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The effects of cervical headgear with an expanded inner bow in the permanent dentition

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SUMMARY In this study, the effects of cervical headgear (CHG) use on the transverse dimension of the maxillary dental arch were evaluated in patients in the permanent dentition. Thirteen girls and 12 boys (mean age: 13.41 ± 0.52 years) with a bilateral full cusp Class II molar relationship comprised the study group. Fifteen girls and 10 boys with a Class I normal occlusion comprised the controls. In the treatment group, CHG with an expanded inner bow was used for a mean period of 11.2 ± 5.6 months. The headgear was used for molar distalization and the force magnitude was 196.1 cN. After CHG treatment, the patients underwent non-extraction fixed orthodontic treatment for 14.1 ± 2.5 months. During this period, the control group received regular dental check-ups. Dental casts obtained at the beginning (T1) and end (T2) of headgear use and at the end of orthodontic treatment (T3) and posteroanterior cephalograms taken at T1 and T2 were evaluated. A Student's *t*-test was used for intergroup comparison at T1, T2, and T3 and a Mann–Whitney *U*-test with a Bonferroni correction for comparison of treatment/observation changes.

At T2, intercanine (0.96 ± 0.56 mm), interpremolar (1.6 ± 0.55 mm for the first premolar, 1.74 ± 0.65 mm for the second premolar), and intermolar (2.31 ± 0.75 mm) widths increased, while the distance between the intersection of the zygomatic process and the maxillary alveolar process on the right (JR) and left (JL) did not change. Fixed orthodontic treatment did not have any effect on any of the measurements. With the intentional expansion of the inner bow of CHG, the amount of maxillary dental arch expansion achieved in the permanent dentition was statistically significant ($P < 0.017$).

Introduction

Cervical headgear (CHG) has been used more than 50 years as an efficient method of treatment for Class II malocclusions following its introduction by Kloehn (1947). Since that time, several claims have been made in numerous studies as to its effects on the dentiton, maxillary complex, and mandibular and cranial bases. Ricketts *et al.* (1979) mentioned its expansive effect on the maxillary dental arch with intentional expansion of the inner bow.

Some studies suggest that a Class II malocclusion is related to deficiency in the maxillary width (Baccetti *et al.*, 1997; Kirjavainen *et al.*, 1997). This deficiency can be masked once the posterior teeth occlude in a narrower portion of the maxilla, compensating for the axial inclination. McNamara (2000) emphasized the importance of maxillary arch expansion in Class II treatment and reported that by expanding the maxillary arch, spontaneous forward repositioning of mandible and additional arch length gain in the maxillary arch could be achieved. You *et al.* (2001) found that the effect of forward growth of the mandible during adolescence, which could potentially bring the lower dentition forward, was negated because of intercuspal locking. With maxillary expansion, intercuspal unlocking can be achieved.

The expansion of the inner bow of CHG has been shown to be efficient in maxillary arch expansion when treatment is started during the mixed dentition (Kirjavainen *et al.*, 1997; Kirjavainen and Kirjavainen, 2003; Fenderson *et al.*, 2004; Mäntysaari *et al.*, 2004; Pirttiniemi *et al.*, 2005). However, Class II subjects do not always seek treatment during the mixed dentition and in some patients, the maxilla can be normally positioned and CHG can be used for molar distalization rather than for its orthopaedic effect.

The aim of this study was to evaluate the effects of CHG with an expanded inner bow on the transversal dimension of the maxillary dental arch, when used for molar distalization in patients in the permanent dentition.

Subjects and methods

Sample size calculation to determine the number of patients necessary to achieve 80 per cent power with an α of 0.05 was based on a clinically meaningful difference in intermolar distance of 1 mm between the study groups. The calculation showed that a minimum of 20 patients was required. To account for an estimated non-completion rate of 30 per cent (Cole, 2002), 29 patients (14 girls and 15 boys, mean age: 13.44 ± 0.61 years) who fulfilled the following criteria were recruited (Figure 1).

1. Bilateral full cusp Class II molar relationship.
2. No history of previous orthodontic treatment.
3. Maximum crowding of 4 mm in the maxillary and mandibular dental arches.

