

# Third molar angulation during and after treatment of adolescent orthodontic patients

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**SUMMARY** The purpose of this study was to analyse the effect of premolar extraction therapy on third molar angulation during active treatment, and to test the significance of such changes on subsequent impaction of the third molars. Lateral cephalograms made before (T1) and after (T2) treatment and at long-term follow-up (T3) of 157 patients treated non-extraction (non-ex) or with extraction of four premolars (ex), all accurately diagnosed for impaction versus eruption of at least one third molar at T3, were evaluated.

Linear regression models demonstrated that the maxillary third molars uprighted more from T1 to T2 ( $P < 0.05$ ) and were less distally angulated at T2 ( $P < 0.01$ ) in the ex than in the non-ex patients. No such differences were detected in the mandible ( $P > 0.05$ ). The regression models also showed similar uprighting of the maxillary and mandibular third molars from T1 to T2 and similar angulation of the maxillary third molars at T2 in those patients with subsequent eruption and impaction ( $P > 0.05$ ), but more mesially angulated mandibular third molars at T2 in the impaction patients ( $P < 0.01$ ). Chi square testing demonstrated a higher frequency of distal tipping of the maxillary third molars from T1 to T2 in the impaction patients ( $P < 0.01$ ), while mesial tipping from T1 to T2 of the mandibular third molars occurred with similar frequency in the two patient groups ( $P > 0.05$ ). Chi square analysis also showed a higher frequency of greater than 30 degree distal angulation as well as an amount mesial angulation of the maxillary third molars at T2 ( $P < 0.01$ ), and a higher frequency of greater than 40 degree mesial angulation of the mandibular third molars at T2 ( $P < 0.01$ ) in patients with impaction than in those with eruption.

## Introduction

The third molar buds are angulated mesially in the mandible and distally in the maxilla at the time of calcification (Sicher, 1965). Approximately 43 per cent of third molar impactions may be classified as mesial in the mandible, while about 25 per cent may be classified as distal in the maxilla (Peterson, 1998). Unsatisfactory uprighting during completion of root formation may therefore be a common cause of third molar impaction, and occur more frequently in the mandible than in the maxilla. Increased tipping may also be more prevalent in the mandible since horizontal impactions occur in approximately 3 per cent of mandibular cases but may be very rare in the maxilla (Peterson, 1998). Developmental over-uprighting may on the other hand be more frequent in the maxilla, with approximately 12 per cent of maxillary impactions being classified as mesial while only about 6 per cent of mandibular impactions are classified as distal (Peterson, 1998).

Longitudinal evaluations show that the average subject with no history of orthodontic treatment experience uprighting of the mandibular third molars during early adolescence (Richardson, 1973; Richardson *et al.*, 1984). However, the individual variation in change may be large, and a few third molars may experience increased mesial angulation during early (Richardson, 1973) and late

(Richardson *et al.*, 1984) adolescence, sometimes even demonstrating initial signs of uprighting before changing to more angulated positions between 14 and 17 years of age (Richardson *et al.*, 1984). Changes in mandibular third molar angulations may also be observed after 18 years of age, typically in the form of reduced mesial tipping (Shiller, 1979; Sewerin and von Wowern, 1990; Richardson, 1992; Hattab, 1997; Kruger *et al.*, 2001), which may sometimes be expressed as a change from a mesial to a distal angulation (Sewerin and von Wowern, 1990). However, the chances of eruption may be limited if the mesial tipping exceeds 30 degrees at 18 years of age (Schiller, 1979; Hattab, 1997). Although information on changes in maxillary third molar angulation before and during adolescence is very limited, changes after 18 years of age appear to be as variable in the maxilla as in the mandible (Kruger *et al.*, 2001).

