

Figure 3 Root curvature measurement at the apical third level

The patterns of molar root curvatures were described using descriptive statistics. Paired *t*-tests were used to compare the root curvature and the occlusal inclination between 7M and 7N. The root curvature and occlusal inclination of 6M and 6N were also compared. Pearson correlations analysis was used to investigate the relationship between 7M occlusal inclination and its root curvatures. All tests were considered significant if $P<0.05$.

The dental calcification stages of 7M and 7N were assessed using the Demirjian Index.[11] Since all molars included were required to have a formation of at least three quarters of their roots, the calcification stages of the molars could be classified as either G stage: the walls of the root canal are parallel, but the apical end is partially open, or H stage: the root apex is completely closed. The periodontal membrane surrounding the root and apex is uniform in width throughout.

All parameters were measured by only one investigator. To assess measurement error and intra-observer reliability, ten panoramic radiographs were randomly selected. All parameters were re-measured within one week after the initial analysis. According to Dahlberg's formula,[14] the random error for the measured parameters ranged from 0.092 to 1.84 degree. The intraclass correlation coefficients for all measurements were >0.92, indicating the measured data were sufficiently reliable.

Results

Overall, 7M was significantly more mesially inclined than 7N (133.3°±12.0° vs. 161.5°±8.4° $P<0.01$; Table 1). For 7M, the apical third of its mesial root was more likely to be mesially curved (194.1°±23.2°) while that of 7N tended to be distally curved (172.0°±13.4°; $P<0.01$; Table 2). In contrast to 7M, 6M was significantly more distally inclined than 6N (172.2°±11.7° vs. 166.4°±6.1°; $P<0.01$; Table 1). The root curvatures of 6M and 6N were different; the apical thirds of the mesial and distal roots of 6M were more distally curved than those of 6N ($P<0.01$), whereas the middle third of the distal root of 6M was more mesially curved than that of 6N ($P<0.05$; Table 3). No significant correlations were observed between the inclination of 7M and its root curvatures ($P>0.05$; Table 4). Thirteen out of the fifty-one 7M teeth had delayed calcification compared to the opposing 7N (Table 5).

Table 1 *Occlusal inclination of 7M, 7N, 6M, and 6N*

Tooth	Occlusal Inclination (degrees)		*P*-value†	95% CI‡ of mean difference
	Mesially impacted (M)	Normal inclination (N)		
Second molars (7) (n = 51)	133.3 ± 12.0	161.5 ± 8.4	0.00**	24.9, 31.6
First molars (6) (n = 51)	172.2 ± 11.7	166.4 ± 6.1	0.00**	2.1, 9.6

*† Paired t-tests; **P < 0.01 ‡ Confidence Interval*

Table 2 *Comparison of root curvature between 7M and 7N*

Root	Root curvature (degrees)		*P*-value†	95% CI‡ of mean difference
	7M	7N		
Mesial root, middle third (n = 51)	153.4 ± 15.8	155.7 ± 14.5	0.35NS	-7.3, 2.6
Mesial root, apical third (n = 39)	194.1 ± 23.2	172.0 ± 13.4	0.00**	13.0, 31.2
Distal root, middle third (n = 51)	189.7 ± 16.9	188.8 ± 12.5	0.75NS	-4.2, 5.8
Distal root, apical third (n = 39)	177.4 ± 22.4	169.4 ± 21.6	0.84NS	-1.1, 17.1

*† Paired t-tests; NS not significant, **P < 0.01 ‡ Confidence Interval*

Table 3 *Comparison of root curvature between 6M and 6N*

Root	Root curvature (degrees)		*P*-value†	95% CI‡ of mean difference
	6M	6N		
Mesial root, middle third (n = 51)	152.6 ± 8.7	152.6 ± 6.7	0.99NS	-2.8, 2.8
Mesial root, apical third (n = 51)	160.3 ± 19.5	176.2 ± 13.3	0.00**	-21.7, -10.1
Distal root, middle third (n = 51)	190.4 ± 12.0	184.9 ± 10.4	0.01*	1.2, 9.6
Distal root, apical third (n = 51)	166.7 ± 23.2	178.2 ± 13.9	0.00**	-17.9, -5.1

*† Paired t-tests; NS not significant, *P < 0.05, **P < 0.01 ‡ Confidence interval*

Table 4 *Pearson's correlation coefficients for 7M inclination and its root curvatures (n = 51)*

Root curvature	Pearson's correlation coefficient	*P*-value	95% CI‡
Mesial root, middle third	-0.08	0.56NS	-0.3, 0.2
Mesial root, apical third	0.20	0.23NS	-0.1, 0.5
Distal root, middle third	0.16	0.27NS	-0.1, 0.5
Distal root, apical third	0.22	0.18NS	-0.1, 0.5

NS not significant ‡ Confidence Interval

Table 5 *Comparison of the developmental stage for 7M and 7N according to the Demirjian Index*

Development of 7M in comparison to 7N	Developmental stage (7M:7N)	N (%)
Equal	G:G	20 (39.2)
	H:H	18 (35.3)
Delayed	G:H	13 (25.5)

Discussion

The present study reveals the root curvatures of 7M and 7N as well as 6M and 6N are varied, and 6M were more distally inclined than 6N. No correlation between 7M root curvature and inclination was observed. Approximately one quarter of 7M teeth have delayed root calcification in comparison to 7N.

