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# The influence of orthodontic extraction treatment on dental structures: a two-factor evaluation

Nilüfer Darendeliler and Lale Taner-Sarisoy
Department of Orthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey

SUMMARY The purpose of this investigation was to evaluate the effects of different growth patterns and treatment types on dentoalveolar structures in patients treated with fixed Edgewise mechanics and the extraction of four first premolars. A total of 41 patients with a mean chronological age of 14 years 7 months and skeletal age of 14 years 6 months were included in the study. The type of growth pattern was assessed as mesio- or hyper-divergent, and the treatment type as the use or non-use of headgear. The results were analysed by two-way analysis of variance (ANOVA).

The decrease in overbite in the mesiodivergent group was statistically significant when compared with the increase in the hyperdivergent group ($P < 0.01$). Extrusion of the lower molar was observed in all groups, and a statistically significant difference was found between the mesio- and hyperdivergent groups ($P < 0.05$). Interaction between growth pattern and treatment type was not found to be significant for any variable.

It can be concluded that premolar extractions and the use of headgear with fixed appliances does not significantly change the overjet, occlusal plane angle, upper and lower anterior dentoalveolar heights, upper posterior dentoalveolar height, or the inclination of the upper and lower incisors. The only significant changes were observed in overbite as a result of treatment mechanics and in lower posterior dentoalveolar height due to the growth pattern.

## Introduction

The orthodontic literature contains numerous studies that have attempted to evaluate the skeletal and dental effects of premolar extractions. Extraction and non-extraction mechanics, as currently recommended, are effective in controlling the facial axis of patients with dolicho and brachyfacial patterns of one to two standard deviations from the mean when the appropriate vector mechanics are applied (Klapper *et al*., 1992).

Persson *et al*. (1989) examined the spontaneous long-term changes following premolar extractions alone, and found marked spontaneous arch alignment and residual space closure with age.

Orthodontic treatment that involves extraction of the first premolars is commonly identified as causing temporomandibular joint disorders, by decreasing the vertical dimensions of the occlusion. Posterior teeth are believed to move forward after premolar extractions, thus permitting the mandible to overclose and shorten the resting length of the muscles of mastication. This theory disregards the concept that all orthodontic mechanics are extrusive to some degree and that extrusion maintains or even increases the vertical dimension (Staggers, 1990, 1994; McLaughlin and Bennett, 1995).

The extra-oral force used to move the maxillary molars distally and to reinforce anchorage has a vertical component of force on the posterior teeth (Nanda, 1988). The vertical changes in the nasomaxillary complex and in the position of the maxillary and mandibular molars can result in a posterior rotation of the mandible (Yamaguchi and Nanda, 1991). The vertical and sagittal positions of the mandible throughout growth largely depend on the vertical growth of the nasomaxillary complex, including the maxillary posterior teeth (Nanda, 1988), the growth of the ramus (Isaacson *et al*., 1971), the shape of the mandible (Fields *et al*., 1984), and vertical development of the mandibular posterior teeth (Yamaguchi and Nanda, 1991).

The aim of this study was to evaluate the effects of different growth patterns, and the use or non-use of headgear on dentoalveolar structures in patients treated with fixed appliances, and extraction of four first premolars.

## Subjects and methods

The patients were treated solely by the authors in the Department of Orthodontics of the Dental Faculty of Gazi University and were selected according to the mandibular plane angle (SN/GoGn), the facial axis angle (BaNa/Gn), and the ANB angle. The mandibular plane angle and the facial axis angle were used to determine the vertical growth pattern of the patients, and the ANB angle to consider the sagittal relationship of the jaws. Patients showing a skeletal Class I or Class II relationship were selected (Table 1).

Forty-one patients were classified according to their growth pattern and treatment type. The growth pattern was assessed as being either mesiodivergent (average type, SN/GoGn 27–37 degrees) or hyperdivergent (SN/GoGn ≥ 38 degrees). The treatment type was either the use or non-use of headgear (cervical headgear was applied to the mesiodivergent and high pull headgear to the hyperdivergent patients when necessary, and a combination of the mesio- and hyperdivergent patients to whom headgear was not applied formed the no headgear group). Headgear was used until the end of canine retraction with a force on one side of 350 g. As a result, four subgroups were constructed: mesiodivergent + headgear, mesiodivergent + no headgear, hyperdivergent + headgear, and hyperdivergent + no headgear (Table 1).

