*Original Article*

# Angular Changes and Their Rates in Concurrence to Developmental Stages of the Mandibular Second Premolar

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**Abstract:** In the early developmental stage of the mandibular second premolar (MnP2), it is not unusual to find the tooth extremely angulated to the lower border of the mandible, as seen in the panoramic roentgenogram. On eruption, the tooth, in most cases, is close to being upright. However, impaction or other types of malocclusions due to its ectopic eruption are not rare. This study follows the angular changes of the MnP2 during development. Two hundred two panoramic roentgenograms of 101 patients were retrospectively analyzed. All patients had two sequential films with a minimal time interval of nine months. Each MnP2 was traced, and its developmental stage as well as its angulation to the lower border of the mandible was registered. We found that normally more MnP2 are distally (56.5%) than mesially (25%) inclined. There is a statistically significant difference in the inclination of the teeth during their development from stage D to stage F (D = 75.17° ± 15.25°, E = 79.35° ± 12.18°, F = 83.38° ± 10.79°). The average amount of total angular change rate of the MnP2s from stage D to stage G is 0.09 ± 0.25°/mo, and the absolute angular change rate is 0.19 ± 0.25°/mo. (*Angle Orthod* 2004;74:332–336.)

**Key Words:** Tooth development; Angular changes; Eruption

## INTRODUCTION

The tooth germ of the mandibular second premolar (MnP2) is ideally positioned between the two roots of the deciduous second molar.[1] Normally, the path of eruption follows the resorption of the roots of the deciduous molar, with no major deviations. However, abnormal tooth germ position and deviated angular changes during tooth development and eruption seem to be quite frequent.[2,3] Those changes might lead to impaction of the tooth.[4–12] Without further treatment it will remain impacted, with the risk of damaging the neighboring teeth or the surrounding bone.[13,14] Malocclusions like crowding, malalignment, and retained deciduous second molars might well be developed.[15]

Most published data concerning the eruption path of mandibular second premolars are cross-sectional. Looking at a one-time panoramic roentgenogram, it is impossible to know the exact path the tooth proceeded through. Therefore, the idea was to follow a large enough sample of MnP2 during their development and to study the behavior from early to later developmental stages as defined by Koch et al.[16]

The purpose of this study is two-fold:

- To follow the angular eruptive changes of the MnP2s during their development and eruption process, longitudinally and cross-sectionally;
- To measure the angular change rate of those teeth in the different stages of development.

## MATERIALS AND METHODS

A sample of 101 patients (56 girls and 45 boys) was selected retrospectively from pretreatment records of patients in two orthodontic practices. The selection criteria were as follows:

- The presence of at least two sequential panoramic roentgenograms of each patient separated by a minimal time interval of at least nine months;
- The presence of two MnP2 tooth buds in stages D to F of tooth formation in the first panoramic roentgenogram.

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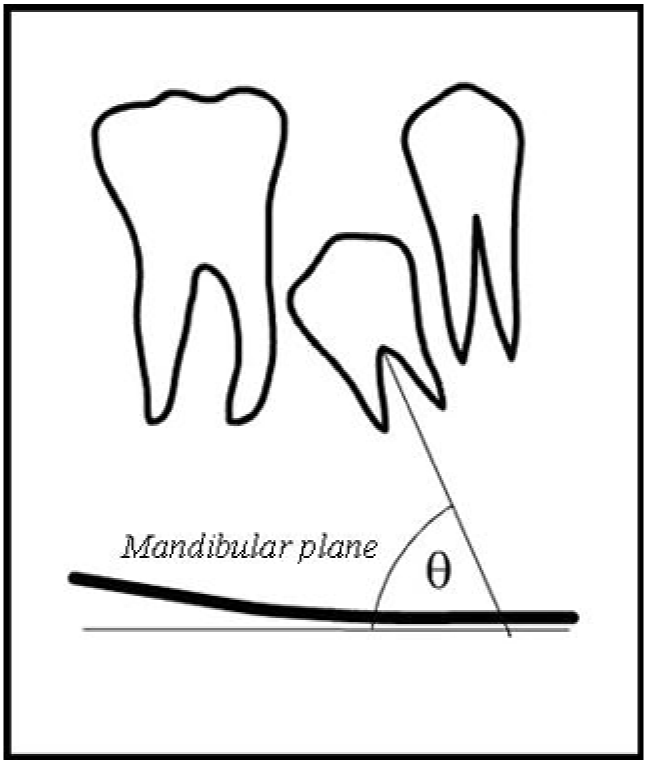


**FIGURE 1.** The distal angle between the long axis of the MnP2 and the tangent to the lower border of the mandible defined on a typical drawing of the relevant part of a panoramic roentgenogram.

