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TREATMENT OF SKELETAL CLASS II MALOCCLUSION IN ADULTS: STEPWISE VS SINGLE-STEP ADVANCEMENT WITH THE HERBST APPLIANCE

Aim: *To compare 2 groups of mature patients treated with the Herbst appliance and present a new protocol based on tissue responses to enhance skeletal response.* ***Methods:*** *Lateral cephalograms taken before and after treatment for 2 groups of patients—the first treated with the Herbst appliance with maximum jumping and the second with the Herbst appliance with stepwise advancement—were examined with conventional cephalometric analysis and the sagittal-occlusal analysis of Pancherz to assess the dental, skeletal, and soft tissue changes.* ***Results:*** *The mode of correction of the Class II malocclusion was through skeletal and dental changes. However, in the stepwise sample, the amount of correction due to skeletal changes was higher. In both groups, the soft tissue profile convexity was reduced significantly.* ***Conclusion:*** *Herbst appliance therapy can be considered a modality for the correction of skeletal Class II malocclusions in mature patients and should be added to orthodontia's armamentarium.* World J Orthod 2008;9:233–243.

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Treatment options for the nongrowing skeletal Class II mandibular retrognathic patient were traditionally twofold. The first was orthodontic camouflage treatment, which is by definition a compromise. The soft tissue convexity that presents with mandibular retrusion is not addressed. Rather, the esthetics are worsened as the upper lip becomes flatter and the nose more prominent. The second option is orthognathic surgery. Whilst this directly addresses the skeletal structures at fault and reduces facial convexity, it involves the risk of surgery under general anesthesia. More recently, Pancherz et al reported a third alternative, which is the reactivation of condylar adaptive growth in young adults.[1–6]

Recent discoveries in basic sciences have led to the realization that condylar growth can be reactivated in mature individuals. Animal and genetic studies[7–28] have proven the ability of an appliance that applies tensile strain to the condyle to stimulate growth and remodel the glenoid fossa, thus indicating that patients previously considered too old could be treated with a functional appliance.

The clinical significance pertains to the patient who presents with borderline skeletal Class II malocclusion and does not place too much emphasis on the facial profile. The severity may not warrant surgical intervention, but the detrimental esthetics of camouflage therapy can be avoided with orthopedics. Funda-

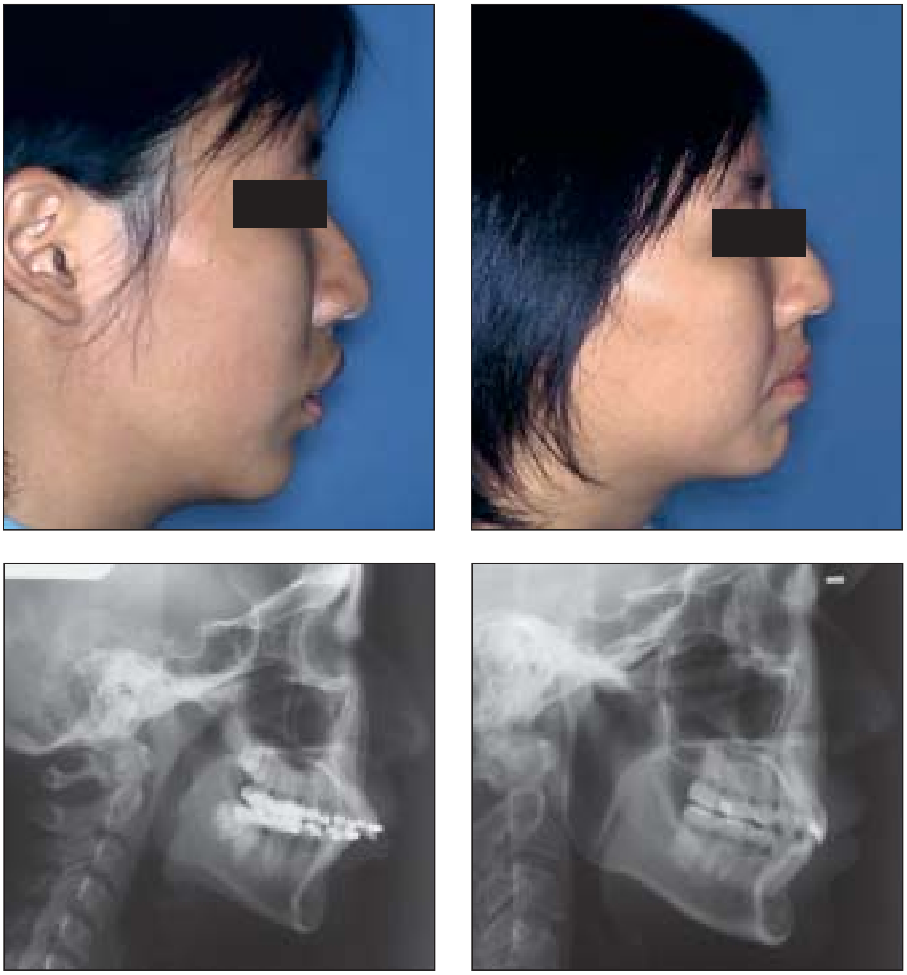


Fig 1 19-year-old female originally treated with headgear and extraction of first premolars. The Herbst appliance phase was 12 months. *Left*, pretreatment; *right*, posttreatment. The profile convexity reduction (excluding the nose) was 4 degrees.

mental to improving the face of a Class II patient is reducing the facial profile convexity, which can be achieved via adult orthopedics.

