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# Effects of headgear Herbst and mandibular step-by-step advancement versus conventional Herbst appliance and maximal jumping of the mandible

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SUMMARY The aims of this study were to compare dental and skeletal treatment changes in Class II division 1 malocclusions with two modes of maxillary control and two modes of bite-jumping. The subjects comprised Chinese children with severe Class II division 1 malocclusions, i.e. 21 consecutive subjects (13.4 ± 1.4 years) treated with a headgear Herbst appliance and step-by-step advancement (HHSSA) of the mandible, and 24 consecutive subjects (13.2 ± 1.4 years) treated with a 'conventional' Herbst appliance with maximal jumping (HMJ) of the mandible. Lateral cephalograms obtained at the start and end of treatment were analysed.

The results showed that the improvement of the sagittal jaw relationship was significantly larger (2.9 mm; $P < 0.001$) in the HHSSA group than in the HMJ group due to the increased effect on the maxilla (–1.5 mm, $P < 0.001$) and the mandible (+1.4 mm, NS). There was no significant difference in the change in lower anterior face height, being 2.7 and 3.1 mm, respectively. The mandibular plane angle decreased significantly in the HHSSA group (–0.7 degrees; $P < 0.05$) and increased insignificantly in the HMJ group (0.4 degrees, NS), the difference being statistically significant ($P < 0.01$). The maxillary molars moved significantly more distally (1.1 mm, $P < 0.05$) and were intruded in the HHSSA group (–1.0 mm, $P < 0.001$) compared with a small extrusion in the HMJ group (+0.3 mm, NS), the difference being statistically significant ($P < 0.001$). There was no significant difference in the effect on the mandibular teeth. Treatment with HHSSA seems to result in a greater effect on the sagittal jaw relationship, improved vertical control and more maxillary molar movement. Mandibular anchorage loss was not reduced with step-by-step advancement of the mandible.

## Introduction

Various modifications of the Herbst appliance have been shown to be very effective in normalizing the dental arch relationship in the treatment of Class II division 1 malocclusions (e.g. Pancherz, 1979, 1981, 1982a,b, 1985; Wieslander, 1984; Pancherz and Hägg, 1985; Pancherz and Hansen, 1986; Pancherz and Anehus-Pancherz, 1993; Wong *et al.*, 1997). However, in a substantial number of successfully treated patients there are post-treatment changes due to unfavourable growth and muscle activity (Hansen *et al.*, 1991). On average, there is enhanced sagittal growth of the mandible when using the Herbst appliance (Pancherz, 1979), but this effect varies between individual patients (from 0.8 to 6.2 mm during 6 months of treatment; Wong *et al.*, 1997), between the sexes and with timing of treatment (Pancherz and Hägg, 1985; Malmgren *et al.*, 1987). Wieslander (1984) by adding high-pull headgear to the Herbst appliance in the early treatment of severe Class II division 1 malocclusions showed marked maxillary and mandibular changes. However, no comparison was made with a control group or patients treated with a Herbst appliance without headgear. Previous studies on functional appliances have shown that there is no enhanced mandibular growth when using activators (Björk, 1951; Harvold and Vargervik, 1971; Ahlgren and Laurin, 1976; Wieslander and Lagerström, 1979; Pancherz, 1984). By adding headgear to the activator (Stöckli and Dietrich, 1973; Teuscher, 1978; Bass, 1982, 1983a,b; Van Beek, 1982; Malmgren and Ömblus, 1985) it has been claimed that some control of excessive maxillary vertical growth can be obtained that indirectly positively affects the positioning of the mandible, and results in enhanced mandibular growth (Malmgren *et al.*, 1987). With any removable functional appliance there is a risk that a patient's lack of co-operation may contribute to failure, reported to be approximately 10–15 per cent in Swedish children (Ahlgren and Laurin, 1976; Malmgren *et al.*, 1987). Since unfavourable facial growth pattern could not be successfully changed with a common activator (*ad modum* Andresen), the failure rate increased by another 25–30 per cent (Ahlgren and Laurin, 1976).