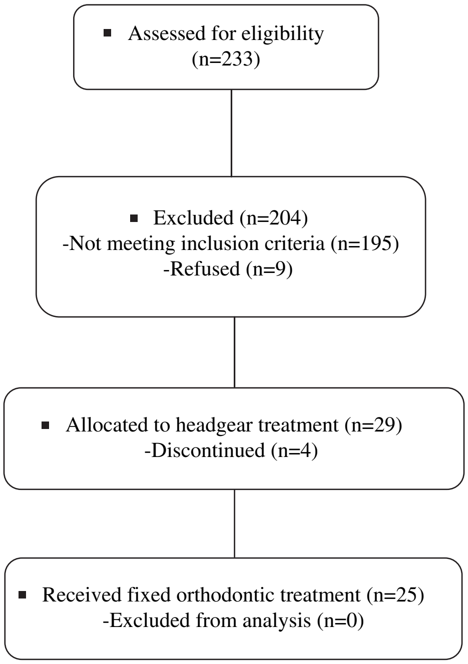

Figure 1 Chart showing the flow of subjects in the study group.

4. Absence of a posterior crossbite.
5. Permanent dentition.
6. No missing teeth.
7. No maxillary skeletal protrusion (SNA angle: 80 ± 2 degrees).
8. Dental casts available at the beginning (T1) and end (T2) of CHG use and at the end of the fixed appliance therapy (T3).
9. Posteroanterior (PA) cephalograms available at T1 and T2.

To distinguish the changes induced by orthodontic treatment from those that occured due to natural growth, a control group comprising 15 girls and 10 boys (mean age: 13.12 ± 0.73 years) were used. For ethical reasons, Class I subjects with normal occlusion formed the control group. The selection criteria for the control group were as follows:

1. Skeletal Class I.
2. Bilateral Class I molar relationship.
3. Well-aligned dental arches (maximum 2 mm crowding).
4. No missing teeth.
5. No history of previous orthodontic treatment.
6. Normal overjet and overbite.

Informed consent was obtained from all subjects in the treatment and control groups.

In the treatment group, a Ricketts' type CHG Micro Progressive universal facebow (GAC International Inc., Bohemia, New York, USA) was used. The long outer bow of the headgear was bent 20 degrees upwards in relation to the inner bow. The inner bow was expanded 10 mm (5 mm each side) wider than the distance between the right and the left first maxillary molar tubes (0.018 × 0.025 inch Micro Progressive convertible triple tube with 0 degree torque and slot offset, and gingival headgear tube, GAC International Inc.). The force magnitude was 196.1 cN. The expansion of the inner bow and the amount of force were controlled at each visit (every 4 weeks) and activation was carried out when necessary. The subjects were asked to wear the headgear 14–16 hours a day. Four patients were removed from the study approximately 2 months after the initiation of CHG treatment because of their unwillingness to use the headgear. The study continued with the remaining 13 girls and 12 boys (mean age: 13.41 ± 0.52 years). Headgear treatment was considered to be complete when a Class I molar relationship was established, and immediately after that fixed orthodontic treatment was started (Roth OmniArch brackets, GAC International Inc.). The headgear treatment lasted between 6 and 17 months (mean: 11.2 ± 5.6 months). All patients in the headgear group received non-extraction fixed orthodontic treatment. The duration of treatment with fixed appliances was between 12 and 17 months (mean: 14.1 ± 2.5 months). During this period, the control group received regular dental check-ups including plaque and caries control and periodontal screening.

The distance between the mesiobuccal cusp tips of the maxillary molars (UR6-UL6), the buccal cusp tips of the maxillary first (UR4-UL4) and second premolars (UR5-UL5), and the maxillary canines (UR3-UL3) were measured with a digital calliper (Mitutoyo, Kanagawai, Japan) to the nearest 0.02 mm.

Standardized PA cephalograms were taken using the same cephalometric unit before and after the headgear use (only at T1 and T2). The distance between the X-ray tube and the ear rod was fixed at 1.5 m (approximately 5 feet). The central ray was in the mid-sagittal plane of the head holder at the height of Frankfort horizontal plane and perpendicular to the transmeatal axis. The subjects were orientated in the Frankfort horizontal plane, and the front of the head and the nose were in contact with the radiographic cassette. The maxillary width was determined by measuring the distance between the intersection of the zygomatic process and maxillary alveolar process on the right and left (JR–JL). All dental cast and cephalometric measurements were carried out by one investigator (SKV).

Statistical analysis

Two weeks after the first measurements, the dental casts and PA cepalograms of 10 randomly selected subjects were remeasured by the same investigator. The casual error was calculated according to the Dahlberg's formula. The error of the measurements ranged from 0.06 to 0.3.