The mandibular third molar crypts have been found to be significantly less tilted in pre-adolescent children with mesial migration of the first molars due to early loss of primary molars, suggesting that mesial migration improves the orientation of the third molar crypts by enabling them to develop further forward (Tait, 1982). The findings that third molars tend to upright both in the maxilla (Whitney and Sinclair, 1987; Staggers, 1990; Orton-Gibbs *et al.*, 2001) and in the mandible (Staggers, 1990; Orton-Gibbs *et al.*, 2001)

during orthodontic treatment with extraction of second molars may be interpreted as support for this therapy. However, individual variation in change is very large, and one study found that the average patient demonstrated a small increase in tipping of the mandibular third molar buds relative to the functional occlusal plane (Whitney and Sinclair, 1987). Moreover, such changes may be of limited predictive value for subsequent eruption, since third molar impaction following second molar extraction is very rare (Gooris *et al.*, 1990, Orton-Gibbs *et al.*, 2001). Very few attempts have been made to evaluate the predictive value of different degrees of third molar angulation during different stages of development for subsequent eruption. However, Richardson (1977) reported that impacted mandibular third molars were more mesially angulated at 10 to 11 years of age than those that had erupted.

Orthodontic closure of premolar extraction sites has been associated with a significant uprighting of the mandibular third molars (Elsey and Rock, 2000). However, lack of comparison with a representative group of non-extraction patients precluded conclusions regarding differences between the two patient categories. Documentation of a relative increase in uprighting of maxillary and mandibular third molars among extraction patients during active treatment may be one of several potential mechanisms explaining the well-documented reduction in impaction rate in adolescent orthodontic patients treated with, compared to without, premolar extractions (Kim *et al.*, 2003). One of the very few attempts at exploring this issue was unsuccessful in confirming the hypothesis (Staggers *et al.*, 1992). However, the extraction and non-extraction samples were relatively small, and any effect of the large intergroup difference in pre-treatment age on initial third molar angulation was not controlled, reducing the chance of detecting any differences in treatment change. Moreover, any differences in post-treatment angulation were not evaluated, and final impaction status was not documented (Staggers *et al.*, 1992).

The purpose of this study was to analyse the effects of premolar extraction therapy on third molar angulation during active treatment, and to test the significance of such changes on subsequent impaction of the third molars.

## Material and methods

### Sample

Lateral cephalograms, panoramic and/or periapical radiographs, and study models from before (T1) and after (T2) treatment and a minimum of 10 years post-retention (T3) of all patients without dentofacial deformities, severe facial asymmetries, or missing teeth other than four premolars, and who had been treated non-extraction (non-ex;  $n = 242$ ) or with extraction (ex) of four premolars ( $n = 315$ ) by faculty members and/or graduate students in the Department of Orthodontics at the University of

Washington, were examined. A total of 389 patients had radiographic evidence of one or more developing third molars at T1 and/or T2. Patients with removal of all third molars before evidence of apical root closure, or without radiographic identification of the apices of the remaining third molars, were eliminated. The final sample consisted of 157 patients, with a mean age of 12.3 years (SD 1.8) at T1, 15.3 years (SD 1.9) at T2, and 30.2 years (SD 4.4) at T3, of which 132 patients could be scored in the maxilla and 134 in the mandible. Non-ex treatment was performed in 51 patients and ex treatment in 106. Angle Class I, II, and III malocclusions were present in 63, 85 and 9 patients in the sample, respectively.

Independent *t*-tests revealed no significant difference in age ( $P > 0.05$ ), and Chi square tests no significant difference in distribution of Angle Class ( $P > 0.05$ ) between the selected and discarded patients. However, females were represented in 56 and 67 per cent, and ex cases in 66 and 56 per cent of the selected and discarded patients, respectively ( $P < 0.05$ , Chi square).

### Impaction and eruption

Third molar impaction was defined as incomplete eruption at T2 or T3 due to an angulated position relative to the second molar or the ascending ramus, or lack of space, with radiographic evidence of apical closure. Third molar eruption was defined as the presence in full occlusion at T2 or T3.