The aims of this study were to compare treatment of Angle Class II division 1 malocclusions with a Herbst appliance, with and without headgear and with step-by-step advancement (HHSSA) of the mandible versus maximal jumping (HMJ) of the mandible.

## Material and methods

The material comprised lateral cephalograms obtained before and after treatment of two groups of Chinese patients with severe Class II division 1 malocclusions. The first group comprised 22 (nine males and 13 females) consecutive patients (mean age 13.3 ± 1.4 years) treated with a splinted HHSSA and the second group 24 (12 males and 12 females) consecutive patients (mean age 13.2 ± 1.4 years) treated with the modified 'conventional' banded HMJ. One patient from the first group moved from Hong Kong before treatment was completed and, thus, the subsequent analysis was based on 21 patients from that group. The average treatment time was 12 months (SD ± 1.4 months) and 10 months (SD ± 1.6 months), respectively; the difference in treatment time, 2 months, was not statistically significant.

The 'conventional' banded Herbst has been described in detail elsewhere (Pancherz, 1985). The only modification was that a rapid palatal expansion (RPE) screw was added for transverse expansion, when indicated, and to increase anchorage. The 'splinted' headgear Herbst consisted of one upper and one lower framework cast in silver (Tse, 1994). The upper framework had an expansion screw and two buccal tubes at the side of the first premolar region used for attaching the high-pull headgear, which was used for 12 hours a day with a force of 400–500 g on each side. The lower arch was advanced initially 2 mm and, thereafter, another 2 mm every 2 months by soldering a 2 mm section of metal tube to the pivot ends of the plungers. This procedure was repeated until a Class III incisor relationship was achieved.

The lateral cephalograms were analysed to evaluate the sagittal (Pancherz, 1982a) and vertical changes (Pancherz, 1982b) during treatment (Figure 1a,b). There was no significant difference in facial morphology between the two groups at the start of treatment (Table 1).

### *Statistical analysis*

The arithmetic means and standard deviations were calculated for all cephalometric variables. A *t*-test for paired samples was used to assess whether changes observed during treatment were significant. Unpaired *t*-tests were undertaken to compare the magnitude of the changes between the two groups. The magnitude of the combined method error (ME) in locating, superimposing, and measuring the changes of the different cephalometric landmarks was calculated with the formula $ME = \sqrt{(\Sigma d^2/2n)}$, where $d$ is the difference between two registrations of a pair and $n$ the number of duplicate registrations. Cephalograms from 10 randomly selected patients were analysed twice at an interval of 1 month. The combined method error did not exceed 0.8 mm for any of the variables measured.

## Results

The results are shown in Table 2 and Figure 2. The overjet correction was 10.4 and 8.7 mm, in the HHSSA and HMJ groups, respectively;

