European Journal of Orthodontics, 2017, 426–432
doi:10.1093/ejo/cjw090
Advance Access publication 4 February 2017

Original article

The effect of headgear on upper third molars: a retrospective longitudinal study

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Summary

Objectives: To investigate the effects of orthodontic non-extraction treatment with or without headgear on the position of and the space available for upper third molars in growing children with class II malocclusions.

Materials and methods: The sample consisted of pre- and post-treatment panoramic radiographs and lateral cephalograms of 294 class II orthodontic patients; 160 were treated with headgear and 134 were treated without headgear. The space available for the upper third molar was measured on the lateral cephalogram as the distance from pterygoid vertical (PTV) to the distal surface of the upper first molar crown (PTV-M1). Angulation, vertical position and tooth development stage of the upper third molars were evaluated on panoramic radiographs. All measurements were evaluated statistically.

Results: In both groups PTV-M1 increased, but the increase in PTV-M1 was significantly higher for patients treated without headgear. A linear model for repeated measures revealed that this difference was still significant after correction for age, gender and molar occlusion. Further, there is no evidence that the change in angulation, vertical position and development stage of the upper third molars during orthodontic treatment is influenced by headgear therapy.

Conclusion: This study indicates that the use of headgear in growing patients significantly affects the space available for upper third molars. However, orthodontic treatment with headgear does not influence the angulation, vertical position and development stage of upper third molars. It is therefore important to always take into account third molars during treatment planning.

Introduction

Third molars are very variable in morphology and eruption time and are often congenitally missing (1, 2). Furthermore, they are the most commonly impacted teeth and are therefore heavily discussed in dental literature. Although not every impacted third molar actually causes clinical problems, it is important to keep in mind that all third molars might be linked with resorption of the adjacent second molar, periodontal disease, tooth decay, cysts and even tumour formation (3). Several studies have shown that impacted third molars rarely remain static over time (4–9). As a consequence, the decision whether or not to extract them continues to be highly debated in recent literature (10). Also in orthodontics, where most of third molars are still in a developing stage by the end of treatment, third molars have been studied extensively (11, 12), but less research has been done with regard to upper third molars.

The main cause of upper third molar impaction is the lack of retromolar space, which depends on the growth of the maxillary tuberosity along with alveolar growth and the mesial drift of the upper first molars (13). The correction of skeletal class II malocclusions in growing patients often requires applying orthopaedic forces to the maxilla, especially in patients with maxillary prognathism. Extraoral traction with a headgear appliance was one of the earliest methods (14). Several authors have argued that the eruption stage of the second and third molars has an impact on the efficiency of headgear therapy (15–17). Flores-Mir, however, recently concluded in a systematic review that the eruption stage of maxillary second and third molars has little effect on molar distalization (18).

Despite the fact that the efficiency of headgear therapy according to the stage of development of second and third molars has been often studied, the effect of headgear therapy on the space available for upper third molars has been less investigated. Therefore, this study aims at examining the possible changes in eruption space for upper third molars in patients treated with and without headgear. Furthermore, the possible differences between patients treated with and without headgear with regard to change in angulation and the vertical position of the upper third molars during orthodontic treatment are analysed.

Materials and methods

Materials

The sample consisted of pre-treatment (T1) and post-treatment (T2) panoramic radiographs and lateral cephalograms of growing children with class II malocclusions who were orthodontically treated in the Department of Orthodontics at the University Hospitals Leuven, Leuven, Belgium. This retrospective study includes patients that received final treatment between January 2008 and December 2014. All patients were treated with fixed modified edgewise appliances in combination with functional appliances, class II elastics or headgear. At the end of treatment, a class I molar relationship was achieved for each patient. This study excluded all patients with craniofacial disorders, agenesis or extractions in the upper jaw. Only the patients with high-quality pre- and post-treatment radiographs and with radiographic evidence of at least one upper third molar were included. The panoramic radiographs as well as the cephalometric radiographs were generated by a Veraview, Morita (Kyoto, Japan) or a Cranex Tome, Soredex (Tuusula, Finland). All radiographs were stored as DICOM files. The final sample consisted of 294 patients (140 males, 154 females) of which 160 patients were treated with headgear; pre-treatment age ranged from 8.7 to 17.1 years (mean age of 12.8 years) and post-treatment age ranged from 12.0 to 19.4 years (mean age of 15.5 years). Patients were instructed to wear the headgear at least 14 hours a day. The control group consisted of 134 patients who were treated without headgear, their pre-treatment age ranged from 7.9 to 15.2 years (mean age 12.4 years) and the post-treatment age ranged from 11.8 to 17.8 years (mean age 15.2 years). Additionally, all patients were subdivided into three subgroups according to the pre-treatment molar occlusion. A molar occlusion up to a quarter premolar width disto-occlusion was categorized as a mild class II molar relationship, a molar occlusion between a half and one premolar width was categorized as moderate, while a premolar width disto-occlusion of one or more was seen as a severe class II molar relationship. These descriptive data are summarized in Table 1.