### Third molar angulation

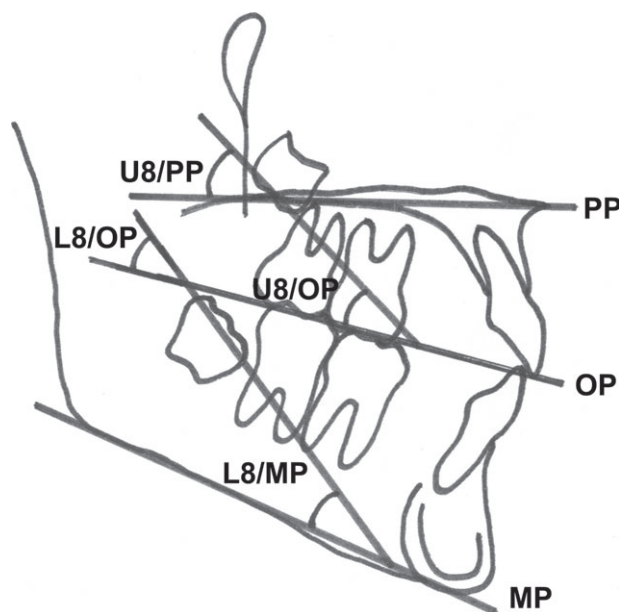
Maxillary third molar angulation was measured on lateral cephalograms as the angle between the occlusal surface and the occlusal plane (U8/OP) as well as the angle between the occlusal surface and the palatal plane (U8/PP) at T1, T2 and T3. Distal angulation was recorded as positive and mesial angulation as negative (Figure 1). Similarly, the angulation of the mandibular third molars was measured both to the mandibular (L8/MP) and the occlusal (L8/OP) planes at all three time periods, with a mesial angulation recorded as positive and a distal as negative (Figure 1). In a few subjects with asymmetry, the most severely angulated third molar was measured.

### Error of the method

The reproducibility of the measurements was assessed by statistically analysing the difference between double measurements taken at least one week apart on 10 randomly selected radiographs. The error was calculated from the equation:

$$S_x = \sqrt{\frac{\sum D^2}{2N}}$$

where D is the difference between duplicated measurements and N is the number of double measurements (Dahlberg, 1940). The errors were 0.58, 0.57 and 0.44 for U8/PP at T1,



**Figure 1** Angles used for determining angulation of the maxillary third molars to the occlusal (U8/OP) and palatal (U8/PP) planes, and of the mandibular third molars to the occlusal (L8/OP) and mandibular (L8/MP) planes.

T2 and T3; 0.56, 0.48 and 0.42 for U8/OP at T1, T2 and T3; 0.61, 0.60 and 0.43 for L8/MP at T1, T2 and T3; and 0.55, 0.53 and 0.38 for L8/OP at T1, T2 and T3.

#### Data analyses

Maxillary and mandibular impaction was scored as present if one or both respective third molars were diagnosed as impacted. In the maxilla, the angulation at T2 as well as the impaction at T3 of the third molars were scored as mesial in situations with  $U8/OP < 0$ , as vertical with  $10 \leq U8/OP \leq 0$ , and as distal with  $U8/OP > 10$ . Similarly, angulation and impaction of the mandibular third molars were scored as mesial with  $L8/OP > 10$ , as vertical with  $0 \leq L8/OP \leq 10$ , and as distal with  $L8/OP < 0$  at T2 and T3, respectively. The number and percentage of subjects with mesial, vertical, and distal inclination at T2 and impaction at T3 in each arch was calculated. Also, the corresponding number and percentage

of subjects with mesial, vertical and distal impaction at T3 in each of the three categories of angulation at T2 was calculated in each arch. Treatment change in maxillary and mandibular third molar angulation was calculated by subtracting T2 U8/PP and T2 L8/MP from T1 U8/PP and T1 L8/MP, respectively. Linear regression models were employed to test for differences in changes between ex and non-ex patients as well as between those with impaction and eruption by adjusting for variation due to intergroup differences in T2 age, gender and Angle classification. Similar regression models were also employed to test for differences in T2 U8/OP and T2 L8/OP between ex and non-ex patients as well as between those with impaction and eruption, adjusting for any effect of confounders as above. Chi-square testing was used to determine differences in the proportion of patients with a severe change in angulation from T1 to T2 and severe angulation at T2 between ex and non-ex patients as well as between subjects with subsequent eruption and impaction.

## Results

### Ex versus non-ex treatment

While the reduction in angle U8/PP from T1 to T2 was larger in the ex than in the non-ex patients ( $P < 0.05$ , Table 1), an increase in this angle occurred with similar frequency ( $P > 0.05$ ) in the ex (14/69) and non-ex (10/28) patients. The non-ex patients demonstrated a larger angle T2 U8/OP than the ex patients ( $P < 0.05$ , Table 1), and the proportion of patients with T2 U8/OP  $> 30$  degrees was higher ( $P < 0.05$ ) in the non-ex (14/37) than in the ex (17/83) subjects. However, the frequency of a negative angle T2 U8/OP was similar ( $P > 0.05$ ) in the ex (6/83) and non-ex (1/37) patients.