This study aimed to compare a group of adult skeletal Class II patients to a similar, previously studied group.[1]

METHODS AND MATERIALS

All patients received Herbst appliance therapy followed by multibracket appliance treatment. Fifteen Chinese patients (11 females and 4 males) were treated in the Orthodontic Department of the University of Hong Kong and compared to 23 Caucasian patients (19 females and 4 males) treated in the Orthodontic Department of the University of Giessen in Germany. The sample data for the latter sample was previously published.[1] At the end of treatment, all patients had an ideal Class I occlusion with normal overjet and overbite. The mean pretreatment age of the German sample was 21.9 years (15.7 to 44.4 years); that of the Hong Kong patients was 22.0 years (16.6 to 39.3 years). The mean pretreatment overjet was 7.14 mm (standard deviation, 2.0 mm) and 8.9 mm (SD, 2.7 mm) for the Hong Kong and German samples, respectively (Figs 1 to 3).

Both samples were treated with a casted splint Herbst appliance.[29,30]

The Hong Kong sample was treated with a stepwise advancement. At the time the Herbst is fitted, the mandible is advanced 4 mm. Subsequent advancement(s) eliminate any remaining overjet. In the German sample, the mandible was advanced to an incisal edge-to-edge position.

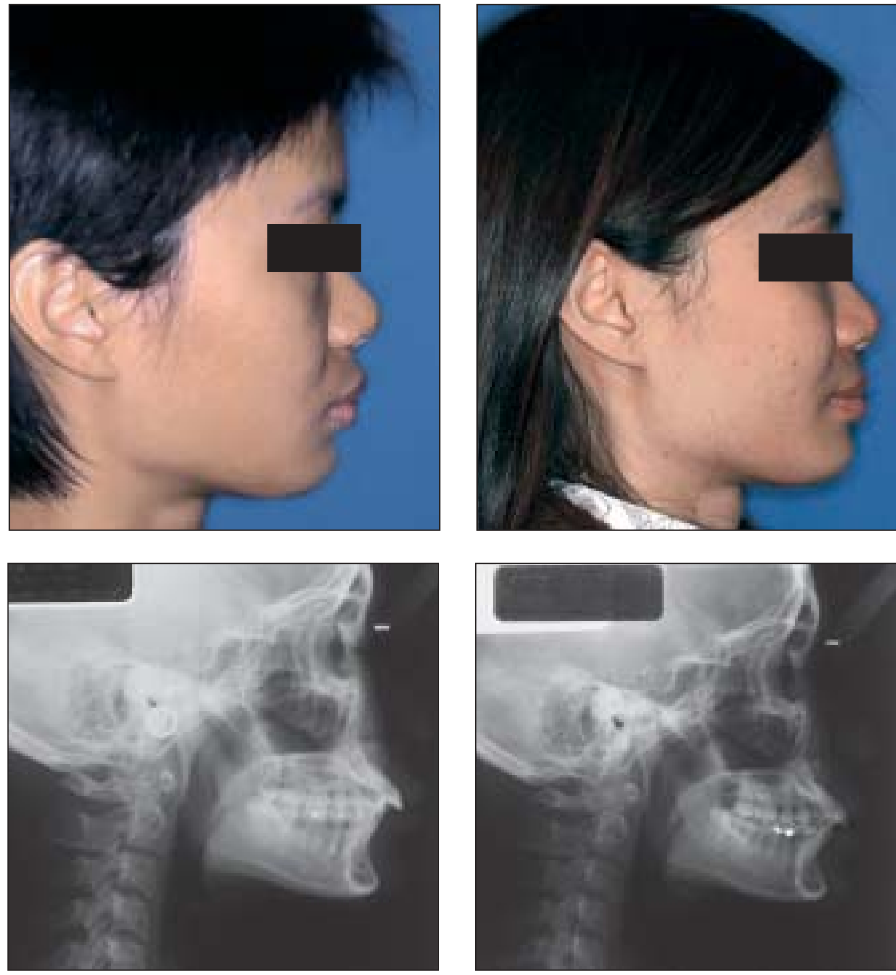


Fig 2 21-year-old female. The Herbst appliance phase was 12 months. *Left*, pretreatment; *right*, posttreatment. Soft tissue profile convexity reduction (excluding the nose) was 3 degrees.