As no significant gender differences were found, the data were pooled.

The results of the Shapiro–Wilk test demonstrated that the variables were normally distributed at T1, T2, and T3; thus, a Student's *t*-test was used for intergroup comparison at the time points. The changes in treatment/observation values (T2–T1, T3–T2, and T3–T1) were not normally distributed therefore a Mann–Whitney *U*-test with a Bonferroni correction was used for comparison of treatment/observation changes. Bonferroni correction lowered the basic $P < 0.05$ level of significance to $P < 0.017$.

Results

Descriptive statistics and comparisons of the two groups at T1, T2, and T3 as well as the comparison of changes in the treatment and control groups from T1 to T2, T2 to T3, and T1 to T3 are summarized in Table 1. The results of the Student's *t*-test revealed that there were no significant differences ($P > 0.05$) between the control and treatment groups at T1. At T2 and T3, the only measurement that showed significant difference ($P < 0.05$) between the groups was the intermolar distance.

The increases observed in the intercanine (0.96 ± 0.56 mm), interpremolar (1.6 ± 0.55 mm for first premolar, 1.74 ± 0.65 mm for second premolar), and intermolar (2.31 ± 0.75 mm) widths in the treatment group due to the CHG (T2–T1) were significantly greater ($P < 0.017$) than the changes that occurred in the control group. CHG treatment did not change the JR–JL distance. All measurements remained essentially unchanged during the fixed appliance therapy (T3–T2) and the comparison of the changes observed during this period revealed no significant difference between the two groups ($P > 0.017$).

Discussion

This study was undertaken to determine the effect of CHG with an expanded inner bow on the transverse dimension of maxillary dental arch. Unlike previous investigations, the study sample consisted of subjects in the permanent dentition and the CHG was used for molar distalization (Kirjavainen *et al.*, 1997; McNamara, 2000; Kirjavainen and Kirjavainen, 2003; Fenderson *et al.*, 2004; Mäntysaari *et al.*, 2004; Pirttiniemi *et al.*, 2005).

The optimal timing for Class II treatment is controversial. Early treatment is aimed mainly at growth modification, the long-term benefit of which is open to dispute (Aelbers and Dermaut, 1996; Dermaut and Aelbers, 1996; Cozza *et al.*, 2006). In this study, Class II subjects in the permanent dentition who did not exhibit maxillary protrusion and maxillary dental or skeletal constriction comprised the

Table 1 Comparison of control (*n* = 25) and treatment (*n* = 25) groups (T1 pre-treatment), (T2 post-headgear), and (T3 post-treatment) and comparison of treatment/observation changes (T2–T1, effect of cervical headgear (CHE) treatment; T3–T2, effect of fixed appliance treatment; T3–T1, effect of total treatment).

	T1*		T2* (end of CHG treatment)		T3* (end of fixed appliance treatment)		T2–T1†		T3–T2†		T3–T1†	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Intercanine												
Control	33.8	1.86	34.1	1.88	34.1	1.88	0.25	0.61	0.02	0.05	0.27	0.61
Treatment	34.0	1.74	35.0	1.92	34.9	1.96	0.96	0.56	−0.07	0.41	0.89	0.70
Significance	NS		NS		NS		*		NS		*	
Interpremolar (first)												
Control	39.6	2.78	39.8	2.74	39.8	2.73	0.16	0.20	0.02	0.05	0.19	0.20
Treatment	39.9	2.15	41.5	2.13	41.6	2.33	1.60	0.55	0.10	0.35	1.71	0.64
Significance	NS		NS		NS		*		NS		*	
Interpremolar (second)												
Control	44.05	2.44	44.29	2.30	44.3	2.32	0.23	0.29	0.04	0.07	0.27	0.30
Treatment	44.44	3.60	46.18	3.59	46.2	3.59	1.74	0.65	0.08	0.28	2.82	0.62
Significance	NS		NS		NS		*		NS		*	
Intermolar (first)												
Control	49.7	3.04	50.0	3.05	50.0	3.03	0.21	0.24	0.02	0.05	0.24	0.25
Treatment	50.0	2.77	52.3	2.88	52.5	3.06	2.31	0.75	0.20	0.69	2.52	0.84
Significance	NS		*		*		*		NS		*	
JR–JL distance												
Control	60.5	2.36	60.5	2.30	—	—	0.02	0.07	—	—	—	—
Treatment	60.6	2.68	60.5	2.71	—	—	0.01	0.20	—	—	—	—
Significance	NS		NS		—		NS		—		—	

*Student's *t*-test: $P < 0.05$.
†Mann–Whitney *U*-test with Bonferroni correction. *$P < 0.017$. NS, not significant.

treatment group; so, redirection or restriction of maxillary growth and orthopaedic maxillary expansion was not intended. The purpose of inner bow expansion was mainly to unlock the occlusion and to gain additional arch length.