The reduction in angle L8/MP was similar in the two groups from T1 to T2 ( $P > 0.05$ , Table 1), with no difference in the frequency of increase between the ex (17/53) and non-ex (2/16) patients ( $P > 0.05$ ). No difference was detected in T2 L8/OP between the groups ( $P > 0.05$ , Table 1), and the proportion of patients with angle T2 L8/OP  $> 40$  degrees was similar in the non-ex (4/31) and ex (17/89)

**Table 1** Changes (degrees) in maxillary (T1 U8/PP–T2 U8/PP) and mandibular (T1 L8/MP–T2 L8/MP) third molar angulation from before (T1) to after (T2) active treatment as well as angulation (degrees) of maxillary (T2 U8/OP) and mandibular (T2 L8/OP) third molars at T2 in adolescent orthodontic patients treated with and without four premolar extractions.

	Extraction				Non-extraction				P
	Mean (n)	SD	Minimum	Maximum	Mean (n)	SD	Minimum	Maximum	
T1 U8/PP–T2 U8/PP	8.83 (69)	11.96	–22.5	41.0	3.34 (28)	9.13	–18.5	17.0	$< 0.05$
T1 L8/MP–T2 L8/MP	5.66 (53)	11.41	–10.0	37.0	7.56 (16)	8.65	–4.5	24.0	$= 0.77$
T2 U8/OP	16.78 (83)	12.95	–11.0	52.5	24.03 (37)	14.73	–4.5	61.5	$< 0.01$
T2 L8/OP	31.20 (89)	9.93	–1.0	57.5	31.87 (31)	9.13	0.0	50.0	$= 0.44$

subjects ( $P > 0.05$ ). No non-ex and only one ex patient had a negative angle T2 L8/OP ( $-1.0$  degrees).

#### *Impaction versus eruption*

The reduction in angle U8/PP from T1 to T2 was similar when comparing patients with subsequent eruption and impaction of the third molars ( $P > 0.05$ , Table 2). However, an increase in angle U8/PP (Figure 2) was more frequent ( $P < 0.01$ ) in those with impaction (11/24) than eruption (13/73). While angle T2 U8/OP was similar in both groups ( $P > 0.05$ , Table 2), the frequency of T2 U8/OP  $> 30$  degrees (Figure 2) was higher ( $P < 0.01$ ) in those with impaction (15/34) than in those with eruption (16/86). Also, a negative angle T2 U8/OP was found in only 1 of the 86 patients with eruption as opposed to 6 of 34 patients with impaction ( $P < 0.05$ ).

The reduction in angle L8/MP from T1 to T2 was similar in both patient groups ( $P > 0.05$ , Table 2), and the increase in angle L8/MP occurred with similar frequency ( $P > 0.05$ ) in the patients with subsequent impaction (5/15) and eruption (14/54) of the mandibular third molars. T2L8/OP was larger in those with impaction than in those with eruption ( $P < 0.01$ , Table 2), and T2 L8/OP  $> 40$  degrees was more frequent ( $P < 0.01$ ) in the impaction (14/35, Figure 3)

than in the eruption (7/85) patients. The third molars in the patient with a negative T2 L8/MP angle erupted.