The functional phase in the German sample was 7 to 9 months, while the Hong Kong sample was treated with a functional appliance for 12 months.

Maturity was determined by hand-wrist radiographs. Individuals were considered mature if hand-wrist radiograph stage R-IJ or R-J had been reached. The presence of R-IJ indicates that the post-pubertal period has begun.[31]

The material comprised lateral cephalograms obtained before and after Herbst and multibracket treatment. The lateral head films were taken in centric occlusion. To minimize method error, the 2 cephalometric tracings for each subject were conducted in the same session. The 2 cephalograms for each patient were then traced with an interval of at least 2 weeks, and mean values of the registrations were calculated. All linear and angular measurements were rounded to the nearest 0.5 mm and 0.5 degrees, respectively. No correction was made for linear magnification, approximately 6% to 8% for all samples.

Sagittal-occlusal analysis of Pancherz[32] (Fig 4) and cephalometric analysis (Fig 5) were conducted as described by Ruf and Pancherz.[1]

Means and standard deviations were calculated for all linear and cephalometric variables. Method error was calculated using Dahlberg's formula,[33] $ME = \sqrt{\Sigma d^2/2n}$. Method error did not exceed 0.7 mm for linear variables, 1.0 degree for angular measurements, and 1.2 for index variables. Unpaired *t* tests were undertaken to assess differences between the Hong Kong and German samples and the magnitude of change between the 2 groups. Paired *t* tests were conducted to assess treatment changes within each sample.

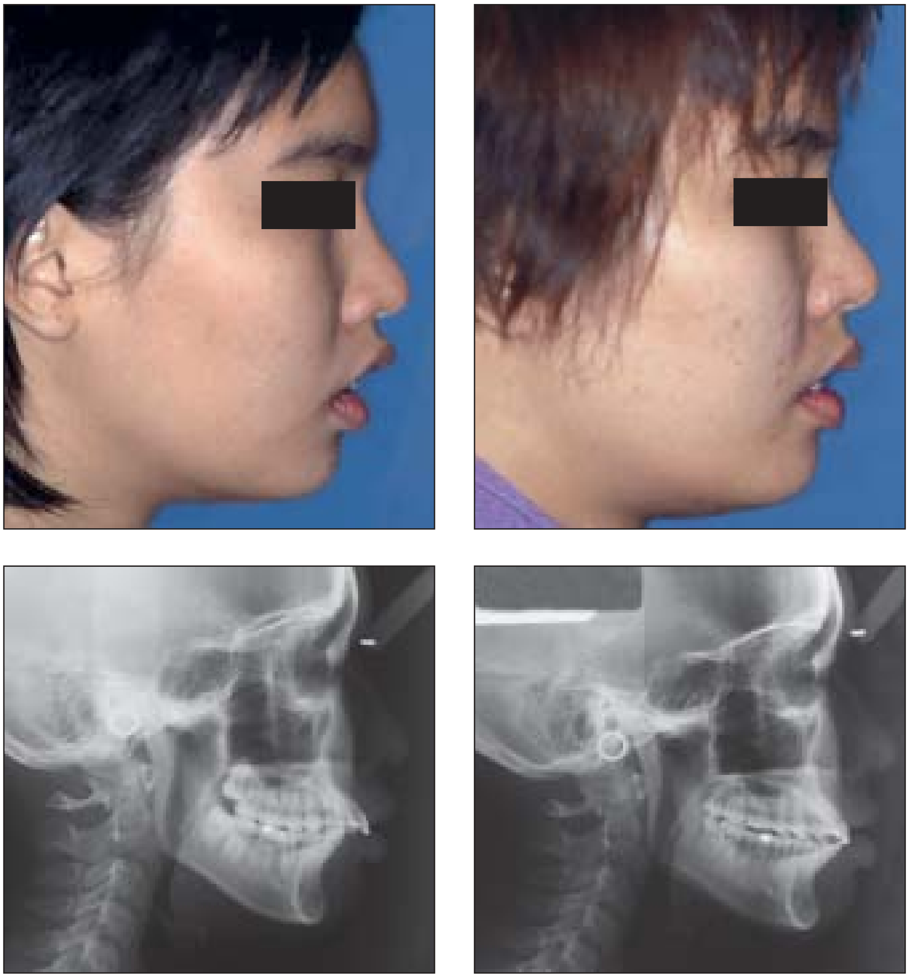
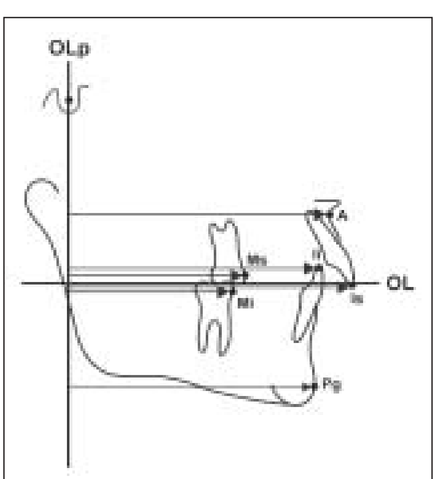


Fig 3 18-year-old female. The Herbst appliance phase was 12 months. *Left*, pretreatment; *right*, posttreatment. Soft tissue profile convexity reduction (excluding the nose) was 3 degrees.