The stages were derived according to the classification of Koch et al,[16] either with or without the presence of the MnP2 predecessors. Stage D is with crown formation completed down to the cementoenamel junction. Stage G is with the walls of the root canal parallel and the root apex still partly open. Stage E is with root length that is less than the crown height, and stage F is with root length that is equal to or greater than the crown height.

The mandibular second premolar in each panoramic roentgenogram was traced along with the neighboring mandibular first molars, the primary first molars if present, and the lower border of the mandibular body facing the second premolars. The long axis of the MnP2 was determined as the line connecting the uppermost point of the pulp with the point bisecting the distance between the mesial and the distal points of the apex. A protractor was then used to measure the distal angle formed between the long axis of the MnP2 and the sketched tangent to the lower border of the mandible (Figure 1). The figure shows a typical drawing along with the assigned lines and the resulting angle. All tracings were made independently by one examiner (AW), using a 0.003-inch frosted acetate paper and a 0.5-mm pencil. The first and second readings relate to the measurements made on the first and second panoramic roentgenograms, respectively.

**TABLE 1.** Mean, SD, SE, Min, and Max for the First and Second Readings in Degrees[a]

| | Number of Teeth | Mean | SD | SE | Min | Max |
|---|---|---|---|---|---|---|
| First reading | 202 | 79.51 | 12.62 | 0.89 | 22.00 | 108.00 |
| Second reading | 202 | 81.93 | 10.95 | 0.77 | 23.00 | 105.00 |

[a] There is a statistically significant difference between the two readings ($P < .0001$).

**TABLE 2.** Inclination in Degrees of Teeth According to Developmental Stage, where all the Panoramic Roentgenograms Were Pooled Together[a]

| 202 Panoramic Roentgenograms | Number of Teeth | Mean | SD |
|---|---|---|---|
| Stage D first and second readings | 70 | 75.17 | 15.25 |
| Stage E first and second readings | 147 | 79.35 | 12.18 |
| Stage F first and second readings | 108 | 83.38 | 10.79 |

[a] There is a statistically significant difference ($P < .001$) between the MnP2 inclination at the three stages.

We found that MnP2 are rotated either mesially or distally. Therefore, we decided to define two parameters:

- Total—relates to the overall movement, taking into consideration the direction—meaning that the mesial rotation might affect the distal one;
- Absolute—relates to the absolute values of the movement itself, with the direction not included.

To quantify the error of the method, a second set of 20 MnP2 were traced and measured one month later. The procedural error found was less than 1°.

### Statistical methods

Student's *t*-test (paired and unpaired), analysis of variance, and descriptive statistics, with StatView 5.0.1 on the Macintosh, were used for analysis in this study. $P < .05$ was used as significant.

## RESULTS

Because no statistically significant differences were found between the readings of boys and girls as well as between the right and the left sides, all angular measurements for each reading were pooled together. The mean ages at the first and second readings were 9.01 ± 1.69 and 11.33 ± 1.72 years, respectively.

Table 1 summarizes the statistics of the first and second readings. The total difference between the first and second readings was 2.42 ± 6.40°, whereas the absolute difference was 4.60 ± 5.06°. The mean time difference between the two readings was 27.86 ± 13.42 months.

Tooth inclination according to developmental stage is found in Tables 2 through 4. In Table 2, all the 202 panoramic roentgenograms were pooled together and gave us

**TABLE 3.** First Reading in Degrees, Split by Developmental Stages[a]

| Age (9.01 + 1.69) | Mean | SD | SE | Min | Max | Count |
|---|---|---|---|---|---|---|
| Stage D | 75.41 | 15.23 | 1.83 | 22 | 108 | 69 |
| Stage E | 81.37 | 10.28 | 0.98 | 47 | 107 | 109 |
| Stage F | 82.88 | 11.56 | 2.36 | 54 | 104 | 24 |

[a] There is a statistically significant difference ($P < 0.05$) between the stages D and E and stages D and F readings.