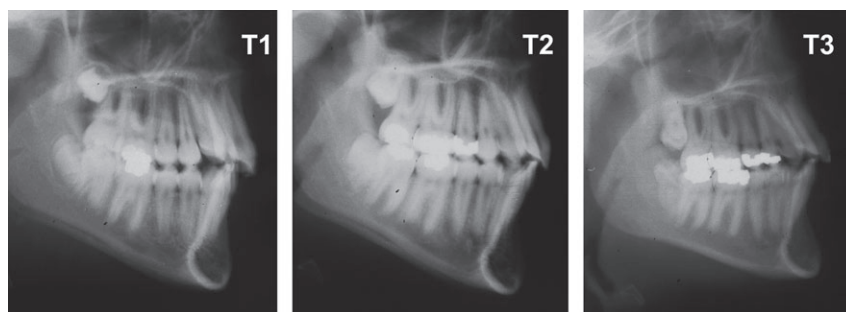
#### *Angulation at T2 versus at T3*

The majority of the third molar impactions were distal in the maxilla (Table 3), of which only one could be classified as horizontal (Figure 4). No patients with mesially inclined maxillary third molars at T2 experienced distal impaction, while 4.8 per cent of those with distal inclination at T2 experienced mesial impaction (Table 3, Figure 2). For the 95 subjects with eruption, the mean value of angle T3 U8/OP was 5.09 degrees (SD 7.15), ranging from  $-5.5$  to  $+31.5$  degrees, and only 45 had T3 U8/OP within the range  $-2.0 \pm +2.0$  degrees.

The majority of the impactions were mesial in the mandible (Table 4), two of which were classified as horizontal. Only two mandibular third molars were scored as vertical and one as distal at T2, and both erupted. Of those that were mesially inclined at T2, 8.5 per cent developed distal impaction (Table 4, Figures 3 and 4). For the 92 subjects with eruption, the mean value of angle T3L8/OP was 5.84 degrees (SD 7.15), ranging from  $-7.0$  to  $+30.0$  degrees and only 36 had T3L8/OP within the range  $-2.0 \pm +2.0$  degrees.

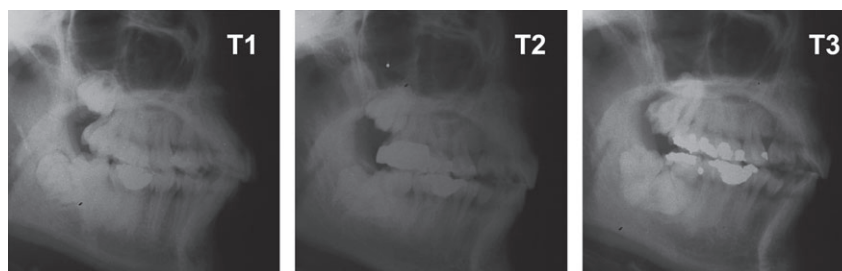
**Table 2** Changes (degrees) in maxillary (T1 U8/PP–T2 U8/PP) and mandibular (T1 L8/MP–T2 L8/MP) third molar angulation from before (T1) to after (T2) active treatment as well as angulation (degrees) of maxillary (T2 U8/OP) and mandibular (T2 L8/OP) third molars T2 in adolescent orthodontic patients with subsequent eruption and impaction of the third molars at follow-up.

	Third molar eruption				Third molar impaction				<i>P</i>
	Mean ( <i>n</i> )	SD	Minimum	Maximum	Mean ( <i>n</i> )	SD	Minimum	Maximum	
T1 U8/PP–T2 U8/PP	8.04 (73)	10.91	$-22.5$	41.0	4.83 (24)	12.89	$-18.5$	33.0	$= 0.70$
T1 L8/MP–T2 L8/MP	6.66 (54)	10.58	$-8.5$	34.5	4.10 (15)	11.75	$-10.0$	37.0	$= 0.38$
T2 U8/OP	17.33 (86)	10.78	$-6.5$	39.0	23.28 (34)	19.21	$-11.0$	61.5	$= 0.32$
T2 L8/OP	29.15 (85)	9.12	$-1.0$	45.0	36.77 (35)	9.01	20.0	57.5	$< 0.01$



**Figure 2** Cephalograms before (T1) and after (T2) non-extraction treatment at 12.7 and 16.2 years of age as well as long-term post-retention (T3) at 27.2 years of age of a patient, allowing accurate diagnosis of both maxillary and one mandibular third molar at T3. Note the 4.0 degrees of distal tipping of the maxillary third molars from T1 to T2 relative to the palatal plane and the 1.0 degree of mesial impaction at T3 relative to the occlusal plane. Also note the 7.5 degrees of uprighting of the mandibular third molar from T1 to T2 relative to the mandibular plane and the 3.5 degrees of distal impaction at T3 relative to the occlusal plane.