The two groups (growth pattern and treatment type) were well matched according to their chronological and skeletal ages. The ranges of these are shown in Table 1. All patients had Angle Class I ($n$ = 30) or Class II division 1 ($n$ = 11) malocclusions and exhibited crowding. All were treated with fixed Edgewise mechanics following extraction of the four first premolars. The extraction decision was taken with respect to total arch circumferential discrepancy and sagittal relationship of the jaws. Class II elastics (100 g) were used when necessary at the end of treatment to obtain interocclusal adjustment. The mean treatment time was 2 years 10 months (2 years 7 months–3 years 1 month).

Lateral cephalometric and hand-wrist radiographs were taken before and after treatment in the same unit using the same equipment. The cephalometric radiographs were traced and measured by hand by one investigator up to 0.5 degrees or millimeters. The hand-wrist radiographs were assessed according to the method of Greulich and Pyle (1959). The landmarks and measurements used are shown in Figure 1.

**Table 1** Definition of groups (growth pattern and treatment type) and subgroups (mesiodivergent, hyperdivergent, headgear, no headgear).

| $n$ = 41 | | Treatment type | |
|---|---|---|---|
| | | Headgear | No headgear |
| Growth pattern | Mesiodivergent<br>SN/GoGn 27–37° | $n$ = 12<br>Age: 10.83–18.08 years<br>ANB 0–7° | $n$ = 12<br>Age: 11.75–19.08 years<br>ANB 0–7° |
| | Hyperdivergent<br>SN/GoGn 38–46° | $n$ = 8<br>Age: 11.00–20.05 years<br>ANB 3–7° | $n$ = 9<br>Age: 10.92–19.08 years<br>ANB 0–7° |

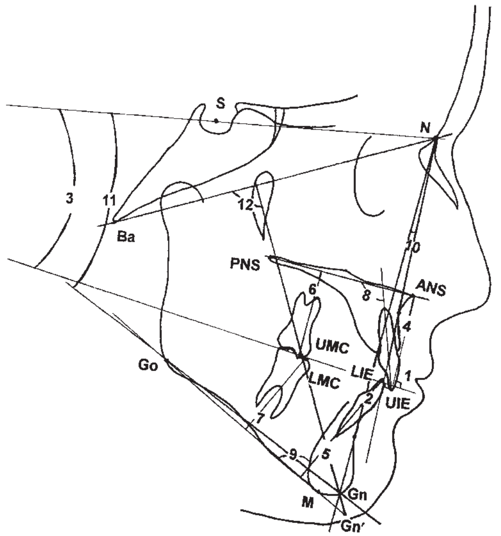


**Figure 1** Diagram showing the angular and linear measurements used in the present study. (1) Overbite (mm). (2) Overjet (mm). (3) SN/occ.plane (°). (4) UIE⊥ANS–PNS (mm). (5) LIE⊥Go–M (mm). (6) UMC⊥ANS–PNS (mm). (7) LMC⊥Go–M (mm). (8) UIE/ANS–PNS (°). (9) LIE/Go–M (°). (10) ANB (°). (11) SN/GoGn (°). (12) BaNa/Gn (°).

*Statistical analysis*

The results were assessed according to a 2 × 2 design: The growth-pattern factor had two levels, mesio- and hyperdivergent; the treatment type factor had two levels, use and non-use of headgear.

The treatment changes (after treatment-before treatment) within the mesio- and hyperdivergent groups as subdivided into treatment type, were analysed by paired comparison *t*-test (Tables 2 and 3).

The assessment of before- and after-treatment measurements (Table 4) and the treatment changes (Table 5) were analysed for each variable by two-way analysis of variance (Steel and Torrie, 1980). Interaction between the two factors (growth pattern × treatment type) was assessed by replication.

## Results

In order to analyse the potential error of the method during cephalometric tracing and measurements, 20 randomly selected lateral cephalometric radiographs were retraced and remeasured after an interval of 15 days. The repeatability coefficients were calculated with the analysis of variance. The coefficients were found to be very close to 1.00.