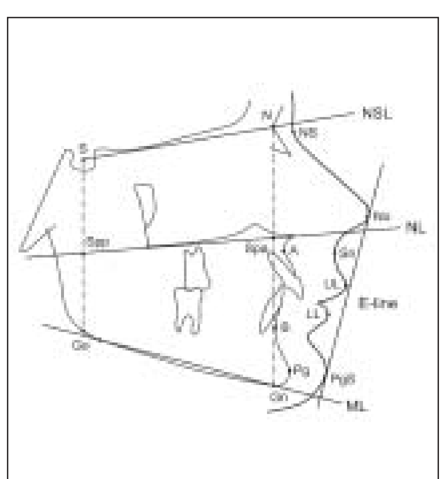


Fig 4 *(left)* Points used in the sagittal-occlusal analysis of Pancherz.

Fig 5 *(right)* Points used in the cephalometric analysis.

Table 1 Cephalometric values of Hong Kong and German samples

	German				Hong Kong			
	Pretreatment		Posttreatment		Pretreatment		Posttreatment	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNA (deg)	80.5	3.2	80.6	3.3	80.1	2.7	79.9	2.7
SNB (deg)	75.2	4.1	76.1	4.4	75.2	3.2	76.3	3.3
SNPg (deg)	76.8	4.3	77.5	4.6	76.3	4.0	77.1	4.1
ANB (deg)	5.2	1.7	4.5	1.8	4.8	1.5	3.5	1.4
ANPg (deg)	3.6	2.3	3.0	2.5	3.8	2.5	2.8	2.5
Wits (mm)	2.5	2.1	1.5	2.0	2.6	2.5	−1.0	2.4
ML/NSL (deg)	34.1	8.6	33.4	9.0	36.7	7.0	36.7	8.0
NL/NSL (deg)	7.3	3.2	6.8	3.6	10.9	3.9	11.3	4.1
ML/NL (deg)	26.8	7.9	26.7	7.7	25.7	4.3	25.4	5.4
Overbite (mm)	4.4	1.8	2.0	0.7	4.7	0.6	2.0	0.0
Spa-Gn index (mm)	54.6	1.8	55.0	1.7	53.4	2.0	53.7	2.1
Spp-Go index (mm)	41.4	5.3	42.4	5.2	48.6	3.9	48.9	5.1
NAPg (deg)	172.1	5.2	173.2	5.4	170.8	6.4	174.1	6.9
NS/Sn/PgS (deg)	159.7	6.3	162.8	6.8	161.2	7.1	164.1	7.2
NS/No/PgS (deg)	126.3	3.9	127.3	4.3	136.0	7.0	137.4	6.6
UL-E (mm)	−3.1	2.3	−4.4	2.5	1.8	2.8	−0.3	3.4
LL-E (mm)	−1.6	3.3	−1.9	3.0	2.6	3.8	3.3	3.3

Table 2 Pretreatment cephalometric value differences of Hong Kong and German samples

	Mean	*t*
SNA (deg)	0.4	0.4
SNB (deg)	0.0	0.0
SNPg (deg)	0.6	0.4
ANB (deg)	0.4	0.7
ANPg (deg)	−0.2	0.2
Wits (mm)	−0.1	0.1
ML/NSL (deg)	−2.5	0.1
NL/NSL (deg)	−3.7	3.2**
ML/NL (deg)	1.1	0.5
Overbite (mm)	−0.2	0.5
Spa-Gn index (mm)	1.1	1.8
Spp-Go index (mm)	−7.2	4.5***
NAPg (deg)	1.3	0.7
NS/Sn/PgS (deg)	−1.5	0.7
NS/No/PgS (deg)	−9.7	5.5***
UL-E (mm)	−4.9	5.9***
LL-E (mm)	−4.2	3.6***

$*P < .05$; $**P < .01$; $***P < .001$; $****P < .0001$.

RESULTS

Significant differences were found for several pretreatment cephalometric variables. The Hong Kong sample had an increased maxillary plane angle relative to the cranial base by 3.7 degrees and a greater posterior facial height index by 7.2 mm. Soft tissue convexity including the nose was 9.7 degrees less in the Hong Kong sample, as well as a greater protrusion of the upper and lower lip of 4.9 mm and 4.2 mm, respectively. These are consistent with the expected variations for the 2 ethnic groups[34] (Tables 1 and 2).