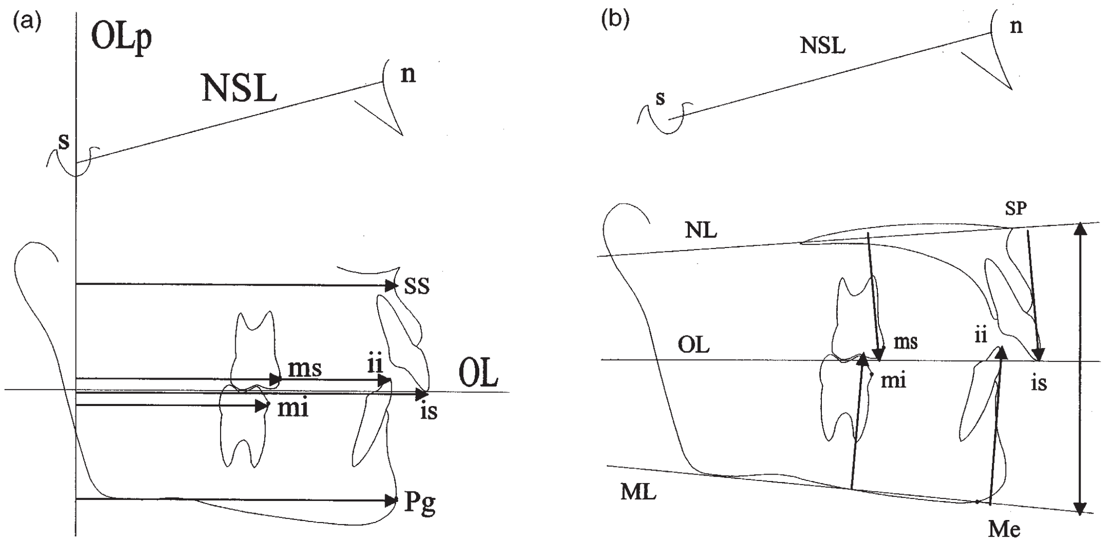


**Figure 1** (a) Cephalometric analysis of sagittal (Pancherz, 1982a) and (b) vertical parameters (Pancherz, 1982b). ii, Incision inferius—the incisal tip of the most prominent mandibular central incisor. is, Incision superius—the incisal tip of the most prominent maxillary central incisor. mi, Molar inferius—the mesial contact point of the mandibular permanent first molar determined by a tangent parallel to OLp; where double projection gave rise to two points, the midpoint was used. ms, Molar superius—the mesial contact point of the maxillary permanent first molar determined by a tangent parallel to OLp; where double projection gave rise to two points, the midpoint was used. Pg (pogonion)—The most anterior point on the bony chin determined by a tangent parallel to OLp. ss, Subspinale—the deepest point on the anterior contour of the maxillary alveolar projection determined by a tangent parallel to OLp. NSL, N–S plane—reference line joining nasion and sella. NL, maxillary plane—reference line joining anterior nasal spine and posterior nasal spine. OL, occlusal plane—reference line joining maxillary incisal edge and molar superius distal cusp tip. ML, mandibular plane—reference line joining menton and gonion. OLp, occlusal plane perpendicular—reference line perpendicular to the occlusal plane through sella (s).

the difference was not statistically significant. The molar correction was significantly larger ($P < 0.001$) in the HHSSA group than in the HMJ group, being 10.8 and 6.3 mm, respectively.

The skeletal changes were larger in the HHSSA group, the change in sagittal jaw relationship being 5.4 mm compared with 2.5 mm in the HMJ group, the difference being statistically significant ($P < 0.001$). Both sagittal changes of the maxilla and the mandible were larger in the HHSSA group than in the HMJ group, the differences being 1.5 mm ($P < 0.001$) and 1.4 mm (NS, $P < 0.10$), respectively. Lower anterior face height increased less (0.4 mm; NS) and the mandibular plane angle decreased (–0.7 degrees, $P < 0.05$) in the HHSSA group, but increased in the HMJ group (+0.4 degrees, NS), the difference (1.1 degrees) being statistically significant ($P < 0.01$). The maxillary plane did not change significantly in either of the two groups.

The sagittal and vertical changes were similar for both groups, except for the maxillary molars, which were significantly more distal (1.1 mm, $P < 0.05$) and intruded (1.0 mm, $P < 0.001$) in the HHSSA group and somewhat extruded (0.3 mm, NS) in the HMJ group. The difference was statistically significant ($P < 0.001$).

The skeletal contribution to the overjet correction was larger in the HHSSA group (52 per cent of 10.4 mm) compared with the HMJ group (30 per cent of 8.7 mm). The skeletal contribution to molar correction was larger in the HHSSA group (50 per cent of 10.8 mm) compared with the HMJ group (39 per cent of 6.3 mm). The differences in skeletal contribution to overjet correction were 4.5 mm ($P < 0.001$) and to the molar correction 2.5 mm ($P < 0.001$) between the HHSSA and the HMJ groups.