The mean changes in the mesiodivergent group are shown in Table 2. Overjet decreased in both subgroups, significantly in the headgear subgroup ($P < 0.01$). Within the headgear

**Table 2** Mean changes in the mesiodivergent group ($n = 24$): paired comparison *t*-test.

| Measurements | Headgear | | | No headgear | | |
|---|---|---|---|---|---|---|
| | $\bar{D}$ | $S_{\bar{D}}$ | $P$ | $\bar{D}$ | $S_{\bar{D}}$ | $P$ |
| Overbite (mm) | –0.71 | 0.71 | NS | –1.17 | 0.60 | NS |
| Overjet (mm) | –1.25 | 0.43 | ** | –1.71 | 0.90 | NS |
| SN/occlusal plane (°) | –0.92 | 0.96 | NS | 0.50 | 1.41 | NS |
| UIE⊥ANS–PNS (mm) | 0.75 | 0.45 | NS | 0.75 | 0.82 | NS |
| LIE⊥Go–M (mm) | –0.71 | 1.04 | NS | –0.33 | 0.63 | NS |
| UMC⊥ANS–PNS (mm) | 1.83 | 0.41 | *** | 0.21 | 0.97 | NS |
| LMC⊥Go–M (mm) | 1.13 | 0.37 | ** | 1.17 | 0.88 | NS |
| UIE/ANS–PNS (°) | –0.75 | 4.44 | NS | –5.54 | 2.69 | NS |
| LIE/Go–M (°) | –3.88 | 1.15 | * | –0.92 | 1.69 | NS |
| ANB (°) | –0.54 | 0.41 | NS | 0.67 | 0.32 | NS |
| SN/GoGn (°) | –0.63 | 0.38 | NS | 0.42 | 0.70 | NS |
| BaNa/Gn (°) | –0.08 | 0.74 | NS | 0.08 | 0.56 | NS |
| Age | 3.08 | 0.41 | | 2.44 | 0.24 | |
| Skeletal age | 3.34 | 0.49 | | 2.56 | 0.31 | |

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

**Table 3** Mean changes in the hyperdivergent group ($n$ = 17): paired comparison $t$-test.

| Measurements | Headgear | | | No headgear | | |
|---|---|---|---|---|---|---|
| | $\bar{D}$ | $S_{\bar{D}}$ | $P$ | $\bar{D}$ | $S_{\bar{D}}$ | $P$ |
| Overbite (mm) | 0.06 | 0.45 | NS | 1.44 | 0.29 | *** |
| Overjet (mm) | –1.50 | 0.82 | NS | –1.83 | 0.83 | NS |
| SN/occlusal plane (°) | 0.94 | 0.92 | NS | –1.56 | 2.06 | NS |
| UIE⊥ANS–PNS (mm) | 1.00 | 0.44 | NS | 1.39 | 0.66 | NS |
| LIE⊥Go–M (mm) | 1.63 | 0.63 | * | 0.50 | 1.18 | NS |
| UMC⊥ANS–PNS (mm) | 2.19 | 0.71 | * | 2.11 | 2.79 | * |
| LMC⊥Go–M (mm) | 4.13 | 1.63 | * | 2.11 | 0.82 | * |
| UIE/ANS–PNS (°) | –3.38 | 2.62 | NS | –5.33 | 2.80 | NS |
| LIE/Go–M (°) | –6.13 | 2.52 | * | –5.89 | 2.50 | * |
| ANB (°) | –1.00 | 0.42 | * | 0.22 | 0.35 | NS |
| SN/GoGn (°) | 0.88 | 1.01 | NS | –1.17 | 0.87 | NS |
| BaNa/Gn (°) | –1.06 | 0.78 | NS | 0.11 | 0.69 | NS |
| Age | 3.12 | 0.46 | | 2.46 | 0.27 | |
| Skeletal age | 3.52 | 0.49 | | 2.72 | 0.50 | |

*$P$ < 0.05; ***$P$ < 0.001.

subgroup, there was also significant extrusion of the upper ($P$ < 0.001) and lower first molars ($P$ < 0.01) and lower incisor ($P$ < 0.05) retroclination.