Patient co-operation is one of the most important factors in achieving the desired result during headgear treatment. In this study, co-operation was assessed subjectively by one clinician (SKV). The patients were questioned about their motivation and also the mobility of the molars, the cleanliness of the headgear tubes and the neck strap, and the ease of CHG placement were assessed. The level of dropout was significantly lower than that predicted initially (30 per cent). Four patients (13.7 per cent) who stated that they did not want to use the headgear were excluded from the study. Ghafari *et al.* (1998) reported a similar (15 per cent) dropout rate during headgear treatment. A Class I molar relationship was achieved in the remaining 25 patients, but the wide range of treatment time (6–17 months) during CHG use was probably due to different co-operation levels of the subjects.

In this research, the study and control groups were matched for age but not for gender or malocclusion. Lux *et al.* (2003) studied dental arch and maxillary base width changes in the early, mixed, and permanent dentition separately for boys and girls. Their results revealed similar changes for both genders. Ferrario *et al.* (1999) and Šlaj *et al.* (2003) did not find sexual dimorphisim with respect to the dental arches. Because of ethical concerns, the control group consisted of subjects with a Class I normal occlusion. Bishara *et al.* (1996) reported that general growth trends for changes in dental arch dimensions from the primary to the mixed and permanent dentitions were similar in subjects with a Class II division 1 malocclusion to those with a normal occlusion. Sayın and Türkkahraman (2004) reported that subjects with a Class II division 1 malocclusion had narrower maxillary interpremolar (measured at the second premolars) and intermolar widths than the Class I subjects. They did not find any significant difference in intercanine width. Uysal *et al.* (2005) found that subjects with a Class II division 1 malocclusion had narrower maxillary interpremolar widths and larger intermolar widths than Class I subjects, but no differences were found in maxillary intercanine widths. In contrast to these two studies, no significant differences between the initial maxillary arch width measurements of Class II and Class I subjects were observed in the present investigation. Differences between these findings could be attributed, in part, to the variations in dental arch development stages and the exclusion of subjects with a posterior crossbite from the present study. One significant point that should to be taken into consideration is that, as the objective of this study was not to compare the arch widths of Class II and Class I malocclusions, the sample size was insufficient for statistical evaluation.

Maxillary dental arch measurements showed expansion after a mean period of 11.2 months of CHG treatment with an expanded inner bow. The mean increase between the maxillary canines, first and second premolars, and molars in the maxillary arch was 0.96, 1.6, 1.74, and 2.31 mm, respectively. These values were markedly less than those in previous studies. Kirjavainen *et al.* (1997) reported a maxillary intermolar treatment increase of 6.6 and 5.1 mm in males and females, respectively, and a maxillary intercanine increase of 4.9 and 5 mm in males and females, respectively. Mäntysaari *et al.* (2004) found a 2.9 mm increase in intercanine width and a 5.4 mm increase in intermolar width after 1 year of CHG use. In the study by Fenderson *et al.* (2004), the increase in the maxillary arch width due to expanding headgear treatment was reported to be 3.2 mm for intercanine width, 4.2 mm for interpremolar width, and 4 mm for intermolar width.

One of the main differences between the present and previous studies, which might have caused the diversity in the results, was probably the mean ages and dentitional stages of the patients. In this study, only subjects in the permanent dentition were included. Their mean age was 13.41 years. It is generally accepted that most arch width dimensions are established in the early mixed dentition and minimal changes occur thereafter (Van der Linden, 1989; Bishara *et al.*, 1997; Šlaj *et al.*, 2003); accordingly, the possible effects of growth on dental arch dimensions were minimized in this sample. The mean ages of the subjects were 9.1 and 9.3 years in the studies by Kirjavainen *et al.* (1997) and Kirjavainen and Kirjavainen (2003), 11.4 years in the that by Fenderson *et al.* (2004), and 7 years in a study by Pirttiniemi *et al.* (2005). It can be assumed that the growth-related increase in arch width contributed to the changes produced by treatment in those studies.