**TABLE 4.** Second Reading in Degrees, Split by Developmental Stages[a]

| Age (11.33 + 1.72) | Mean | SD | SE | Min | Max | Count |
|---|---|---|---|---|---|---|
| Stage E | 73.59 | 15.03 | 2.40 | 23 | 96 | 39 |
| Stage F | 83.46 | 10.74 | 1.18 | 49 | 105 | 82 |
| Stage G | 84.46 | 5.39 | 0.63 | 65 | 97 | 72 |

[a] There is a statistically significant difference ($P < 0.05$) between the stages E and F and stages E and G readings.

the idea of the average angle at different developmental stages for this large sample. Tables 3 and 4 are the split of the first and second readings, respectively, according to tooth development stages. All three tables are actually the cross-sectional results of this study.

In the longitudinal part of the study, we examined each tooth germ individually. In Table 5, we see the results of the angular changes of 38 tooth germs that developed from stage D to E, 17 tooth germs that developed from stage D to F, 11 tooth germs that developed from stage D to G, 66 tooth germs that developed from stage E to F, 40 tooth germs that developed from stage E to G, and 21 teeth germs that developed from stage F to G.

In the angular part of the study, 114 teeth (56.5%) rotated mesially, 51 teeth (25.0%) rotated distally, and 37 teeth (18.5%) did not rotate during the study period. The average total angular change rate was 0.09 ± 0.25°/mo, whereas the absolute angular change rate was 0.19 ± 0.25°/mo.

Tables 6 and 7 are the results of the total and absolute angular change rates through different developmental stages, respectively.

**TABLE 6.** Total Rotational Rates (Degrees Per Month)[a]

| | Mean | SD | Min | Max | Count |
|---|---|---|---|---|---|
| Total rotation | 0.09 | 0.25 | −1.07 | 1.69 | 202 |
| Total rotation D to E | 0.02 | 0.30 | −1.06 | 0.70 | 38 |
| Total rotation D to F | 0.05 | 0.17 | −0.12 | 0.56 | 17 |
| Total rotation D to G | 0.17 | 0.22 | −0.24 | 0.58 | 11 |
| Total rotation E to F | 0.09 | 0.21 | −0.50 | 0.75 | 66 |
| Total rotation E to G | 0.16 | 0.38 | −1.01 | 1.69 | 40 |
| Total rotation F to G | 0.15 | 0.45 | −1.07 | 1.56 | 21 |

[a] The negative (−) sign reflects rotation to the distal. Positive sign (+) (no sign) reflects rotation to the mesial.

**TABLE 7.** Absolute Rotational Rates (Degrees Per Months)[a]

| | Mean | SD | Min | Max | Count |
|---|---|---|---|---|---|
| Absolute rotation | 0.19 | 0.25 | 0.00 | 1.69 | 202 |
| **Absolute rotation D to E** | **0.19** | **0.23** | **0.00** | **1.06** | **38** |
| Absolute rotation D to F | 0.10 | 0.14 | 0.00 | 0.56 | 17 |
| Absolute rotation D to G | 0.21 | 0.18 | 0.00 | 0.58 | 11 |
| **Absolute rotation E to F** | **0.15** | **0.17** | **0.00** | **0.75** | **66** |
| Absolute rotation E to G | 0.25 | 0.32 | 0.00 | 1.69 | 40 |
| **Absolute rotation F to G** | **0.26** | **0.39** | **0.00** | **1.56** | **21** |

[a] Bolded numbers are for sequential stages.

## DISCUSSION

Among their many applications, panoramic roentgenograms serve as a tool to follow inclination changes of tooth germs in the jaws. Because there is no true reference line in the mandible, several lines like the lower border,[17–19] the alveolar crest line,[17] the teeth contact line, the anterior border of the ramus,[20] and finally the inferior dental nerve contour were suggested.[21] Most studies, as well as this one, relate the measurements to the lower border of the mandible as their reference line.

The accuracy of tooth angulations as read from the radiograph might be distorted[22] and is dependent on many factors such as head rotation, tilting, or lateral canting of the occlusal plane.[23,24] However, the posterior mandibular teeth, although affected, are in a so-called relative safe area, where the above changes have less impact on the accuracy of the measurements.