The mean changes in the hyperdivergent group are shown in Table 3. Overbite increased in both subgroups, significantly in the no headgear subgroup ($P$ < 0.001). Extrusion of the lower incisors was found to be significant in the headgear subgroup ($P$ < 0.05). Upper and lower molar extrusion and lower incisor retroclination were significant in both subgroups ($P$ < 0.05).

A comparison of the mean values, depending on the growth pattern and treatment type before and after treatment, is shown in Table 4. It can be seen that the patients were matched according to age between the groups. The treatment changes assessed from the two-way analysis of variance for each group are shown in Table 5. The change in overbite ($P$ < 0.01) and extrusion of the lower molar ($P$ < 0.05) was found to be significant between the mesio- and hyperdivergent groups. The change in ANB angle showed a significant difference between the headgear and no headgear groups ($P$ < 0.01). Growth pattern × treatment interaction was not found to be statistically significant for each variable.

## Discussion

The main purpose of this study was to investigate the effects of extraction therapy dependent upon growth pattern type and use/non-use of headgear on dental and skeletal variables. The growth pattern was assessed as being either mesiodivergent (average type, SN/GoGn 27–37 degrees) or hyperdivergent (SN/GoGn ≥38 degrees; Schudy, 1964; Bell *et al*. 1980; Table 1). The treatment changes in the mesio- and hyperdivergent groups as subdivided into the treatment type groups were analysed by paired comparison $t$-test (Tables 2 and 3). Since, the results obtained from the two-way analysis of variance give the inter-relationships of the effects of different growth pattern types and treatment types, basically Table 5 will be discussed.

### *Overjet and overbite changes*

Persson *et al*. (1989) found no detrimental effects with regard to overjet or overbite in a study of long-term spontaneous changes following four first premolar removals. However, other studies involving orthodontic treatment and premolar extractions, have shown that overbite increases after treatment (Bishara *et al*., 1973; Little *et al*., 1981).

**Table 4** Comparison of growth patterns (mesiodivergent and hyperdivergent) and treatment types (headgear and no headgear), before and after treatment means (two-way analysis of variance).