Methods

The space available for the upper third molar was measured on the lateral cephalogram as the distance from PTV to the distal surface of the upper first molar parallel to the occlusal plane (PTV-M1; Figure 1) (19). This study relies on the classifications as suggested by Archer to analyse the vertical position and the angulation of the upper third molars on panoramic radiographs (20). Compared to the adjacent second molar, the vertical position of the upper third molar was classified into five stages; at the first stage the occlusal surface of the third molar is at the same level as the occlusal surface of the second molar, whereas at the last stage the occlusal surface of the upper third molar is situated above the apex of the second molar (Figure 2). The angulation of the upper third molar was classified into mesioangular, distoangular, vertical, horizontal, buccoangular, linguoangular and inverted (Figure 3). This classification is based on the inclination of the upper third molar to the long axis of the second molar. Additionally, the angle between the long axes of the second and third molar was measured on the panoramic radiographs (M2^M3). In case the upper third molar had a distoangular inclination, the angle was taken as a positive value, whereas a mesioangular inclination was classified as a negative angle. Finally, the mineralization status of the third molars was scored using Demirjian's classification, which recognizes eight stages starting from initial calcification to root completion (Figure 4) (21).

To remove possible bias, a scoring program was written in MATLAB™ randomizing the order of DICOM images presented consecutively for the observation task (22). The results measured in

Table 1. Sample distribution by gender, age, treatment duration and molar occlusion.

Variable	Statistic	Non-headgear (*N* = 134)	Headgear (*N* = 160)	*P* value
Gender (%)	male	45.5	49.4	0.558
	female	54.5	50.6	
Age pre-treatment (years)	mean	12.4	12.8	0.046*
	range	14.4-15.2	8.7-17.1	
	Std	1.5	1.4	
Age post-treatment (years)	mean	15.2	15.5	0.059
	range	11.8-17.8	12.0-19.4	
	Std	1.3	1.4	
Treatment (years)	mean	2.7	2.7	0.563
Right molar occlusion (%)	mild	15.7	37.5	<0.001*
	moderate	58.9	45.0	
	severe	25.4	17.5	

*$P < 0.05$.

MATLAB were saved as comma separated value files, reducing the possibility of man made errors; meanwhile facilitating efficient data handling and statistical analyses.

Two trained and calibrated observers were involved in the observational task under standard viewing conditions. Those two observers also reassessed 20 per cent of the radiographs for all mentioned classifications to determine the intra- and inter-observer variability. Intra-class correlation (ICC) and the standard error of measurement (SEM) were calculated for the continuous measurements (PTV-M1, M2^M3), Weighted kappa was used for the ordinal measurements and a simple kappa was calculated for the nominal measurements.