**Figure 3** Cephalograms before (T1) and after (T2) four premolar extraction treatment at 14.2 and 16.7 years of age as well as long-term post-retention (T3) at 29.5 years of age of a patient, allowing accurate diagnosis of all four third molars at T3. Note the asymmetric mandibular third molar positions with 8.5 degrees of mesial tipping of the most severely angulated mandibular third molar from T1 to T2 relative to the mandibular plane, and 63.5 degrees of mesial impaction of one, and vertical impaction of the other, at T3 relative to the occlusal plane. Also note the eruption of the maxillary third molars to a distally angulated position relative to the occlusal plane.

**Table 3** Number of subjects with eruption as well as mesial, vertical and distal impaction of the maxillary third molars at follow-up (T3) among subjects with mesial, vertical and distal angulation of the maxillary third molars at the end of active treatment (T2).

	Eruption	Mesial impaction T3 U8/OP<0	Vertical impaction 0 ≤ T3 U8/OP ≤ 10	Distal impaction T3 U8/OP>10	Total
Mesial angulation T2 U8/OP<0	1	6	0	0	7
Vertical angulation 0 ≤ T2 U8/OP ≤ 10	26	1	1	2	30
Distal Angulation T2 U8/OP>10	59	4	7	13	83
Unscored at T2	9	1	0	2	12
Total	95	12	8	17	132



**Figure 4** Cephalograms before (T1) and after (T2) four premolar extraction treatment at 13.2 and 15.6 years of age as well as long-term post-retention (T3) at 30.1 years of age of a patient, allowing accurate diagnosis of all four third molars. Note the 12 degrees of uprighting of the maxillary third molars from T1 to T2 relative to the palatal plane and the 40.5 degrees of distal impaction of one, and horizontal impaction of the other, at T3 relative to the occlusal plane. Also note the 4.0 degrees of uprighting of the mandibular third molars from T1 to T2 relative to the mandibular plane and 12.0 degrees of distal impaction at T3 relative to the occlusal plane.

## Discussion

The present findings contradict those of Staggers *et al.* (1992), and suggest that premolar extraction therapy has a favourable impact on maxillary third molar angulation in the average adolescent orthodontic patient (Table 1). The mechanism may be that mesial molar movement associated with extraction site closure (Kim *et al.*, 2003) promotes mesial tipping of the third molar bud. However, this relative

increase in uprighting in ex versus non-ex patients may not explain the difference in maxillary third molar impaction that has been documented between the two patient groups (Kim *et al.*, 2003), since the regression analyses suggest a similar amount of uprighting during active treatment and similar angulation at the end of active treatment in the average patient with subsequent impaction and eruption (Table 2).

**Table 4** Number of subjects with eruption as well as mesial, vertical and distal impaction of the mandibular third molars at follow-up (T3) among subjects with mesial, vertical and distal angulation of the mandibular third molars at the end of active treatment (T2).

	Eruption	Mesial impaction T3 L8/OP>10	Vertical impaction 0 ≤ T3 L8/OP ≤ 10	Distal impaction T3 L8/OP<0	Total
Mesial angulation T2 L8/OP>10	82	28	0	7	117
Vertical angulation 0 ≤ T2 L8/OP ≤ 10	2	0	0	0	2
Distal angulation T3 L8/OP<0	1	0	0	0	1
Unscored at T2	7	7	0	0	14
Total	92	35	0	7	134

Elsely and Rock (2000) concluded that closure of mandibular premolar extraction sites frequently allows improvement in the position of unerupted third molars. However, the conclusion was based on a mean uprighting of only about 7 degrees in the extraction patients, with no comparisons to a representative group of non-extraction patients. The findings in the present study suggest similar changes in mandibular third molar angulation during active treatment in patients treated with and without premolar extractions (Table 1). The hypothesis put forward by Tait (1982) that mesial movement of the mandibular molars following extraction improves the orientation of the third molar crypts by enabling them to develop further forward may therefore be questioned. Regression analyses also suggested that the amount of uprighting during treatment is of minimal predictive value for impaction. However, impacted mandibular third molars appear to be more mesially inclined at the end of active treatment than those that erupt (Table 2).