## Discussion

Prior to treatment, all subjects had a severe Class II malocclusion, but there was no significant difference in facial morphology between the two

**Table 1** Facial morphology prior to treatment in the headgear Herbst with step-by-step advancement group (HHSSA) and the Herbst with maximal jumping group (HMJ).

| Variable (mm) | HHSSA ($n$ = 22) | | HMJ ($n$ = 24) | | Difference* |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Sagittal distances | | | | | |
| Overjet | 9.6 | 2.2 | 9.7 | 2.5 | –0.1 |
| Molar relationship | 1.7 | 2.0 | 2.3 | 1.6 | –0.6 |
| Maxillary base | 80.7 | 3.6 | 79.3 | 3.1 | 1.4 |
| Mandibular base | 78.9 | 6.0 | 78.7 | 5.4 | 0.2 |
| Maxillary incisor | 93.2 | 4.0 | 93.1 | 3.8 | 0.1 |
| Mandibular incisor | 83.7 | 4.0 | 83.4 | 4.7 | 0.3 |
| Maxillary molar | 58.2 | 3.2 | 57.7 | 3.3 | 0.5 |
| Mandibular molar | 56.5 | 4.0 | 55.5 | 3.5 | 1.0 |
| Vertical distances | | | | | |
| Maxillary incisor | 31.2 | 2.3 | 31.2 | 3.6 | 0.0 |
| Maxillary molar | 21.9 | 2.3 | 21.7 | 2.2 | 0.2 |
| Mandibular incisor | 47.4 | 4.4 | 47.1 | 4.1 | 0.3 |
| Mandibular molar | 33.1 | 3.0 | 32.5 | 2.9 | –0.6 |
| Lower facial height | 70.2 | 5.0 | 68.6 | 5.2 | 1.6 |
| Angles (°) | | | | | |
| Maxillary plane angle | 10.0 | 3.5 | 7.8 | 2.7 | 2.2 |
| Mandibular plane angle | 36.0 | 4.7 | 34.3 | 6.5 | 1.7 |

*No statistically significant difference.

**Table 2** The sagittal and vertical changes in the headgear Herbst with step-by-step advancement of the mandible group (HHSSA) and the Herbst with maximal jumping of the mandible group (HMJ).

| Variable (mm) | HHSSA ($n$ = 22) | | HMJ ($n$ = 24) | | Difference* |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Sagittal distances | | | | | |
| Overjet | –10.4*** | 2.7 | –8.7*** | 4.1 | –1.7 |
| Molar relationship | –10.8*** | 3.2 | –6.3*** | 3.2 | –4.5*** |
| Maxillary base | –0.5 | 1.5 | 1.0* | 1.0 | –1.5*** |
| Mandibular base | 4.9*** | 3.3 | 3.5*** | 2.2 | 1.4 |
| Maxillary incisor | –2.0*** | 2.0 | –2.6*** | 2.0 | 0.6 |
| Mandibular incisor | 3.0*** | 1.3 | 3.6*** | 2.5 | –0.6 |
| Maxillary molar | –2.8*** | 1.5 | –1.7*** | 1.5 | –1.1* |
| Mandibular molar | 2.6*** | 1.3 | 2.1*** | 1.5 | 0.5 |
| Vertical distances | | | | | |
| Maxillary incisor | 2.2*** | 1.2 | 1.4*** | 1.8 | 0.8 |
| Maxillary molar | –1.0*** | 1.0 | 0.3 | 1.4 | –1.3*** |
| Mandibular incisor | –2.4*** | 2.1 | –1.4*** | 1.9 | –1.0 |
| Mandibular molar | 2.0*** | 1.4 | 1.5*** | 0.8 | 0.5 |
| Lower facial height | 2.7*** | 2.2 | 3.1*** | 1.8 | –0.4 |
| Angles (°) | | | | | |
| Maxillary plane angle | 0.1 | 0.8 | 0.4 | 0.7 | –0.3 |
| Mandibular plane angle | –0.7* | 1.3 | 0.4 | 0.7 | –1.1** |

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

groups (Table 1). In all patients, the dental arch relationship was changed to Class I or Class III at the end of treatment. However, even if the difference in the length of treatment was not statistically significant between the two groups, it should be borne in mind that the length of