The finding that the apical third of the mesial roots of 7M curved mesially is in contrast to the natural tendency for the mesial root tips of the mandibular molars to point distally.[15] Nevertheless, our result is in accordance with Yamaoka *et al.*,[16] who also found mesially impacted mandibular third molars tended to have mesially curved roots at the apical third level. This observation may be related to the findings of a previous investigation, which reported unilateral impacted mandibular second molars had a reduced mesial root length compared to their normal counterparts.[3] In that study, root length was measured linearly from the occlusal plane to the root apex; hence, the shorter root length may be due to increased curvature of the roots.

The increased distal inclination of 6M in comparison to 6N may be due to the influence of 7M. It has been theorized that an inclined impacted tooth may exert pressure on an adjacent normal tooth and alter tooth inclination.[17] In the patients examined in this study, pressure from 7M may disturb the normal eruption path of the developing 6M, causing the teeth to be more upright. This effect may also cause the more distally curved apical thirds of both mesial and distal roots and mesially curved middle third of the distal root for 6M in comparison to 6N.

The absence of a significant relationship between occlusal inclination and root curvature for 7M supports the conclusion of Yamaoka *et al.*,[16] that curved root apices are mainly caused by restricted root development, not by the tooth position, and that curved roots are the result of a combination of genetics and environmental influences.

One of the etiologic factors associated with molar impaction is a lack of space in the retromolar area.[2,7] Under-development of the mandibular molars on the affected side among a group of patients with hemifacial microsomia had been observed.[18] After distraction osteogenesis, the development of the molars on the affected side accelerated towards normal. The authors suggested that the available space may play an important role in dental development. The mesial impaction and delayed root development observed for 7M in a quarter of our study samples may be attributed to the same etiologic factor, i.e. inadequate space. A further analysis relating the degree of impaction, root calcification stage and retromolar space would provide additional insight into the influence of space on dental development and position.

The delayed root development of 7M in comparison with 7N observed in this study agrees with two previous studies reporting delayed root formation for mesially inclined molars.[13,19] In a study done with rats, the authors found and discussed that the normal occlusal force may regulate the normal degree of root formation.[20] The delayed root development of the 7M in our study may be due to less exposure to occlusal force than a tooth with normal path of eruption.

This study has several strengths. Previous studies assessing root curvature used radiographic films and usually defined the root angle on the basis of the intersection of the apical third root canal axis and tooth axis.[16,21,22] This methodology raises two issues. First, the quality of film images varies due to film processing and storage procedures. Moreover, image contrast cannot be adjusted, unless the film is scanned and transformed to a digital file. Secondly, observing only apical root curvature may not be sufficient to describe the characteristics of the whole root since a root may not only curve at the apical level, but also at the middle level. Therefore, the whole root measurement methods of Weine[23] and Schneider[24] were adapted to assess digital radiographic files by using Image J which is a public domain image manipulation software that features a number of tools for digital image processing, enabling determination of linear and angular measurements, calculation of areas, particle analysis and cell counts, etc.[25] Image J has been employed in a number of dental research studies during the last decade.[26,27] It has also been used to quantify root curvature and tooth inclination.[27] Moreover, an external horizontal reference plane was used to measure occlusal inclination. As a result, the inclination of each molar could be compared with that of the adjacent molars and the contralateral molars on the same plane. Apart from a naturally low prevalence of 7M, radiographs with questionable quality was excluded, leading to a decreased sample size. A multicenter study would beneficially increase the number of samples which would increase the power of the study. Although all parameters were measured by only one investigator to prevent inter-observer measurement bias, the affected and control sides could not be blinded from the investigator. This may inevitably lead to observer bias. Moreover, some interesting parameters such as types of malocclusion may be an influencing factor which may play a role on the occurrence of 7M. This should be considered to be included in further study.

The limitations of measuring occlusal inclination and root curvature from panoramic radiographs should not be overlooked. First, although well-standardized, an alteration in the tilt of the head position along the transverse axis during radiography would influence the appearance of occlusal inclination. However, should this problem occur, it would affect the left and right teeth equally, which would not affect the comparisons within the same patient. Secondly, panoramic radiographs can produce less sharp images than periapical radiographs. Yet, in order to compare the occlusal inclination of the teeth bilaterally, the use of panoramic radiographs was necessary. The other important limitation is that this study had a cross-sectional design, which cannot explain the cause-effect relationship between occlusal inclination and root curvature, nor the effects of age or the development of the third molars on the development of second molar impaction. A longitudinal prospective cohort study should be performed to explore these relationships.

Although the results of this study cannot explain the cause-effect relationship between parameters, it may be implied that, if left untreated, 7M may not only disturb development of its roots, but also affect the inclination and roots of adjacent first molars. The pattern of root curvature of 7M and 6M as founded in this study may pose difficulty in orthodontic treatment, root canal treatment or extraction. This information justifies the importance of early detection and prevention of late complications associated with 7M.

Conclusion

This study demonstrates that the degrees of root curvature vary between 7M and 7N as well as between 6M and 6N. The apical third of the mesial root of 7M was more mesially curved than that of 7N. While 6M was more upright than 6N, 6M was more distally curved at apical third in both the mesial and the distal root, and more mesially curved at the middle third of the distal root than 6N. There was no association between 7M occlusal inclination and its degrees of root curvature. Lastly, one quarter of 7M had delayed calcification compared to their normal counterparts.

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