In keeping with previous studies (Whitney and Sinclair, 1987; Staggers, 1990; Staggers *et al.*, 1992) a wide variation in the change of maxillary third molar angulation during active treatment was found in the ex as well as in the non-ex patients (Table 1), with some patients demonstrating an increase in the amount of distal angulation (Figure 2). Chi square analyses indicate that distal tipping of the maxillary third molar buds during active treatment as well as severe distal angulation relative to the occlusal plane of more than 30 degrees at the end of treatment may be risk factors for impaction. Although uprighting of the maxillary third molars during treatment may be considered favourable, the present findings indicate that over-uprighting to the extent that a mesial angulation is formed relative to the occlusal plane at the end of treatment, may be a risk factor for impaction (Table 3).

Previous findings (Whitney and Sinclair, 1987; Staggers, 1990; Staggers *et al.*, 1992) of a wide variation in the change of mandibular third molar angulation during treatment are supported. The variation appears to be similar in ex and non-ex patients, with a similar frequency of subjects demonstrating mesial tipping. However, over-uprighting

to a distal angulation of the mandibular third molars prior to the end of active treatment may be very rare (Table 4). While Chi square analyses suggest that mesial tipping of the mandibular third molars during treatment is of minimal predictive value for impaction, severe mesial angulation of more than 40 degrees at the end of treatment may be a risk factor (Figure 3).

In keeping with previous studies (Shiller, 1979; Sewerin and von Wowern, 1990; Richardson, 1992; Hattab, 1997; Kruger *et al.*, 2001) the present findings suggest that changes in third molar angulation from one direction to another may be common in both arches during the final stages of root development (Tables 3 and 4, Figures 2, 3 and 4). Distally inclined maxillary third molars and mesially inclined mandibular molars at the end of treatment may erupt as well as become mesially, vertically, or distally impacted. The current findings suggest that less than 50 per cent of erupted third molars assume an ideal angulation in the dental arch. Similar conclusions have been made regarding erupted mandibular third molars following second molar extractions (Gooris *et al.*, 1990).

Measurements of third molar angulation on lateral cephalograms, as in the present and previous studies (Richardson *et al.*, 1984; Whitney and Sinclair, 1987), may be biased due to differences in angulation between the superimposed contralateral images. Similar problems are present in any cephalometric study on changes in posterior tooth positions, and can only be overcome if measurements are made on 60-degree headfilms of right and left sides. Prevalence and severity of bilateral differences in third molar angulation have not been documented in studies evaluating such records (Richardson, 1973, 1977, 1992; Tait, 1982). Undetected, minor asymmetries are not likely to have affected the statistical results of the present study, due to the relatively wide range of the individual measurements (Tables 1 and 2), and severe asymmetries (Figures 3 and 4) were rarely observed. It may also be criticized that calculation of changes in third molar angulation relative to the mandibular and palatal planes at each time period may be misinterpreted in the event of remodelling changes of the palatal processes and mandibular borders over time. However, such changes

are likely to be small during the relatively short treatment period of the subjects in the present study.

Of the 157 subjects in the sample, 132 could be scored in the maxilla and 134 in the mandible, representing every case from a large patient pool that allowed accurate diagnosis of impaction versus eruption of the third molars. In addition they were all of a sufficient age at follow-up to rule out the likelihood of subsequent eruption of the teeth diagnosed as impacted. Statistical tests also ensured that the selected cases were similar to those that were excluded because of insufficient records. Finally, the patients in the large background pool were originally selected at random. The sample may therefore be representative of the general population of adolescent extraction and non-extraction patients. However, third molar angulation prior to treatment could be measured in the maxilla in only 97 patients and in the mandible in only 69 patients, reducing the power of detecting differences in changes in third molar angulation during active treatment, particularly in the mandible. In addition, some subgroups were rather small when performing some of the Chi square tests.

### Conclusions

The findings of the present investigation suggest that premolar extraction therapy has a favourable effect on maxillary third molar angulation, while changes in mandibular third molar angulation during treatment may be similar in patients treated with and without premolar extractions. The findings also indicate that distal tipping of the maxillary third molars during active treatment, more than 30 degrees of distal angulation, and any mesial angulation relative to the occlusal plane at the end of treatment, are risk factors for subsequent impaction. In addition, mandibular third molars angulated more than 40 degrees mesially relative to the occlusal plane at the end of treatment may be at increased risk of impaction. Changes in third molar angulation from one direction to another may be common in both arches during the final stages of root development, and less than 50 per cent of erupted third molars assume an ideal angulation in the dental arch.

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