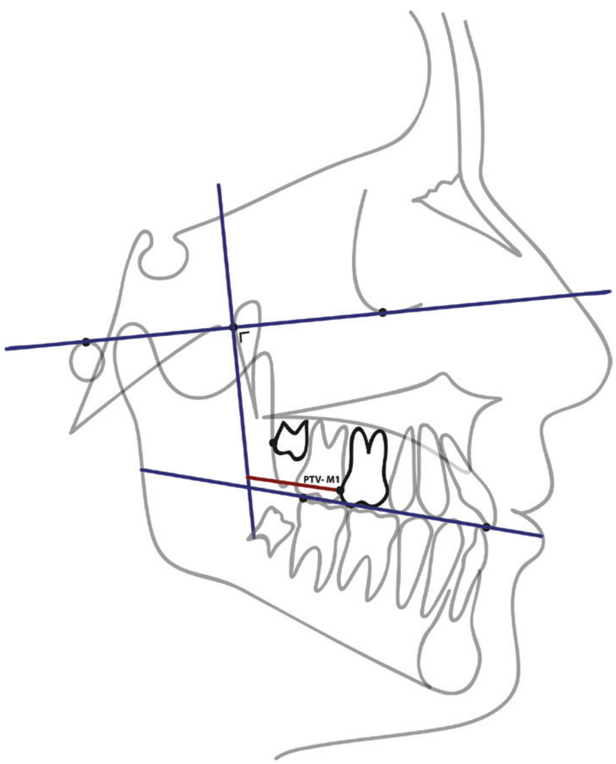

Figure 1. Cephalometric measurement to analyse the eruption space for the upper third molar.

Fisher's exact test and Mann-Whitney U test were used for the comparison of nominal, ordinal and continuous variables between subjects with and without headgear. Associations between ordinal and/or continuous variables were evaluated with Spearman correlations. A linear model for longitudinal measures with an unstructured covariance matrix was constructed to evaluate the changes over time for the continuous measurements (PTV-M1, M2^M3). Age, sex and molar occlusion were added as confounders. Outcomes of the classification suggested by Archer for upper third molar angulation were analysed with a logistic regression model using generalized estimating equations (GEE). Due to the low outcome of score 4, 5, 6 and 7, the analysis is restricted to score 1, 2 and 3 (mesioangular, distoangular and vertical). Binary logistic regressions are used, each time contrasting one level with the other two. For the ordinal measurements a cumulative logit-model with GEE was applied. *P* values smaller than 0.05 were considered statistically significant. All analyses have been performed using SAS software, version 9.2 of the SAS System for Windows. Copyright © 2016 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

This study was registered and approved by medical ethics committee of University Hospitals Leuven (registration number S56447).

Results

Intra-observer reliability

for the continuous measurements, ICC ranged between 0.88 and 0.99. For PTV-M1, the SEM equals 1.25mm; for M2^M3 the SEM equals 1.28 degrees. Weighted kappa was higher than 0.95 for both ordinal measurements (i.e. vertical position of the upper third molar and Demirjian classification). For the orientation of the upper third molar, the simple kappa equalled 0.94.

Inter-observer reliability

for the continuous measurements, ICC ranged between 0.69 and 0.95. For PTV-M1, the SEM equals 2.00 mm; for M2^M3, the SEM equals 3.60 degrees. Weighted kappa was higher than 0.85 for both ordinal measurements. For the orientation of the upper third molar, simple kappa equals 0.87.

Patients treated with headgear were older at the start of treatment and the end of the treatment ($P = 0.046$ and $P = 0.059$,

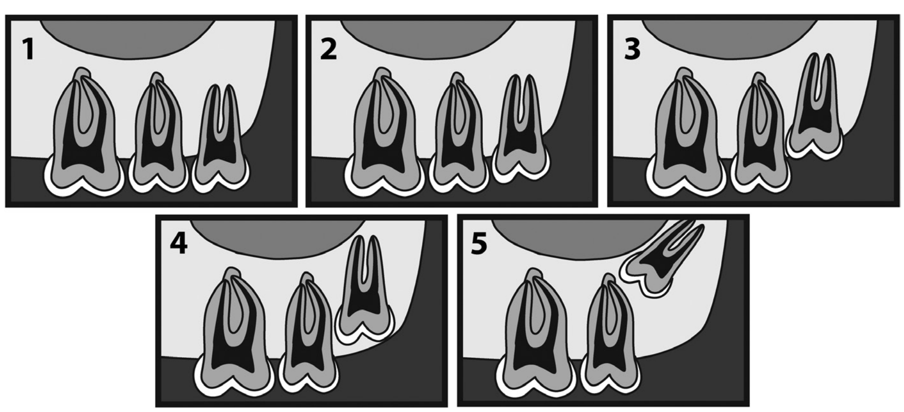

Figure 2. Classification of upper third molars according to Archer, classifying upper third molars depending on their vertical position compared to the adjacent second molar. (1) The occlusal surface of the third molar is at the same level as the occlusal surface of the second molar. (2) Occlusal surface above the cementoenamel junction of the second molar. (3) Occlusal surface at the same level of the cementoenamel junction. (4) Occlusal surface underneath the cementoenamel junction. (5) Occlusal surface above the apex of the second molar.