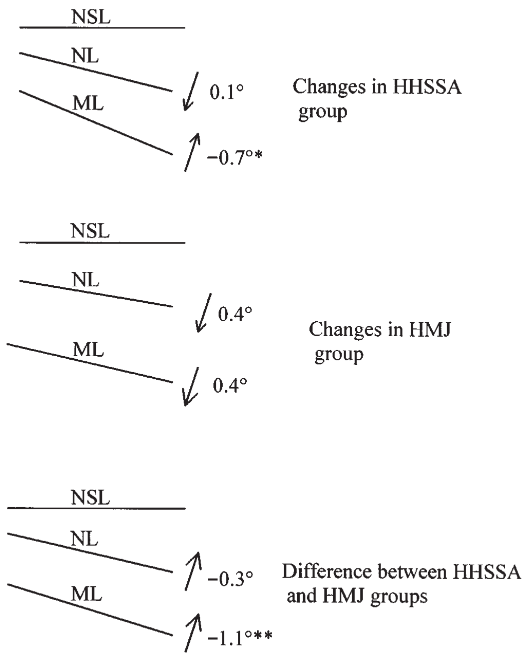


**Figure 2** Diagrammatic representation of the rotational changes in headgear Herbst with step-by-step advancement group (HHSSA) and Herbst with maximal jumping group (HMJ). $*P < 0.05$; $**P < 0.01$.

treatment was on average 2 months or 16 per cent longer in the HHSSA group. Eventually, the treatment changes were, to some extent, more pronounced in the HHSSA group due to the longer treatment time and/or increased growth. At the actual age, 13–14 years, the average sagittal forward growth of the maxilla and mandible during 2 months was 0.2 and 0.4 mm, respectively (Du, 1999). Consequently, the figures given in Table 2 should be interpreted with caution, as with all clinical studies in which treatment changes in groups of patients are compared.

There are reports showing differences in treatment response due to sex, age, and maturity, therefore to assess treatment effects, a matched control group is required (Pancherz and Hägg, 1985; Malmgren *et al.*, 1987; Hägg and Pancherz, 1988). To compare the net effect between different appliance treatment of the same malocclusion no control group is needed, but the groups should be matched (Pancherz *et al.*, 1989). Since this study aimed to investigate the effects of two different treatment approaches of Class II division 1 malocclusions, no control group was necessary. The sexes were pooled, and there was no statistical difference in the mean age or length of treatment between the two groups. The design of the Herbst appliance differed between the two groups. However, no differences in the dental and skeletal changes have been reported between the banded and splinted Herbst with maximal jumping of the mandible (Tse, 1994). A fixed functional appliance cemented to the arches does not require the patients' daily compliance. However, one group was required to add high-pull headgear 10–12 hours a day. One month after the start of treatment the patients were asked about compliance, and it was found to be as requested or better.

### *Mandibular changes*

The effect of the HHSSA on the sagittal mandibular position was larger (1.4 mm, NS, $P < 0.10$) than that of the HMJ. Condylar growth response is probably improved when the mandible is repositioned forward in a stepwise manner than when greater protrusion in one step is carried out. This is in agreement with the findings from mandibular protrusion experiments with other functional appliances (DeVincenzo and Winn, 1989; Falck and Fränkel, 1989; Op Heij *et al.*, 1989; Pancherz *et al.*, 1989; Remmelink and Tan, 1991).

Forward positioning of pogonion with Herbst treatment does not necessarily result in an increase in sagittal mandibular growth. Rotation of the lower jaw will affect the position of pogonion (Hägg and Attström, 1992). In this study, the mandibular plane angle closed significantly in the HHSSA group, whereas it was not significantly affected in the HMJ group, the difference between the two groups being statistically significant. Subsequently, in the HHSSA group, anterior rotation of the mandible enhanced movement of pogonion forward, but in the HMJ group, posterior rotation eventually moved pogonion relatively backward. However, the difference between the two groups of the combined effect of mandibular rotation and sagittal forward growth (1.4 mm, $P < 0.10$) did not reach statistical significance. It has been suggested that with the initial construction bite in an incisor edge-to-edge relationship, the increase in the distance between pogonion and articular or condyle primarily results from a positional change of pogonion inferiorly, which is accompanied by a significant increase of the mandibular plane angle (DeVincenzo and Winn, 1989; Falck and Fränkel, 1989). Another reason for the difference in rotation of the mandibular plane angle between the two groups is that vertical growth of the maxillary molar was different. There was significant maxillary molar intrusion in the HHSSA group, but not in the HMJ group. This is probably a result of the high-pull headgear used in the step-by-step group.