Table 3 Cephalometric values: Comparison of treatment changes of Hong Kong and German samples

	German			Hong Kong			Difference		
	Mean	SD	*t*	Mean	SD	*t*	Mean	SD	*t*
SNA (deg)	0.1	0.6	0.8	−0.2	0.8	−1.0	0.3	1.6	1.4
SNB (deg)	0.8	0.8	5.0****	1.1	0.5	9.5****	−0.3	2.4	1.3
SNPg (deg)	0.7	0.9	4.0***	0.8	0.4	7.6****	−0.1	1.3	0.6
ANB (deg)	−0.7	0.8	−4.3***	−1.3	0.8	−6.3****	0.6	2.9	2.3*
ANPg (deg)	−0.6	0.9	−3.3**	−1.1	0.7	−6.1****	0.5	2.6	1.7
Wits (mm)	−1.1	1.3	−4.1***	−3.6	1.8	−7.7****	2.6	5.4	5.1****
ML/NSL (deg)	−0.7	1.3	−2.6*	0.1	1.8	0.1	−0.7	1.6	1.5
NL/NSL (deg)	−0.5	1.5	−1.7	0.4	1.8	0.7	−0.9	1.8	1.6
ML/NL (deg)	−0.1	1.6	−0.3	−0.3	2.4	−0.5	0.2	0.3	0.3
Overbite (mm)	−2.5	2.0	−6.1****	−2.7	0.6	−16.7****	0.2	1.2	0.4
Spa-Gn index (mm)	0.4	0.7	2.8*	0.3	1.0	0.1	0.2	0.7	0.6
Spp-Go index (mm)	1.0	1.5	3.4**	0.3	3.2	0.4	0.7	0.9	0.9
NAPg (deg)	1.1	1.6	3.3**	3.3	2.2	5.7****	−2.2	3.8	3.5**
NS/Sn/PgS (deg)	3.1	1.8	8.4****	2.9	1.1	10.6****	0.2	0.9	0.5
NS/No/PgS (deg)	1.0	2.0	2.5*	1.4	0.8	7.2****	−0.4	2.0	0.7
UL-E (mm)	−1.3	1.1	−5.6****	−2.1	1.7	−4.7***	0.8	2.0	1.9
LL-E (mm)	−0.3	1.1	−1.1	0.7	2.4	1.2	−1.0	1.6	1.8

*$P < .05$; **$P < .01$; ***$P < .001$; ****$P < .0001$.

Table 4 Sagittal-occlusal analysis values (in mm) of Hong Kong and German samples

	German				Hong Kong			
	Pretreatment		Posttreatment		Pretreatment		Posttreatment	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Overjet (Is/OLp – Ii/Olp)	8.9	2.7	2.1	0.6	7.1	2.0	1.9	0.6
Molar relation (Ms/OLp-Mi/OLp)	1.5	1.4	−2.6	1.0	1.1	1.3	−3.2	1.8
Maxillary jaw base (A/Olp)	78.5	4.0	78.9	4.8	78.8	4.0	78.9	4.2
Mandibular jaw base (Pg/Olp)	80.1	5.0	81.4	4.8	80.9	6.8	82.1	6.7
Maxillary incisor (Is)	88.2	4.5	85.4	4.8	89.8	4.1	89.6	4.6
Mandibular incisor (Ii)	79.3	5.4	83.3	4.9	82.7	4.8	87.7	4.5
Maxillary molar (Ms)	57.8	4.7	56.4	4.7	60.4	5.2	59.7	4.9
Mandibular molar (Mi)	56.3	5.3	58.9	5.0	59.2	5.0	63.0	3.8

Treatment changes of the Hong Kong sample showed significant SNB and SNPg increases of 1.1 degrees and 0.8 degree, respectively. Reductions in ANB (1.3 degrees), ANPg (1.1 degrees), Wits appraisal (3.6 mm), and overbite (2.7 mm) were significant. These sagittal parameter changes were expressed as significant reductions in both hard and soft tissue convexity. NAPg increased by 3.3 degrees, while soft tissue profile convexity including and excluding the nose were reduced 1.4 degrees and 2.9 degrees, respectively. Upper lip fullness also decreased 2.1 mm.

Treatment changes for the German sample showed significant increases for SNB (0.8 degrees) and SNPg (0.7 degrees) and significant decreases for ANB (0.7 degrees), ANPg (0.6 degrees), and the Wits analysis (1.1 mm). Regarding the vertical parameters, the mandibular plane decreased by 0.7 degrees, and both the anterior and posterior facial height (mean indices) increased 0.4 mm and 1.0 mm, respectively. Dentally, the overbite was reduced 2.5 mm. All 3 measurements relating to hard and soft tissue convexity increased, resulting in a reduction in the profile convexity: NAPg by 1.1 degrees, soft tissue profile including the nose by 1.0 degrees, and soft tissue profile excluding the nose by 3.1 degrees. The retraction of the upper lip in the sagittal plane was 1.3 mm.