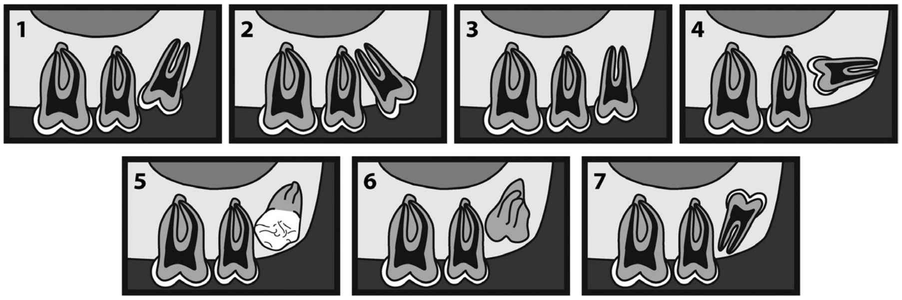

Figure 3. Classification of upper third molars according to Archer, classifying upper third molars according to their inclination to the long axis of the upper second molar. (1) Mesioangular, (2) distoangular, (3) vertical, (4) horizontal, (5) buccoangular, (6) linguoangular and (7) inverted.

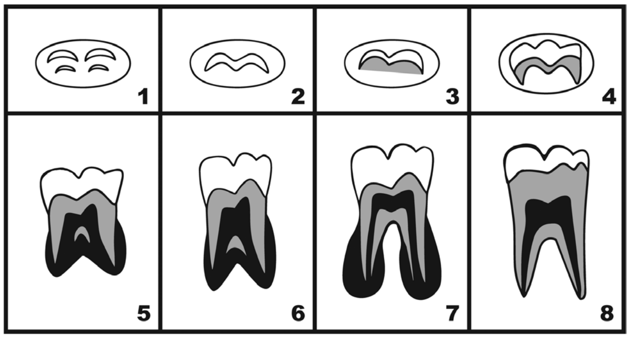

Figure 4. Demirjian's classification. Third molars are classified according to their developmental stage. (1) Cusp tips are mineralized, (2) mineralized cusps are united, (3) crown is about half formed, (4) crown formation is complete, (5) formation of the inter-radicular bifurcation has begun and root length is less than the crown length, (6) root length is at least as great as crown length and roots have funnel-shaped endings, (7) root walls are parallel but apices remain open and (8) apical ends of the roots are completely closed.

respectively) (Table 1). However, the observed differences are negligible from a clinical perspective. Note also that the disto-occlusion at the start of treatment was less severe for patients treated with headgear ($P < 0.001$).

The observed information for the PTV-M1 measurements is summarized in Table 2. At start of treatment the mean values for PTV-M1 were 16.4 mm (SD = 3.1) and 16.7 mm (SD = 3.1) respectively for the non-headgear and headgear groups. At the end of treatment, these values increased to 18.3 mm (SD = 3.6) and 17.7 mm (SD = 3.7). As a result, the percentage of patients with an increase in PTV-M1 is lower for patients with headgear (78.4 per cent versus 65.5 per cent, $P = 0.020$). Figure 5 presents the results derived from the linear model without correction for confounders. The PTV-M1 increases with 0.91 mm (95 per cent confidence interval (CI): 0.54 to 1.27, $P < 0.001$) and 1.94 mm (95 per cent CI: 1.54 to 2.34, $P < 0.001$) for patients treated with and without headgear, respectively. The difference in change between both groups (i.e. the interaction effect) is significant ($P < 0.001$).

At start of treatment, older patients have higher values for PTV-M1 (Spearman rho = 0.41, $P < 0.001$) and males have slightly higher values for PTV-M1 at start of treatment (17.0 mm (SD = 3.0) versus 16.2 mm (SD = 3.2), $P = 0.049$). The observed differences in PTV-M1 between the three subgroups were not significant (mild class II: 16.7 mm (SD = 3.3); moderate class II: 16.4 mm (SD = 3.0); severe class II: 17.1 mm (SD = 3.3), $P = 0.25$).