*Maxillary changes*

Maxillary forward growth was significantly reduced in the HHSSA group compared with the HMJ group. Similar results have been reported by Wieslander (1984) using a headgear-Herbst appliance, but in a younger sample. Extra-oral force against the maxilla has been documented in numerous studies to decrease the amount of forward and/or downward growth (e.g. Wieslander, 1963; Ringenberg and Butts, 1970; Melsen, 1978; Baumrind *et al*., 1981, 1983; Teuscher, 1986). Studies on activators with high-pull headgear have claimed to retard maxillary growth in patients with skeletal Class II division 1 malocclusions (Hasund, 1969; Stockfisch, 1971; Pfeiffer and Grobéty, 1972, 1975, 1982; Teuscher, 1978; Bass, 1982, 1983a; Kigele, 1987; Lehman *et al*., 1988; Lehman and Hulsink, 1989; Lagerström *et al*., 1990; Öztürk and Tankuter, 1994). The results of this study show that high-pull headgear is an effective tool in control of maxillary growth during Herbst treatment of Class II malocclusion in adolescent patients.

*Change in jaw relationship*

The change in sagittal jaw relationship was as a result of the combined changes in the position of the maxillary and mandibular bases. The change in jaw relationship in the HHSSA group was more than twice that of the HMJ group. This seems to be primarily due to the significantly greater effect on the maxilla, which restrained forward growth in the HHSSA group, but not in the HMJ group. The mandible came forward more (+1.4 mm; $P < 0.10$) when it was advanced step-by-step compared with maximum advancement, although the difference did not reach significance. A similar pattern has been reported in a study comparing the effect of maximal advancement with the Herbst appliance with that of step-by-step advancement with a headgear activator *ad modum* Bass (Pancherz *et al*., 1989). The potential straightening effect on the profile is then due to changes in both arches, not only to forward movement of the mandible.

*Dentitional changes*

Despite the mandible being advanced gradually during the course of treatment in the HHSSA group, assuming that the forces transmitted to the dental arches would become relatively lower compared with maximal jumping of the mandible, in both groups forward movement of the mandibular molars and incisors was very similar. The threshold level for physiological movement of teeth is extremely low, and for orthodontic movement is only 15–25 g per tooth. It has been reported that when the mandible is advanced anteriorly by 1 mm the forces of the stretched retractors are approximately 100 g (Falck and Fränkel, 1989). The results of this study seem to show that even by advancing the mandible by only a small amount, sufficient force was transmitted via the appliance to move the teeth forward in the mandible. The dental changes seen during Herbst appliance treatment are basically a result of anchorage loss in the two dental arches (Pancherz, 1979, 1981, 1982a). The telescopic mechanism produces an anterior-directed force on the lower teeth, resulting in mesial mandibular tooth movements (Pancherz, 1985). Proclination of the mandibular incisors has been found in all previous Herbst studies (Pancherz, 1982a; Pancherz and Hansen, 1986; Pancherz, *et al*., 1989; McNamara *et al*., 1990; Konik *et al*., 1997).

Whilst distal movement of the maxillary molars with the Herbst appliance seems to be significantly enhanced by the effect from the high-pull headgear compared with that of the telescopic mechanism only, lingual movement of the maxillary incisors is due to use of an anterior sectional archwire for alignment and distalization of the anterior teeth. It has been shown that if the maxillary anterior teeth are not directly involved in the appliance, this position will not be affected (Pancherz, 1982a,b).

## Conclusions

The Herbst appliance, with high-pull headgear and step-by-step mandibular advancement, seemed to have a greater influence on maxillary jaw base position, jaw relationship and improved control over the rotation of the mandibular plane than the Herbst appliance without headgear and maximal jumping of the mandible. The step-by-step advancement of the mandible did not reduce the mandibular anchorage loss.

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