Original Article

Herbst treatment with mandibular cast splints—revisited

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ABSTRACT

Objective: The objective of this study was to reassess the dento-skeletal treatment effects and the amount of anchorage loss during reduced mandibular splint (RMS) Herbst treatment.

Materials and Methods: One hundred consecutive Class II patients treated with a RMS-Herbst appliance were analyzed. The mean pretreatment age of the patients was 14.5 years, and the mean treatment time with the Herbst appliance was 8.1 months. Both before (T1) and after (T2) Herbst treatment a cephalometric measurement of lower incisor inclination, a sagittal occlusion analysis, and a dental cast analysis were performed. A comparison was performed with a historic Herbst control group treated with total mandibular cast splints (TMS).

Results: During treatment the lower incisors proclined markedly ($12.9^\circ \pm 4.6^\circ$). The amount of incisor proclination in the RMS group was, on average, 3.6° larger ($P < .001$) than in the TMS group. The lower incisor proclination increased from 11.9° (prepeak) to 14.3° (young adult). The level of professional experience of the practitioners performing the treatment did not influence the amount of incisor proclination significantly. The total available space in the lower arch increased by an average of 1.8 mm, and a space opened between the lower second premolars and lower permanent first molars in 62% of the present RMS-Herbst (average of 0.4 mm per side).

Conclusions: Treatment with RMS-Herbst appliances leads to higher proclination of the lower incisors than does treatment with TMS-Herbst appliances; it also leads to an overall larger amount of anchorage loss. (*Angle Orthod.* 2011;81:820–827.)

KEY WORDS: Herbst treatment; Reduced mandibular cast splints; Total mandibular cast splints; Anchorage loss; Incisor proclination

INTRODUCTION

Since Pancherz's reintroduced the Herbst appliance into modern orthodontics, many different Herbst designs testing a variety of different anchorage forms have been used. However, none has been able to prevent or significantly reduce mandibular incisor proclination and/or protrusion.[1–3]

One of the most popular designs is total mandibular cast splints (TMS) (Figure 1A). Despite a similar complication frequency, cast splints have been shown[4,5] to be superior to banded designs because of savings in chair and laboratory time. A typical complication of cast splints not frequently described in the literature is a partial dislodgement of the lower splints from the posterior teeth[6] (Figure 1B). This dislodging is due to a tilting of the lower occlusal plane and a leveling of the curve of Spee during Herbst therapy[7,8] and leads to spacing between the lower molars and the splints, where plaque and food debris gather. As a result of the leveling of the curve of Spee, re-cementation of the splint is not possible.

It was assumed[6,9] that a reduced mandibular cast splint (RMS) (Figure 1C) extending from second premolar to second premolar only might be an alternative to TMS splints that may possibly be able to prevent partial dislodgements. Although von Bremen et al.[6] showed no difference in anchorage loss between RMS and TMS splints, several cases have appeared in our department that exhibited a very large amount of incisor proclination and even marked space opening between the lower second permanent premolars and the lower first permanent molars (Figure 2). Therefore, the aim of this study was to reassess the dento-skeletal treatment effects and the amount of anchorage loss during RMS-Herbst treatment, giving special attention to the influence of skeletal maturity and professional experience.