Table 5 Difference in pretreatment sagittal-occlusal analysis values of Hong Kong and German samples

	German pretreatment (mm)		Hong Kong pretreatment (mm)		Difference (mm)	
	Mean	SD	Mean	SD	Mean	*t*
Overjet (Is/OLp − Ii/Olp)	8.9	2.7	7.1	2.0	1.7	2.1*
Molar relation (Ms/OLp-Mi/OLp)	1.5	1.4	1.1	1.3	0.4	0.9
Maxillary jaw base (A/Olp)	78.5	4.0	78.8	4.0	−0.3	0.2
Mandibular jaw base (Pg/Olp)	80.1	5.0	80.9	6.8	−0.8	0.4
Maxillary incisor (Is)	88.2	4.5	89.8	4.1	−1.6	1.1
Mandibular incisor (Ii)	79.3	5.4	82.7	4.8	−3.4	2.0
Maxillary molar (Ms)	57.8	4.7	60.4	5.2	−2.6	1.6
Mandibular molar (Mi)	56.3	5.3	59.2	5.0	−3.0	1.7

*$P < .05$; **$P < .01$; ***$P < .001$; ****$P < .0001$.

Compared to the German sample, the Hong Kong sample showed greater changes for some sagittal measures. The cephalometric variables of ANB, Wits, and NAPg showed significant differences: ANB decreased an average of 0.6 degrees, Wits appraisal decreased 2.6 mm, and NAPg increased 2.2 degrees more than in the Hong Kong sample (Table 3).

When regarding the pretreatment sagittal-occlusal analysis variables, the German patients had larger overjets by 1.7 mm (Tables 4 and 5).

The treatment changes in the Hong Kong sample showed a mean overjet reduction of 5.2 mm; molar relation correction was 4.4 mm. On average, the pogonion moved anteriorly 1.2 mm and the mandibular incisors 3.8 mm. Mean mandibular molar mesial movement was 2.1 mm.

The mean overjet reduction for the German sample was 6.8 mm. Molar relation correction was 4.1 mm. Average maxillary molar distal movement was 1.8 mm; mandibular molar mesial movement was 1.4 mm. On average, A point and pogonion moved anteriorly 0.4 mm and 1.3 mm, respectively. The maxillary incisor moved distally 3.2 mm, and the mandibular incisor moved mesially 2.7 mm.

When comparing the treatment changes for both groups, the German sample exhibited greater maxillary incisor retraction by 2.9 mm and maxillary molar distalization by 1.1 mm (Table 6).

DISCUSSION

This study presented an additional modality for skeletal Class II correction in mature patients. Herbst therapy was shown to have reactivated condylar growth in this cohort. These patients had a hand-wrist stage of R-I or R-IJ and were considered to have little to no growth left.[31] The reactivation of condylar growth led to a reduction in the severity of the skeletal Class II malocclusion, as well as a reduction in soft tissue convexity.

Sagittal correction occurred as a result of dental and skeletal changes. The former involved mesialization of the mandibular dentition and distalization of the maxillary molars. The latter is achieved by the reactivation of growth in the adult condyle. In the Hong Kong sample, the skeletal contribution to the overjet reduction and molar relationship change was 22% and 26%, respectively. The skeletal component in the German sample was 13% for overjet and 22% for molar correction (Figs 6 and 7).

Both groups demonstrated that mandibular growth can be stimulated with consequent anterior movement of the B point. What was remarkable was the higher skeletal component found in the Hong Kong sample. This was reflected cephalometrically in the ANB, Wits appraisal, and NAPg for the Hong Kong patients. However, the Hong Kong group exhibited greater amounts of anchorage loss in the mandibular arch