Also after correction for age, gender and molar occlusion, the change in PTV-M1 differs significantly between both groups ($P < 0.001$). PTV-M1 decreases with 0.96 mm (CI: 0.31 to 1.60mm, $P = 0.004$) for patients treated with headgear. This implies that if you consider two groups of patients of the same age, sex and level of molar occlusion, those after treatment have a lower PTV-M1 compared to those before treatment. On the other hand, for patients treated without headgear there is almost no difference in PTV-M1 before and after treatment when corrected for age, gender and molar occlusion; the change equals 0.04mm (CI: –0.64 to 0.71 mm, $P = 0.92$; Figure 6).

Table 2. Observed information for PTV-M1.

Measurements	Non-headgear (N = 134)	Headgear (N = 160)	P value
PTV-M1 at start of treatment			
Mean (mm)	16.4	16.8	
Median (mm)	16.2	16.8	
>18 mm (%)	26.1	38.4	0.033
PTV-M1 at end of treatment			
Mean (mm)	18.3	17.7	
Median (mm)	18.2	17.6	
>18 mm (%)	51.5	45.3	0.294
Change in PTV-M1			
Mean (mm)	1.9	0.9	
SD (mm)	2.5	2.3	
Median (mm)	1.9	0.8	
>0 mm (%)	78.4	65.6	0.020*
PTV-M1 at start ≤18 mm and at end >18 mm (%)	36.4	21.4	0.028*

*$P < 0.05$.

There was no evidence that the effect of headgear depends on the molar occlusion at the start of treatment ($P = 0.52$, detailed results not shown).

The orientation of the upper third molars changed over time in both groups. At the start of treatment the mean angle between the upper third molar and the adjacent second molar was 13.0 degrees in the headgear group and 15.5 degrees in the non-headgear group. At the end of treatment the mean angle was 14.0 degrees for the headgear group and 14.9 degrees in the non-headgear group. The angle between the upper third molar and the adjacent second molar increases with 0.99 degrees (95 per cent CI: –1.27 to 3.25, $P = 0.390$) and decreases with 0.77 degrees (95 per cent CI: –3.63 to 2.09, $P = 0.598$) for patients treated with and without headgear, respectively. The difference in change between both groups was not significant, neither without ($P = 0.34$) nor with corrections for confounders ($P = 0.36$). At start of treatment, using Archers classification, a mesioangular inclination was seen in 8.4 per cent and 5.1 per cent, a distoangular inclination in 16.1 per cent and 21.8 per cent whereas a vertical position was seen in

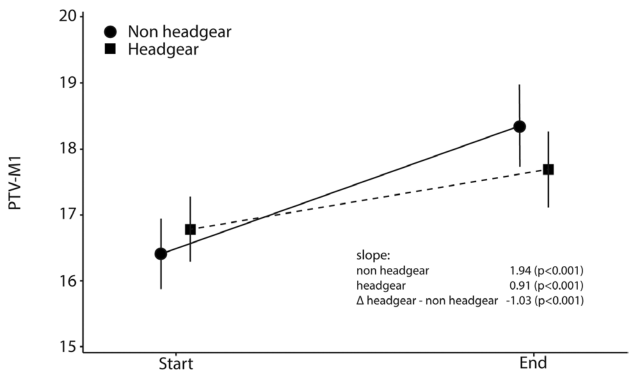

Figure 5. Results of a bivariate regression model for PTV-M1 without correction for confounders.

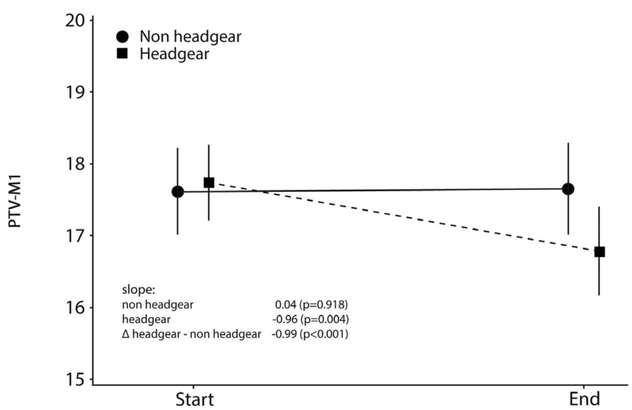

Figure 6. Results of a bivariate regression model for PTV- M1 with correction for age, gender and molar occlusion.