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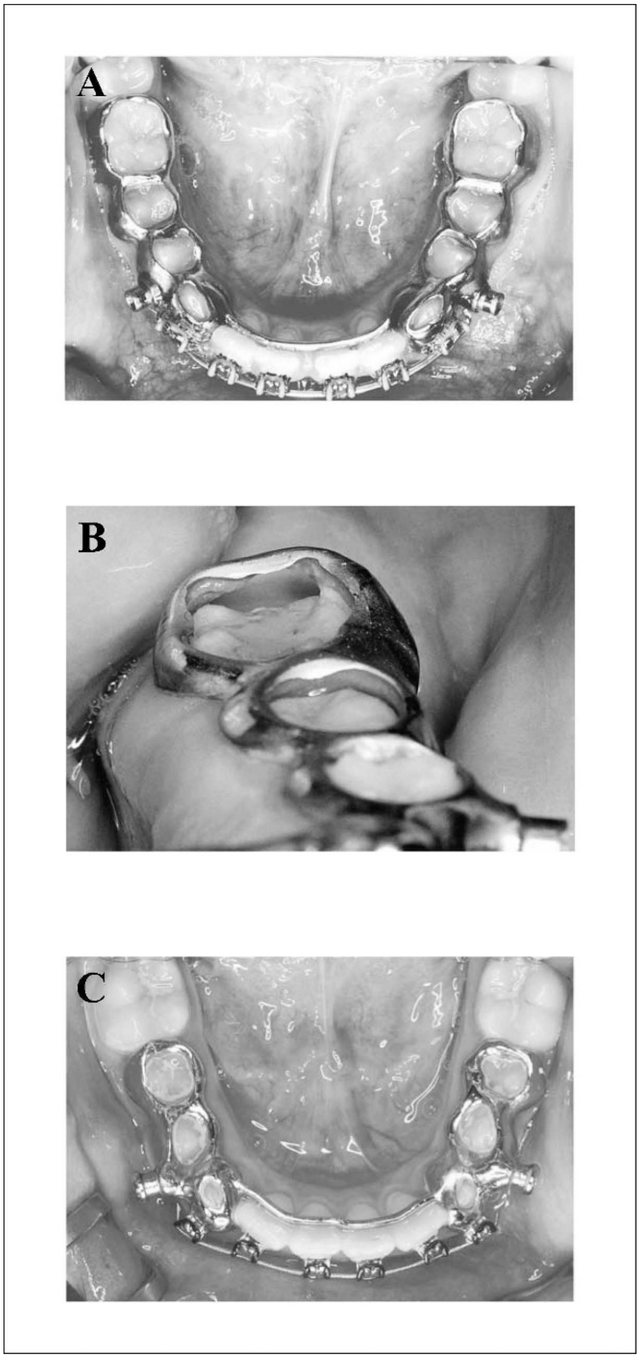

Figure 1. (A) TMS extending from first molars to canines. (B) Partial dislodgement of a lower TMS cast splint. (C) RMS extending from second premolars to canines.

MATERIALS AND METHODS

Subjects

All Class II patients from the orthodontic department of the University of Giessen, Germany, treated with a RMS-Herbst appliance since their introduction in 2003 were consecutively included in this retrospective study until a total of 100 patients was reached. All patients displayed permanent dentition and had a unilateral or bilateral Class II molar relationship ≥1/2 cusp width, no missing or retained permanent teeth, no syndromes, and complete available records. The final 100 patients comprised 57 females and 43 males. The mean pretreatment age of the patients was 14 years and 6 months (standard deviation [SD] = 3 years and 3 months), and the mean treatment time with the Herbst appliance was 8.1 months (SD = 1.5 months).

Lateral head films, in habitual occlusion from before (T1) and after (T2) treatment with a RMS-Herbst appliance, were analyzed. All angular and linear measurements were taken to the nearest 0.5° and 0.5 mm, respectively. No correction was made for radiographic enlargement (approximately 7% in the median plane).

Measurement of lower incisor proclination was performed by assessing the inclination of the long axis of the most proclined mandibular incisor (*IiL*) relative to the mandibular line (*ML*).

The lower incisor inclination changes [IiL/ML (d)] were analyzed in four skeletal maturity groups (Table 1). The skeletal maturity of the patients was assessed using either hand-wrist radiographs using the method of Hägg and Taranger[10] or lateral head films and cervical maturation, according to Hassel and Farman,[11] as available from the clinical records. Furthermore, a comparison was performed between patients treated by certified orthodontists (n = 25) and patients treated by postgraduate students (n = 75).

The lower incisor proclination changes of Weschler and Pancherz[3] were taken as a historic control. The control comprised of 34 Class II patients (15 boys and 19 girls) treated with TMS-Herbst appliances. The mean pretreatment age of the patients was 14.4 years, and the average length of TMS-Herbst treatment was 0.6 years.

The sagittal occlusion (SO) analysis[7] was used to relate the changes in SO (overjet, molar relationship) to their skeletal and dental components in the maxilla and mandible, respectively (Figure 3).