| | | Mesiodivergent $n = 24$ | | Hyperdivergent $n = 17$ | | | Headgear $n = 20$ | | No Headgear $n = 21$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | $S_{\bar{x}}$ | $\bar{X}$ | $S_{\bar{x}}$ | $P$ | $\bar{X}$ | $S_{\bar{x}}$ | $\bar{X}$ | $S_{\bar{x}}$ | $P$ |
| Overbite (mm) | Before | 3.13 | 0.10 | 1.19 | 0.14 | * | 2.56 | 0.12 | 1.76 | 0.12 | NS |
| | After | 2.19 | 0.06 | 1.95 | 0.08 | NS | 2.24 | 0.07 | 1.90 | 0.07 | NS |
| Overjet (mm) | Before | 2.10 | 0.11 | 2.60 | 0.15 | NS | 2.47 | 0.13 | 2.24 | 0.13 | NS |
| | After | 0.63 | 0.03 | 0.93 | 0.05 | NS | 1.09 | 0.04 | 0.47 | 0.04 | * |
| SN/occ.plane (°) | Before | 16.81 | 0.19 | 20.99 | 0.26 | ** | 18.31 | 0.23 | 19.49 | 0.21 | NS |
| | After | 16.60 | 0.16 | 20.68 | 0.22 | ** | 18.32 | 0.19 | 18.97 | 0.18 | NS |
| UIE⊥ANS–PNS (mm) | Before | 31.25 | 0.13 | 30.72 | 0.18 | NS | 31.11 | 0.16 | 30.85 | 0.15 | NS |
| | After | 32.00 | 0.14 | 31.91 | 0.19 | NS | 31.99 | 0.17 | 31.92 | 0.16 | NS |
| LIE⊥Go–M (mm) | Before | 43.75 | 0.19 | 44.15 | 0.27 | NS | 43.92 | 0.24 | 43.99 | 0.22 | NS |
| | After | 43.23 | 0.17 | 45.22 | 0.24 | NS | 44.38 | 0.21 | 44.07 | 0.20 | NS |
| UMC⊥ANS–PNS (mm) | Before | 24.96 | 0.15 | 24.22 | 0.22 | NS | 24.15 | 0.19 | 25.03 | 0.18 | NS |
| | After | 25.98 | 0.12 | 26.36 | 0.17 | NS | 26.16 | 0.15 | 26.19 | 0.14 | NS |
| LMC⊥Go–M (mm) | Before | 33.04 | 0.15 | 32.10 | 0.22 | NS | 32.81 | 0.19 | 32.33 | 0.18 | NS |
| | After | 34.19 | 0.18 | 35.22 | 0.26 | NS | 35.44 | 0.22 | 33.97 | 0.21 | NS |
| UIE/ANS–PNS (°) | Before | 106.7 | 0.48 | 109.3 | 0.68 | NS | 108.3 | 0.58 | 107.7 | 0.55 | NS |
| | After | 103.6 | 0.46 | 104.9 | 0.65 | NS | 106.3 | 0.56 | 102.3 | 0.53 | NS |
| LIE/Go–M (°) | Before | 93.31 | 0.28 | 92.65 | 0.40 | NS | 95.44 | 0.35 | 90.53 | 0.33 | * |
| | After | 90.92 | 0.34 | 86.65 | 0.49 | NS | 90.44 | 0.42 | 87.12 | 0.40 | NS |
| ANB (°) | Before | 3.85 | 0.09 | 5.43 | 0.12 | * | 5.45 | 0.11 | 3.83 | 0.10 | * |
| | After | 3.92 | 0.09 | 5.04 | 0.12 | NS | 4.68 | 0.11 | 4.28 | 0.10 | NS |
| SN/ GoGn (°) | Before | 32.10 | 0.13 | 40.50 | 0.18 | *** | 35.50 | 0.16 | 37.10 | 0.15 | NS |
| | After | 32.00 | 0.15 | 40.85 | 0.21 | *** | 35.62 | 0.18 | 37.23 | 0.17 | NS |
| BaNa/Gn (°) | Before | 85.58 | 0.15 | 82.14 | 0.22 | ** | 84.07 | 0.19 | 83.65 | 0.18 | NS |
| | After | 85.58 | 0.17 | 81.67 | 0.24 | ** | 83.50 | 0.21 | 83.75 | 0.20 | NS |
| Age | Before | 14.64 | 0.11 | 14.50 | 0.15 | NS | 14.29 | 0.13 | 14.85 | 0.12 | NS |
| | After | 17.40 | 0.11 | 17.29 | 0.16 | NS | 17.38 | 0.14 | 17.30 | 0.13 | NS |
| Skeletal age | Before | 14.75 | 0.12 | 14.18 | 0.17 | NS | 14.04 | 0.15 | 14.89 | 0.14 | NS |
| | After | 17.70 | 0.10 | 17.30 | 0.15 | NS | 17.47 | 0.13 | 17.53 | 0.12 | NS |

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Magill (1960) examined extraction and non-extraction subjects with Class I and Class II malocclusions, and found the characteristic reduction of overbite during treatment and increase in overbite post-treatment, with an overall net reduction in the degree of overbite. There was no significant difference between Class I and Class II subjects, or extraction and non-extraction cases. Paquette *et al.* (1992) compared the changes in patients treated with and without extractions, and found that the reduction in overbite and overjet after treatment was not statistically significant. Mills *et al.* (1988) observed a reduction of overbite and overjet in subjects treated with cervical headgear.

In this investigation, the results obtained concerning overbite (Table 5) showed a different pattern of change during the study within the growth pattern groups. The decrease in the mesiodivergent group was significantly different from the increase in the hyperdivergent group. This outcome was a result of the mechanics used to treat patients with different growth pattern types. Since most hyperdivergent patients have open bites, the aim is to close the bite with fixed mechanics. An increase in over-bite was observed in the absence of headgear whereas a decrease was seen when headgear was used. These differences were found to be insignificant. (Table 5). The decrease of overbite

**Table 5** The changes that occurred during treatment and comparison of these changes between growth pattern types and treatment types (two-way analysis of variance).