75.5 per cent and 73.1 per cent patients treated with and without headgear, respectively. At the end of treatment, these percentages were respectively 13.9 per cent and 14.1 per cent, 24.2 per cent and 19.4 per cent, and 61.9 per cent and 66.5 per cent. Without headgear the increase in probability of mesioangular inclination is higher compared to subjects with headgear ($P = 0.046$ after correction for confounders).

To analyse the change in vertical position of the upper third molars compared to the adjacent second molar, we only considered patients with fully-erupted second molars at the start of treatment. In 98.2 per cent and 96.2 per cent of the patients treated with and without headgear, the third molar was located under the level of the cementoenamel junction at the start of treatment. At the end of treatment, 86.2 per cent and 89.5 per cent of the third molars were located under the level of the cementonenamel junction, 11.4 per cent and 9.5 per cent were located at the same level of the cementoenal junction, whereas in 2.4 per cent and 1 per cent of the patients respectively treated with and without headgear, the third molar was located above the cementoenamel junction. Although the change over time was statistically significant with and without corrections of confounders ($P < 0.05$), there was no significant difference between patients treated with and without headgear ($P = 0.296$ after correction for confounders).

The results of the Demirjian classification revealed no significant difference between both groups at start of treatment ($P = 0.572$). There was a significant increase of the scores over time ($P < 0.05$), but it did not differ between both groups ($P = 0.635$).

Discussion

In order to study comparable groups that are only expected to differ with regard to treatment related factors, the sample only included growing patients with a class II maloclussion.

Firstly, this study aims at investigating the possible changes in eruption space for upper third molars in patients treated with and without headgear. The results suggest that in growing patients, the increase in retromolar space is smaller in patients treated with headgear compared to patients treated without headgear. After correction for age, gender and molar occlusion, statistical analysis even revealed a decrease in PTV-M1 for patients treated with headgear. These findings can be explained by the fact that headgear treatment prevents the mesial drift of the upper first permanent molars and the forward displacement of the maxilla (23, 24). As mentioned in the introduction, there has been little research on the effects of cervical headgear on the space available for the eruption of the upper second and third molars. In a longitudinal study, Ricketts investigated the mesial drift of the upper first molars in a group of patients with untreated Class I malocclusions, untreated Class II malocclusions and a group of patients treated with cervical headgear (25). At start, the mean age in all groups was approximately 8 years. The mesial drift of the upper first molar was investigated by measuring the distance from the upper first molar to a line passing through the posterior margin of the pterygomaxillary fissure and perpendicular to the Frankfort plane. The time interval between the cephalometric head films was in the two control groups 30 months and in the headgear group 27 months. In the untreated Class I control cases, the molar drifted 3.5 mm forward, in the Class II control cases the molar drifted only 2.0 mm forward and in the patients treated with headgear the molar moved backwards 1.3 mm (25). The same behaviour of the maxillary first molar in relation to the pterygomaxillary fissure was reported by Mitani, who compared a group of untreated Class I patients with a group of patients treated with headgear (26). In a more recent retrospective cephalometric study, Piva et al investigated the effects of cervical headgear and fixed appliances on the space available for upper second molars (23). Pre- and post-treatment lateral cephalograms of 34 patients were investigated. All patients were treated with cervical headgear and fixed appliances in the upper and lower jaw, but since their linear measurement differed from our method, it is not possible to compare both results. However, Piva *et al.* also concluded that the space needed for eruption of the upper third molars might be compromised by treatment with cervical headgear and fixed appliances (23). The amount of mesial molar movement that occurs during active appliance therapy was considered to be one of the most important predictive variables for upper third molar impaction by Årtun *et al.* (27). Furthermore, they concluded that every millimeter increase in retromolar space (PTV-M1) between the start and the end of treatment, reduced the risk of impaction by 13 per cent. If this finding is applied to our results, the risk of impaction at the end of treatment is reduced by only 13 per cent for patients treated with headgear, while for patients treated without headgear this risk is reduced by approximately 24 per cent. Since we only used radiographs of growing patients before and after orthodontic treatment, the results do not allow conclusions with regard to the minimum retromolar space needed for predictable eruption. However, several authors have already tried to create a predictive model for upper third molar impaction (27–29). Schulhof reported that at least 18 mm is required between the distal surface of the upper first molar and PTV for proper eruption of the upper third molars. Looking at the results of our study, at the end of treatment a retromolar space of at least 18 mm is seen in 45.3 per cent of the cases in the headgear group and in 51.5 per cent of the cases in the non-headgear group. Although this difference was not significant, the percentage of patients who started with less than 18 mm of retromolar space and finished their treatment with more than 18 mm of retromolar space was statistically higher in the non-headgear group compared to the headgear group ($P = 0.028$). However, it must be mentioned that in a recent study Kim *et al.* have questioned the clinical significance of 18 mm as an absolute threshold (29). 20 per cent of the patients in their sample experienced impaction despite a distance equal to or greater than 18 mm. In addition, the largest space associated with impaction was 24 mm and the smallest space associated with eruption was 13 mm (29). In a study of 27 patients, Ganss *et al.* found that 60 per cent of the maxillary third molars had erupted if PTV-M1 was greater than 25 mm compared with only 10 per cent if there was less than 25 mm space available (30). In this respect, it could be wondered if the tooth size of the upper third molar influences the risk of impaction. However, Årtun *et al.* reported a minimal predictive value for this parameter (27). Their univariate analyses revealed only a marginal association between the width of the maxillary third molars and subsequent impaction. Therefore, third molar width was not included in their final prediction model.