Dental casts from before (T1) and after (T2) RMS-Herbst treatment were analyzed. All linear measurements were taken to the nearest 0.5 mm. The following variables were analyzed:

- Arch length discrepancy: Difference between the available and required space in the dental arch; and
- Space P2-M1: Space between the second permanent premolar and first permanent molar in the lower arch. It was measured on both the right and left sides; the mean value of the two sides was used in the further evaluation.

Method Error

In order to calculate the method error (ME), the evaluation of the lateral head films and dental casts

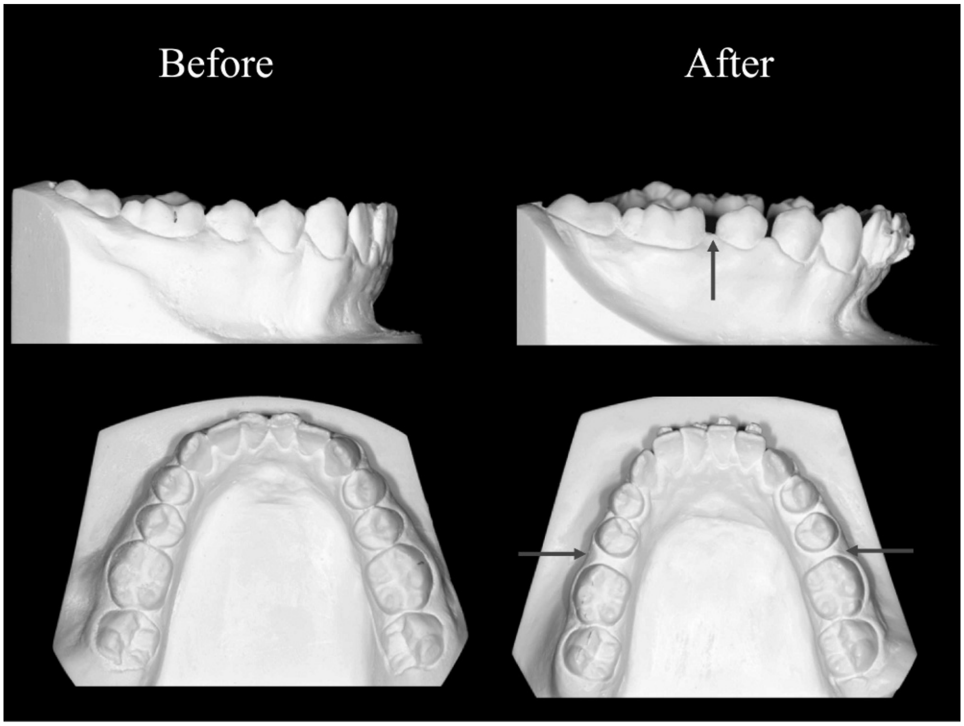

Figure 2. Space opening between the lower second premolar and first permanent molar during RMS-Herbst treatment.

from before and after RMS-Herbst of 15 randomly selected patients were repeated with a time interval of at least 4 weeks between the measurements. The following formula was used for the ME calculation:

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

where *d* is the difference of double measurement and n the number of subjects.[12]

The lateral head film ME was acceptable, as it did not exceed 0.9 mm or 1.1°, respectively. The highest ME (1.1°) was found for lower incisor inclination (*IiL/ML*). This is most likely due to the fact that the root apex of the lower incisors is a reference point that is difficult to locate.[13] The dental cast ME was 0.4 mm for arch length discrepancy and 0 mm for Space P2-M1.

Table 1. The Four Different Skeletal Maturity Groups in the 100 Class II Patients Treated with a Reduced Mandibular Splint (RMS)-Herbst Appliance

Skeletal Maturity Groups	Hand-Wrist Radiographs	Lateral Head Films
Prepeak (n = 13)	MP_3 E-F	S 1-2
Peak (n = 42)	MP_3 FG-G	S 3-4
Postpeak (n = 28)	MP_3 H-I	
Young adults (n = 17)	R I-J	

Statistical Analysis

The statistical evaluation was performed using SPSS for Windows, version 17 (SPSS, Chicago, Ill). The existence of a normal distribution was verified by the Kolmogorov-Smirnov test. The treatment changes, the effect of professional experience on the lower incisor inclination, and the comparison between the RMS and TMS-Herbst groups were analyzed by means of Student's *t*-test for paired and unpaired samples, respectively. The effect of skeletal maturity on incisor proclination was assessed by the one-way analysis of variance Duncan test.