| | Mesiodivergent $n = 24$ | | Hyperdivergent $n = 17$ | | | Headgear $n = 20$ | | No Headgear $n = 21$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D$ | $S_D$ | $D$ | $S_D$ | $P$ | $D$ | $S_D$ | $D$ | $S_D$ | $P$ |
| Overbite (mm) | –0.94 | 0.08 | 0.75 | 0.11 | ** | –0.32 | 0.10 | 0.14 | 0.09 | NS |
| Overjet (mm) | –1.48 | 0.10 | –1.67 | 0.14 | NS | –1.38 | 0.12 | –1.77 | 0.12 | NS |
| SN/occ.plane (°) | –0.21 | 0.19 | –0.31 | 0.26 | NS | 0.01 | 0.23 | –0.53 | 0.22 | NS |
| UIE⊥ANS–PNS (mm) | 0.75 | 0.09 | 1.19 | 0.12 | NS | 0.88 | 0.11 | 1.07 | 0.10 | NS |
| LIE⊥Go–M (mm) | –0.52 | 0.12 | 1.06 | 0.17 | NS | 0.46 | 0.15 | 0.08 | 0.14 | NS |
| UMC⊥ANS–PNS (mm) | 1.02 | 0.10 | 2.15 | 0.14 | NS | 2.01 | 0.12 | 1.16 | 0.12 | NS |
| LMC⊥Go–M (mm) | 1.15 | 0.12 | 3.12 | 0.17 | * | 2.63 | 0.15 | 1.64 | 0.14 | NS |
| UIE/ANS–PNS (°) | –3.15 | 0.46 | –4.35 | 0.65 | NS | –2.06 | 0.56 | –5.44 | 0.53 | NS |
| LIE/Go–M (°) | –2.40 | 0.25 | –6.01 | 0.36 | NS | –5.00 | 0.31 | –3.40 | 0.29 | NS |
| ANB (°) | 0.06 | 0.05 | –0.39 | 0.07 | NS | –0.77 | 0.06 | 0.44 | 0.06 | ** |
| SN/GoGn (°) | –0.10 | 0.10 | 0.35 | 0.14 | NS | 0.13 | 0.12 | 0.13 | 0.11 | NS |
| BaNa/Gn (°) | 0.00 | 0.09 | –0.48 | 0.13 | NS | –0.57 | 0.11 | 0.10 | 0.11 | NS |
| Age | 2.76 | 0.05 | 2.79 | 0.07 | NS | 3.10 | 0.06 | 2.45 | 0.05 | NS |
| Skeletal age | 2.95 | 0.06 | 3.12 | 0.08 | NS | 3.43 | 0.07 | 2.64 | 0.07 | NS |

*$P < 0.05$; **$P < 0.01$.

with headgear may be due to the extrusion of molars, the extrusive effect of cervical headgear (Merrifield and Cross, 1970; Ben-Bassat *et al.*, 1986; Mills *et al.*, 1988) and the mesialization of molars as a result of treatment mechanics in hyperdivergent patients.

### *Occlusal plane changes*

In the present study, the change of the SN/occlusal plane angle was not found to be statistically significant between the groups (Table 5), which is in agreement with the results of Paquette *et al.* (1992), and Luppanapornlarp and Johnston (1993) who found no significant changes in the occlusal plane angle in patients treated with and without extractions.

### *Incisor and molar changes*

Luecke and Johnston (1992) stated that incisor retroclination, bite deepening, and incisor interferences are not inevitable results of premolar extraction treatment and Persson *et al.* (1989) noted that the lower incisor position after four premolar extractions did not differ from that of a normal occlusion sample. Both groups showed similar retroclination.

Bishara *et al.* (1995a) reported that lower incisor protrusion showed a slight decrease in a four premolar extraction group and an increase among subjects treated without extractions. The upper incisor protrusion decreased significantly in the extraction group; on the other hand, the retroclination of both upper and lower incisors in the four premolar extraction patients has been reported (Williams and Hosila, 1976; Looi and Mills, 1986; Staggers, 1990; Paquette *et al.*, 1992; Luppanapornlarp and Johnston, 1993; Bishara *et al.*, 1995b, 1997; Saelens and De Smit, 1998).

In the present investigation, retroclination of both the upper and lower incisors was observed in all groups (Table 5), but the differences between the groups were not significant. This was a result of the retraction of the anterior teeth toward the extraction spaces with Edgewise mechanics.