The distance between the tooth formation area and the final eruption site, as well as growth and development of

**TABLE 5.** Longitudinal Angular Changes

| Stage at First Reading | Stage at Second Reading | No of Teeth | First Reading | Second Reading | Total Difference | Absolute Difference | Time Difference (Months) | *P* |
|---|---|---|---|---|---|---|---|---|
| D | E | 38 | 73.59 + 16.26 | 74.21 + 14.72 | 0.62 + 5.82 | 3.68 + 4.47 | 20.99 + 8.03 | .78 |
| D | F | 17 | 81.59 + 15.88 | 83.29 + 12.21 | 1.71 + 5.19 | 3.12 + 4.44 | 30.18 + 6.74 | .19 |
| D | G | 11 | 73.00 + 9.34 | 81.55 + 4.30 | 8.55 + 8.88 | 9.45 + 7.80 | 49.56 + 13.00 | .009 |
| E | F | 66 | 81.73 + 10.55 | 83.47 + 10.34 | 1.74 + 4.17 | 3.17 + 3.20 | 21.95 + 8.36 | .04 |
| E | G | 40 | 81.45 + 8.89 | 85.65 + 4.24 | 4.20 + 8.37 | 7.10 + 6.04 | 36.78 + 12.93 | .003 |
| F | G | 21 | 81.23 + 11.12 | 83.71 + 1.55 | 2.48 + 6.04 | 4.38 + 4.77 | 23.70 + 7.80 | .07 |

the jaws, suggests that some changes in the tooth inclination during normal eruption are possible. The amount of those angular changes in different developmental stages was never studied longitudinally. This study follows the eruption path and the inclination changes of mandibular second premolars from developmental stage D to developmental stage G for 27.86 ± 13.42°/mo.

The overall result of tooth inclination (Table 2) demonstrates that longitudinally, during time and developmental changes, the teeth become more upright with statistical significance ($P < .001$).

Examination of the average tooth bud inclination to the mandibular plane (Table 2) reveals that at early developmental stage D, on average, the teeth are distally inclined, 75.17 ± 15.25° (70 teeth), moving into 79.35 ± 12.18° in stage E (147 teeth) and later into 83.38 ± 10.79° (108 teeth) in stage F. There is a statistically significant difference between these three angles ($P < .001$). Those changes, which are in essence cross-sectional, are reinforced in Tables 3 and 4, where the developmental changes are again cross-sectional. The longitudinal changes found in Table 5 for each group individually demonstrate that the teeth become more upright during development.

The results demonstrate that at the same developmental stage E, there is a significant difference in the first and second readings, 81.37 ± 10.28° and 73.59 ± 15.03°, respectively (Tables 3 and 4). It might be assumed that an MnP2 that develops relatively late demonstrates a lower angle to the mandibular border than similar teeth that developed earlier.

Initially, 114 teeth (56.5%) were distally inclined and during development rotated mesially, whereas only 25% (51 teeth) were mesially inclined and rotated distally. Thirty-seven teeth (18.5%) did not rotate during the study period. We could not find any morphological clue to the question of how and why the tooth rotates. We can only speculate that this probably genetic and environmental trend is part of the induction process that is fundamental in other parts of tooth development.

In trying to analyze the angular change rates, we found large differences between the developmental stages E to F (0.15 ± 0.17°/mo) and F to G (0.26 ± 0.39°/mo). It might be that just before eruption, the teeth rotate slightly faster than during the earlier developmental stages. On average, the total angular change rate was 0.09 ± 0.25°, and the absolute rotational rate was 0.19 ± 0.25°/mo. The maximum absolute angular change rate measured in this study was 1.56°/mo. In this patient, the MnP2 inclination changed from 61° when the tooth was in stage F to 75° in stage G. This change occurred in almost a nine-month period.

Clinically, this study discusses a tool to evaluate the potential of a tooth germ of the mandibular second premolar, as seen in the panoramic roentgenograms, to erupt or, on the other hand, to undergo impaction.

## CONCLUSIONS

Normally, in the early developmental stage, more MnP2s are distally (56.5%) than mesially (25%) inclined.

Teeth that are distally inclined rotate in a mesial direction, and teeth that are mesially inclined rotate distally to reach the eruption position. No morphological clue to this behavior was found.

There is a statistically significant difference in the inclination of the teeth during their development and eruption from stage D to F (D = 75.17° ± 15.25°, E = 79.35° ± 12.18°, F = 83.38° ± 10.79°). The average amount of total angular change rate of the MnP2s from stage D to stage G is 0.09 ± 0.25°/mo, and the absolute angular change rate is 0.19 ± 0.25°/mo. We found that in cases where the MnP2 develops late in the chronological age, its inclination to the mandibular plane is expected to be more diverted, at least in early developmental stages D or E.

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