RESULTS

Lower Incisor Proclination

The inclination of the lower incisors in relation to the mandibular plane (IiL/ML) varied considerably both before (97.8 ± 5.8°) and after (110.7 ± 6.9°) treatment. During treatment the lower incisors were proclined by an average of 12.9 ± 4.6° ($P < .001$). The amount of proclination showed a high interindividual variation, ranging from +3.0° to +25.0° (Figure 4).

The amount of lower incisor proclination changes relative to the mandibular plane (IiL/ML) increased gradually from the prepeak group (11.9 ± 3.3°) to the young adult group (14.3 ± 4.6°). However, the group differences did not reach statistical significance ($P \geq .05$). A large within-group variation of lower incisor

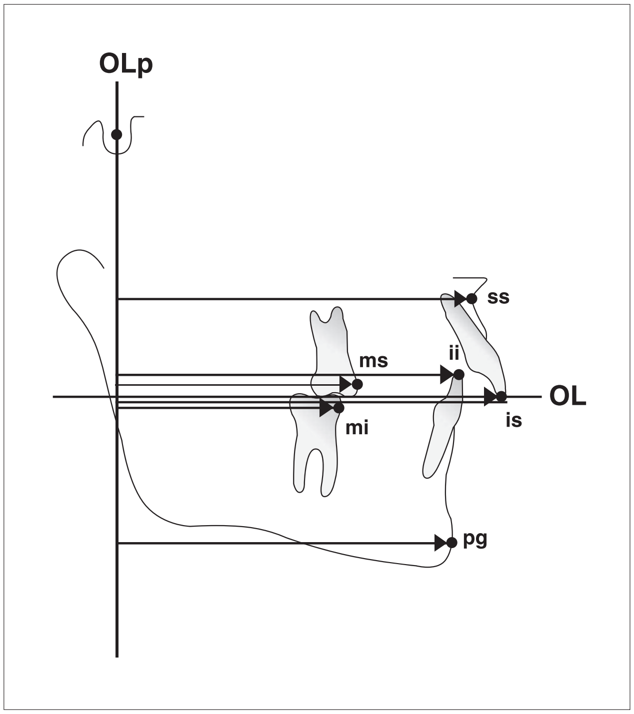

Figure 3. The SO analysis[7] is performed on lateral head films in habitual occlusion. For all linear measurements, the occlusal line (OL) and the occlusal line perpendicular (OLp) from the first head film were used as a reference grid. The grid was transferred from the first tracing (T1) to the second tracing (T2) by superimposition of the tracings on the Nasion-Sella line (NSL) at Sella (S).

proclination changes was found, regardless of skeletal maturity (Figure 5).

Lower incisor proclination was smaller (11.6 ± 3.4°) in RMS-Herbst treatments performed by certified orthodontists than in those performed by postgraduate students (13.3 ± 4.9°). The group difference of 1.7° was, however, not statistically significant.

In the 100 Class II RMS-Herbst patients the amount of incisor proclination was on average 3.6° larger ($P <$ .001) than in the 34 Class II TMS-Herbst patients[3] (Table 2). However, individual variations of lower incisor inclination changes [IiL/ML (d)] in both groups were large.

SO Analysis

Before treatment (T1) the patients exhibited an average overjet of 6.9 ± 2.3 mm, which was reduced by 7.7 ± 3.3 mm ($P <$ .001) as a result of treatment. After Herbst treatment (T2), an average anterior cross bite of −0.8 ± 1.9 mm existed (Tables 3, 4).

Before treatment (T1) the patients exhibited an average upper to lower molar relationship of 1.8 ± 3.1 mm, corresponding to 3/4 cw distal occlusion, which was changed by an average of 6.3 ± 2.5 mm (P $<$ .001) as a result of treatment. Thus, after Herbst treatment (T2), an average molar relationship of −4.5 ± 3.5 mm, corresponding to a slightly overcorrected Class I, existed.