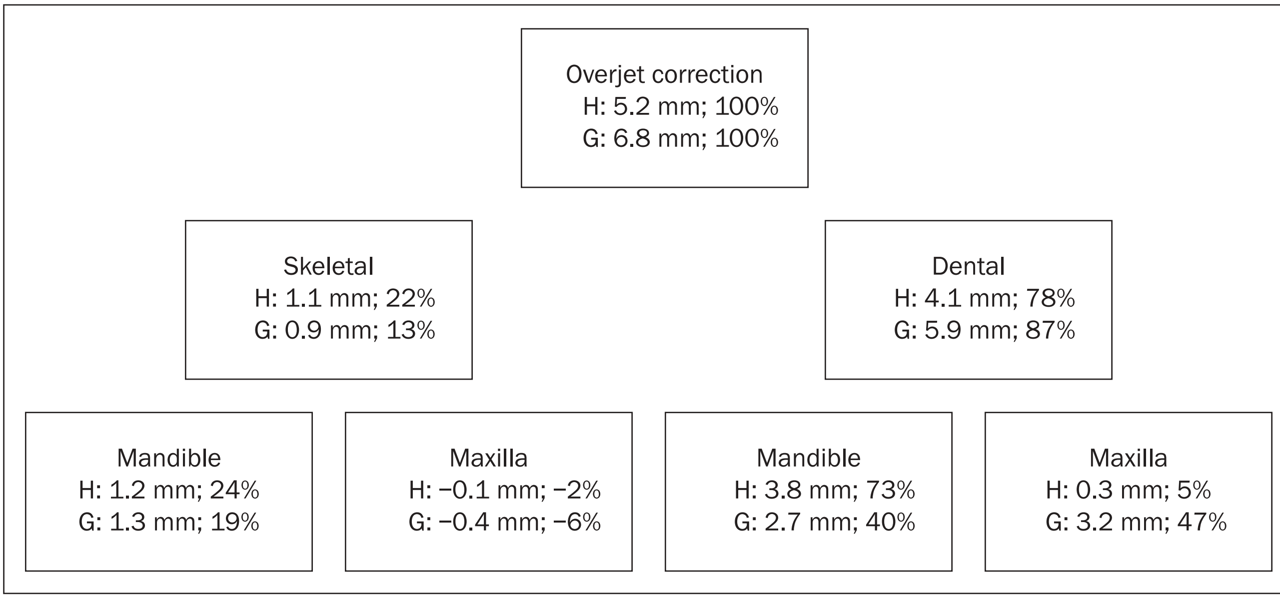


Fig 6 Mechanism of overjet correction in Hong Kong and German samples. H = Hong Kong sample; G = German sample.

Table 6 Comparison of sagittal-occlusal analysis treatment changes (in mm) in Hong Kong and German samples

	German			Hong Kong			German- HK	
	Mean	**SD**	***t***	**Mean**	**SD**	***t***	**Mean**	***t***
Overjet (Is/Olp − Ii/OLp)	−6.8	2.6	−12.3****	−5.2	2.2	−9.4****	−1.5	1.8
Molar relation (Ms/OLp − Mi/OLp)	−4.1	1.5	−13.6****	−4.4	1.8	−9.3****	0.3	0.5
Maxillary base (A/OLp)	0.4	0.7	2.9**	0.1	0.7	0.4	0.3	1.3
Mandibular base (Pg/OLp)	1.3	1.3	4.9****	1.2	0.5	8.8****	0.1	0.2
Maxillary incisor (Is/OLp − A/OLp)	−3.2	2.1	−7.2****	−0.3	2.1	−0.9	−2.9	4.1***
Mandibular incisor (Ii/OLp − Pg/OLp)	2.7	1.9	6.7****	3.8	1.7	7.7****	−1.1	1.8
Maxillary molar (Ms/OLp − A/OLp)	−1.8	1.1	−8.0****	−0.7	2.1	−1.2	−1.1	2.1*
Mandibular molar (Mi/OLp − Pg/OLp)	1.4	1.1	5.9****	2.5	2.3	4.0**	−1.1	2.0

*$P < .05$; **$P < .01$; ***$P < .001$; ****$P < .0001$.

compared to the German sample. The maxillary incisors of the Hong Kong patients were retracted less. This can be partly explained by the fact that the southern Chinese population has more anteriorly placed incisors than do Caucasians.[34]

The greater skeletal response found in the Hong Kong sample could be attributed to the clinical protocol used. The German sample was treated by maximum jumping of the mandible to an edge-to-edge position, and the functional phase lasted 7 to 9 months. The Hong Kong protocol differed in 3 key factors that are based upon the clinical integration of basic science research conducted by the Hard Tissue Research Team at the University of Hong Kong: stepwise advancement; 6-month duration for each advancement; and initial advancement of at least 4 mm.