It has been suggested that extraction of first premolars produces a loss in vertical dimension of the occlusion (Perry, 1973; Wyatt, 1987). Premolar extraction is undertaken primarily to relieve tooth/arch length discrepancies and to reduce the proclination of the anterior teeth. Much of the extraction space is used to relieve crowding and the remainder to retract the anterior teeth. When the anterior teeth are being retracted, the objective of anchorage is to maintain the position of the posterior teeth. If anchorage is maintained, then very little protraction of the posterior teeth occurs without loss of the vertical dimension. The extraction spaces can also be used to correct the molar relationship and the molars can be protracted if necessary. Most orthodontic mechanics, including Class II elastics and cervical headgear, are extrusive in nature and, as a result, the vertical dimension may be increased in cases treated with extraction and fixed appliances (Merrifield and Cross, 1970; Mills *et al*., 1988; Staggers, 1994).

Staggers (1994) reported that the mean changes resulting from treatment, either extraction or non-extraction, were extrusion of the maxillary and mandibular first molars.

Yamaguchi and Nanda (1991) evaluated the effects of extraction and non-extraction orthodontic treatment procedures. In the group with high-pull face bow headgear, the extraction/non-extraction procedure had no significant effects on the horizontal and vertical position of the molars. However, in the extraction group, the type of force application had a significant effect on the changes in the vertical distances of the upper and lower molars to the SN plane. The changes in horizontal and vertical position of the molars are dependent on the type of force application, but not on extraction/non-extraction procedures.

Cusimano *et al*. (1993) investigated the changes in high-angle patients treated with the extraction of four first premolars and protraction of the posterior teeth. Extrusion occurred in all four teeth measured (upper and lower molars and incisors) with the greatest amount in the lower incisors. Mesial movement of both the upper and lower molars, and distal movement of both the upper and lower incisors were also noted. Bravo *et al*. (1997) compared the changes in patients treated with and without extraction of four premolars, and found a more retruded position of the incisors, a significant decrease in the inclination of the incisors in both arches and a reduced overbite among the extraction subjects. Isaacson *et al*. (1971) found more vertical growth of the anterior dentoalveolar regions in high angle patients in order to compensate for the vertical increase in the posterior regions.

The changes in the vertical positions of the upper and lower incisors in this study were not significant when a comparison was made between the groups. Extrusion of the lower molars was observed in all groups, with a significant difference noted between the mesio- and hyperdivergent groups (Table 5).

The extrusion of molars can be attributed to the use of Class II elastics, treatment mechanics (mesialization of molars to obtain a Class I relationship) and to the extrusive effect of cervical headgear (Staggers, 1990, 1994; Cusimano *et al*. 1993). Growth may also be an important factor (Staggers, 1994). As the mandible develops, it is displaced downward and forward because of primary and secondary displacement (Enlow, 1990). Iscan and Sarısoy (1997) found extrusion of the upper and lower molars in a control group consisting of patients with a skeletal open bite who showed a hyperdivergent growth pattern observed for 8 months. Kalra *et al*. (1989) noted eruption of upper and lower posterior dento-alveolar areas in a control group consisting of patients with hyperdivergent growth patterns. Most of the patients in this investigation had growth potential, thus part of the changes seen can be attributed to growth.

In this study, extrusion of the lower molars was observed in all groups, with a statistical difference between the two growth pattern types. As a result an increase in the mandibular plane angle (SN/GoGn) would be expected, but this angle showed only slight changes with no significant difference between the groups as a result of remodelling compensation (Table 5).

## Conclusions

The effects of different growth patterns and treatment on dentoalveolar structures were evaluated in patients treated with fixed mechanics and four first premolar extractions. The comparison of the change in overbite and in the height of the lower posterior dentoalveolar region between mesio- and hyperdivergent patients was found to be statistically significant.

It can be concluded that premolar extraction and the use of headgear with fixed mechanics does not significantly change dental and dentoalveolar structures.

## Address for correspondence

Dr Nilüfer Darendeliler
Department of Orthodontics
Faculty of Dentistry
Gazi University
82 Sokak
Emek 06510 Ankara
Turkey

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