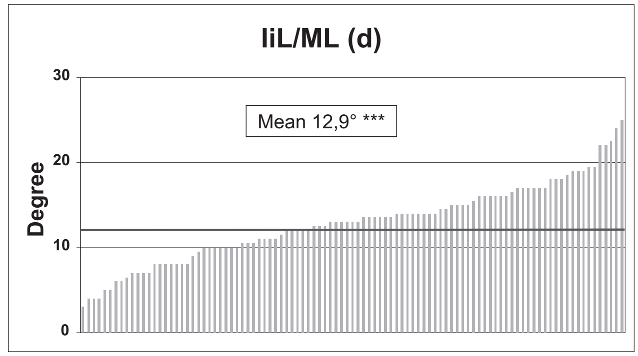

Figure 4. Individual treatment changes (T2-T1) for lower incisor inclination (IiL/ML) in 100 Class II patients treated with a RMS-Herbst appliance.

The mandibular base (*pg/OLp*) was advanced significantly ($P <$ .001) by an average of 3.1 ± 2.4 mm; however, the maxillary base (*ss/OLp*) also moved slightly forward ($P <$ .01) an average of 0.4 ± 1.7 mm. The mandibular incisors [*ii/OLp(d)-pg/OLp(d)*] and mandibular molars [*mi/OLp(d)-pg/OLp(d)*] were mesialized significantly ($P <$ .001) by an average of 3.5 ± 2.0 mm and 1.9 ± 1.8 mm, respectively, whereas the maxillary incisors [*is/OLp(d)-ss/OLp(d)*] and maxillary molars [*ms/OLp(d)-ss/OLp(d)*] were distalized significantly ($P <$ .001) by an average of 1.5 ± 3.3 mm and 1.7 ± 1.9 mm, respectively. Both the improvement in overjet and molar occlusion were achieved with more dental changes (58–65%) rather than with skeletal changes (35–42%) (Figure 6).

Dental Cast Analysis

Before treatment, an average space deficiency in the lower arch of 0.70 ± 2.50 mm existed, while after treatment there was an average spacing of 1.10 ± 2.70 mm. Thus, during treatment the available space increased significantly ($P <$ .001) by an average of 1.80 ± 1.70 mm. There was, however, a high interindividual variation, ranging from −2.00 mm to 7.00 mm (Figure 7).

The amount of space present between the lower second permanent premolar and the lower first permanent molar (P2-M1) showed no spacing (0.00 ± 0.10 mm) before treatment but an average spacing of 0.40 ± 0.40 mm per side after treatment. The increase in interproximal space P2-M1 was statistically significant (P $<$ .001) but showed a high interindividual variation, ranging from −0.50 mm to +1.75 mm (Figure 7).

DISCUSSION

Proclination of the lower incisors is a general side effect of Herbst appliance treatment[3,7,14–16] due to the