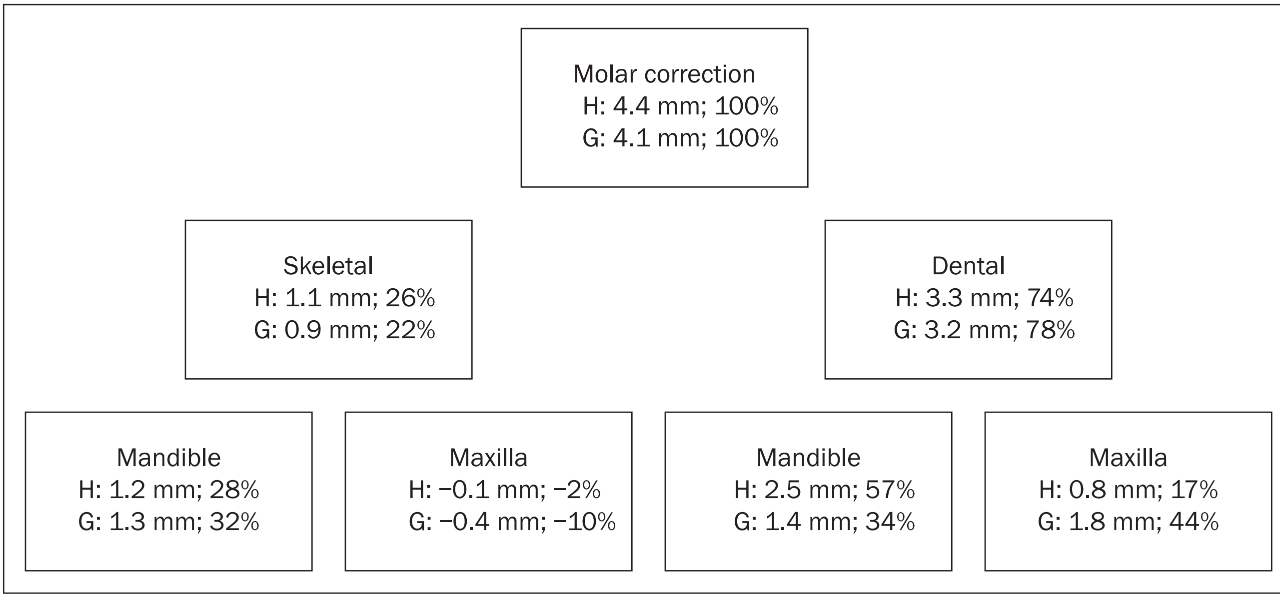


Fig 7 Mechanism of molar relation in Hong Kong and German samples. H = Hong Kong sample; G = German sample.

Ruf and Pancherz[5] showed conclusively via the use of MRI that the use of functional appliances leads to remodelling of the glenoid fossa and condyle. Rabie et al demonstrated in rat experiments an increased condylar and fossa response to mechanical strain provided by a mandibular advancement appliance with a step-by-step advancement procedure compared to maximum jumping.[20] Stepwise advancement was shown to result in 100% and 50% more bone formation in the glenoid fossa and condyle respectively. Importantly, while with 1-step advancement, the rate of bone formation fell to that of natural growth after an initial increase, stepwise advancement resulted in a significantly greater amount of bone formed than natural growth throughout the entire experimental period.

The duration of the advancement is critical to the prognosis of the newly formed bone and the stability of the results.[35] The matrix of newly formed bone is of the same nature as bone formed during development and bone repair. Accordingly, we increased the duration of treatment in our samples to 12 months, with 6 months for each advancement. This allows the newly formed bone with type III collagenous matrix to mature to more stable bone with type I collagenous matrix.

The amount of initial advancement is important. Results of experimental research highlighted the fact that there is a minimum threshold of strain that needs to be exceeded to elicit a response.[17] Therefore, we decided to determine such a threshold in our clinical research. A 2-mm advancement elicited a much lesser response than a 4-mm advancement on condylar growth (unpublished data). All of the Hong Kong patients had an initial advancement of at least 4 mm. The magnitude of the subsequent advancements depended upon the size of the overjet to be corrected.

Now let us consider the basic scientific evidence that explains the effects presented in this study. Rabie et al investigated the biochemical and genetic factors responsible for the response of the mandibular condyle to tensile strain produced by orthopedically advancing the adult mandible.[7–27] Results of a morphological study in adult rats revealed that the length of the condylar process and width of the condylar head were significantly increased.[7] The ramus angle was reduced, showing backward tilting of the ramus leading to forward movement of the body of the mandible.[21] This morphological data supported the concept that condylar growth could be reactivated in nongrowing individuals.

However, we needed an explanation as to how the tensile strain produced by mandibular advancement could result or be translated into a cellular response that gave rise to the morphological changes observed. The discovery of the Indian Hedgehog morphogen (Ihh)[8,25] in the condylar cartilage and its role as a mechanotransduction mediator of condylar growth was of great importance to the field of growth modification. Upon application of mechanical strain as a result of mandibular advancement, the cells within the condylar tissues endogenously express Ihh. In turn, Ihh enhances cellular replication and cartilage formation in the condyle, leading to reactivation of adaptive condylar growth. Furthermore, we reported that mandibular advancement of the adult condyle led to the expression of angiogenic mediators and thus led to significantly more bone formed in these condyles.[10,13,27,28]

Thus, it is becoming evident that condylar growth and orthopedic mandibular advancement is not the preserve of children and young adolescents. This information affords the clinical orthodontist an improved understanding of the responses to functional appliances. The lynchpin is the demonstration of the critical role an individual's genetics play in the ability to stimulate growth by advancing the mandible.

CONCLUSION

It is important to consider these results in light of the recent advances in basic molecular tissue responses. When the adult condyle is subjected to mechanical strain as a result of mandibular advancement, the condyle cartilage cells express Ihh, a mechanotransduction mediator. This mediator reads and understands the mechanical forces and converts these forces into cellular responses that reactivate condylar growth. This explains the reactivation of condylar growth seen in the 2 samples. In response to reactivation of condylar growth, new cartilage and new bone are formed, leading to an increase in condylar size. Such an increase was of clinical significance as it significantly reduced the patients' profile convexity (see Figs 1 to 3).

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