Secondly, we wanted to investigate the possible change in angulation of upper third molars in both groups. Our results show that the angulation changes during orthodontic treatment, but the difference between both groups was not significant. Only for the classification suggested by Archer, we noticed a small increase in mesioangular angulation after treatment in the non-headgear group, suggesting too much uprighting of some upper third molars in this group. Studies have shown that individual variation in uprighting of third molars appears to be large (8, 9, 31). This is in accordance with our results. Distally angulated upper third molars should upright during the period of root development for eruption to occur. In the current study, the angulation of the upper third molars changes on average 1 degree in a more distal direction, whereas in the non-headgear group it changed an average of 0.5 degree in the opposite direction. Although the interval of our study was relatively short, the results indicate a possible negative effect of headgear therapy on the uprighting of upper third molars. Ghosh and Nanda, who investigated the effect of the pendulum appliance in 41 objects even found a net distal tipping of 2.94 degrees after treatment (14). Peterson reported that 25 per cent of the impacted molars were distally angulated, suggesting that if uprighting fails to occur, impaction is likely to happen (32).

Thirdly, we compared the change of vertical position of the upper third molars of both groups and concluded that there was no remarkable difference between patients treated with and without headgear. We did not find any other study to compare our results with. However, in relation to the above it is interesting to refer to the studies of Abed and Nanda and Dandajena (33, 34). Abed investigated the effect of early headgear therapy on the eruption pattern of the upper second permanent molars and concluded that headgear therapy has a slowing down effect on the eruption of the upper second molar buds (33). Nanda and Dadjena also reported that headgear therapy for an extended period of time may result in delayed eruption of the second molars (34).

Panoramic radiographs and lateral cephalograms have been widely used in orthodontic research. Recently they have been criticized because of their 2 dimensional character, whereas they are used to asses 3 dimensional objects. Lateral cephalograms make the differentiation between right and left very difficult because of superimposition (35). Linear measurements from dental panoramic radiographs are considered to be not sufficiently reliable because of distortions and magnifications (35). By combining both radiographs, we are convinced that our method to investigate the retromolar space and positional changes of upper third molars is sufficiently precise.

It is however important to mention certain limitations of our study. Firstly this retrospective study only used pre- and post-treatment radiographs, which restrict the time of follow up to on average 2.7 years. Secondly, our data does not allow evaluation of pure headgear effects, since lateral cephalograms taken immediately after headgear-therapy were not available. We used lateral cephalograms which were taken at the end of treatment with fixed appliances.

To conclude, this study indicates that the retromolar space in the upper jaw might be compromised by orthodontic treatment using headgear and fixed appliances. Although the space for upper third molars increases during orthodontic treatment, this increase is significantly less when the patient has been treated with a headgear appliance. In accordance with our results, headgear therapy has no influence on angulation or vertical position of third molars, but the position of upper third molars is not static, it changes over time. Future, ideally prospective studies, are required to add further insight into this topic.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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