PA cephalograms are helpful in evaluating transversal skeletal and dentoalveolar relationships despite their limitations, such as the difficulties in reproducing head posture and identifying landmarks, as a result of their superimposed structures, and being prone to errors arising from minor head rotations. In this study, PA cephalograms obtained at T1 and T2 were used to measure JR–JL distance to evaluate the transverse skeletal effects of CHG with an expanded inner bow. PA cephalograms are not included in the clinic's routine patient records; for this reason, as no transversal skeletal change was anticipated after fixed orthodontic treatment, PA cephalograms were not obtained at T3. The initial mean values of JR–JL (approximately 63.3 mm), which were lower than the norms for this age group (Ricketts *et al.*, 1982), did not change after CHG treatment. This indicated that tipping of the teeth accounted for the expansion achieved. Thus in subjects with a skeletal crossbite, other means of expansion should be used. Kirjavainen and Kirjavainen (2003) reported a JR–JL increase of 1.6 mm. One factor that might have led to this different skeletal response could be the magnitude of the force applied by the headgear. As the headgear was used for molar distalization in this study, only 196.1 cN of force was used. The magnitude of the headgear force was much higher (490.3 cN) in the study of Kirjavainen and Kirjavainen (2003). According to Ricketts *et al.* (1979), the expansive effect of the CHG derives from the anatomical configuration of the maxillary complex. When any force places distal compression on this complex, the palatal vaults slide down the outward sutural bevel formed by the palatal bone and a mid-palatal disjunction can be seen. One prerequisite for this to occur is that the applied transverse force should be of sufficient magnitude to overcome the bioelastic strength of the sutural elements (Bell, 1982). In previous studies of slow expansion, force magnitude ranged from 500 to 2000 cN depending on the patient's age, and rapid maxillary expansion was reported to have a cumulative force of approximately 100 N (Hicks, 1978; Bell, 1982; Mossaz-Joelson and Mossaz, 1989; Boysen *et al.*, 1992; Henry, 1993; Proffit and Fields, 2000). The findings of the present study (no change in the JL–JR distance) clearly indicated that a transversal component of 196.1 cN distal force was not sufficient for any transversal skeletal change to occur. The modest increase observed in maxillary arch width at the end of CHG application could be explained by the passive expansion resulting from the shield effect of the inner bow, which acted to keep the buccal musculature away from the dentition, and buccal tipping of the first molars. Differences in the mean ages of the groups could be another factor responsible for the difference between the skeletal effects achieved since a direct relationship has been observed between increased resistance to skeletal expansion and increasing age (Bell, 1982; Chaconas and Caputo, 1982).

Adkins *et al.* (1990) reported that for every millimetre of interpremolar width increase, the resultant gain in arch length was approximately 0.7 mm. If these values are used to calculate the increase in arch length, the expansion in the present study can be considered of little clinical importance. However, together with the concomitant arch length gain resulting from molar distalization, the increase in arch length can become efficacious in Class II subjects with moderate crowding.

After a Class I molar relationship was achieved with the CHG, non-extraction orthodontic treatment with fixed appliances was initiated in all subjects in the treatment group. The fixed appliance treatment lasted approximately 14.1 months and no change was observed in the maxillary arch widths. Bishara *et al.* (1996), who compared dental arch changes after extraction and non-extraction Class II division 1 treatment, reported an increase of 0.5–2, 2.1–3.3, and 1.2–1.8 mm between the canines, second premolars, and molars, respectively, in the non-extraction group.

A major limitation of this study is the unavailability of long-term follow-up results as the retention period is still continuing, To date, there have been only two studies that presented the long-term outcomes of maxillary expansion with CHG. Fenderson *et al.* (2004) reported that this expansion method retained 90 per cent of the initial intermolar expansion 15 years after expansion therapy and Pirttiniemi *et al.* (2005) found that the expansion remained unchanged after 8 years.

Conclusion

With the intentional expansion of the inner bow of a CHG exerting a distal force of 196.1 cN, a statistically significant maxillary arch expansion was achieved in the permanent dentition. Although the changes (T2–T1) observed in the treatment group were significantly different from those of the control group, the only measurement, which differed between the two groups at T2 and T3, was intermolar distance.

No transversal skeletal change was observed after CHG use and the amount of dental expansion was less than that achieved by other means of orthodontic expansion.

The expansion achieved with the CHG remained unchanged and the fixed appliance treatment did not cause any additional transverse changes in the maxillary arch.

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