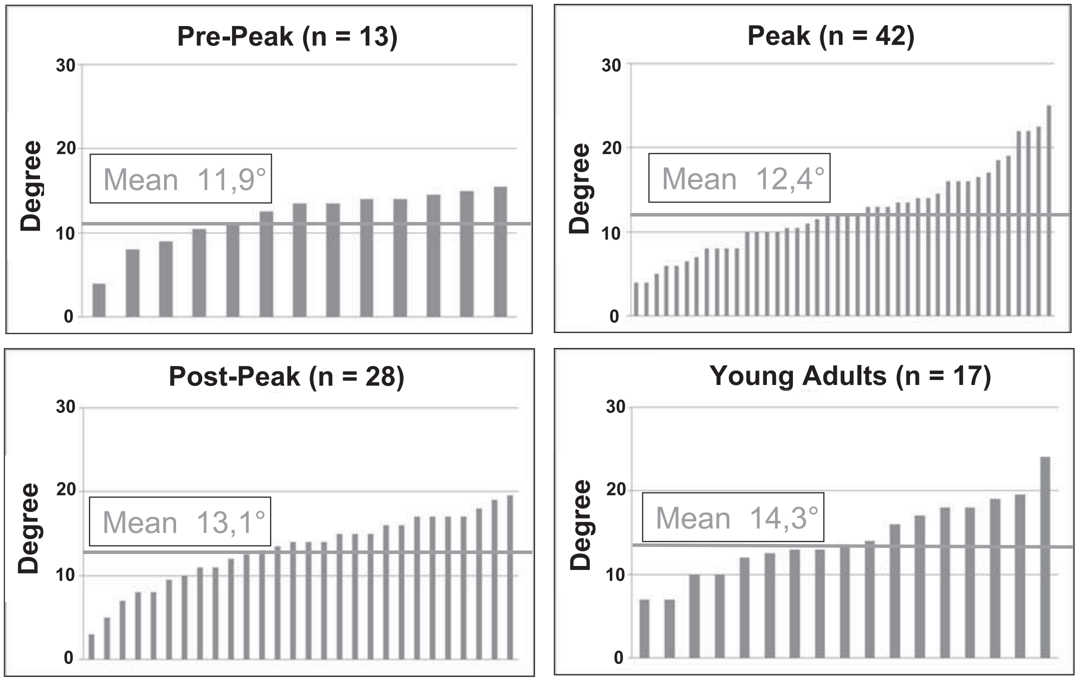

Figure 5. Individual treatment changes (T2-T1) for lower incisor inclination changes [IiL/ML*(d)*] in the prepeak (stages MP_3 E-F or S 1-2), peak (stages MP_3 FG-G or S 3-4), postpeak (stages MP_3 H-I) and young adults (stages R I-J) skeletal maturity groups.

anteriorly directed forces exerted onto the lower teeth by the telescope mechanism.[7,17–21] Unfortunately, none of the anchorage forms investigated to date has been able to reliably control this anchorage loss. Nevertheless, there is a recent case report and a pilot study using a customized lingual appliance showing promising results.[22,23]

In the present sample the lower incisors were proclined significantly by an average of 12.9 ± 4.6°. High amounts of proclination (11.8 ± 4.3°) were also reported by von Bremen et al.,[6] in whose study the RMS design was first used. Hansen et al.[20] analyzed 24 Class II division 1 Herbst subjects and found a mandibular incisor proclination of 10.8° in relation to the mandibular plane. Ruf et al.[21] reported an average lower incisor proclination of 8.9° in 98 Class II Herbst patients. Pancherz[24] analyzed 22 Class II division 1 Herbst cases and showed an average mandibular incisor proclination of 6.6° in comparison to untreated controls. Thus, the amount of incisor proclination with the RMS-Herbst was clearly greater in comparison with other studies using other anchorage forms for the Herbst appliance. In contrast to older studies, a small percentage of the present subjects had fixed appliances on the lower incisors during Herbst treatment. While an active leveling of the curve of Spee was not attempted, the alignment might additionally have contributed to the amount of proclination.

In both the study by von Bremen et al.[6] and the present investigation a statistical comparison was performed between RMS and TMS-Herbst treatment using the same historical control group.[3] While no statistically significant difference was found in the first study, despite a mean difference of 2.5°, the present

Table 2. Amount of Lower Incisor Proclination Changes [IiL/ML *(d)*] in 100 Class II Reduced Mandibular Splint (RMS)-Herbst Patients as Compared to 34 Class II Total Mandibular Cast Splints (TMS)-Herbst Patients[a]

	RMS (n = 100)		TMS (n = 34)		Group Difference	
Variables	Mean	SD	Mean	SD	Mean (*d*)	*P* value
IiL/ML (*d*)	12.9	4.9	9.3	4.8	3.6	***

[a] SD indicates standard deviation.
*** $P < .001$.

Table 3. Sagittal Occlusion (SO) Analysis Data of 100 Class II Patients Before (T1) and After (T2) Treatment with a Reduced Mandibular Splint (RMS)-Herbst Appliance[a]

	Before (T1)		After (T2)	
Variable (mm)	Mean	SD	Mean	SD
1. Overjet *is/OLp – ii/OLp*	6.9	2.3	−0.8	1.9
2. Molar relation[b] *ms/OLp – mi/OLp*	1.8	3.1	−4.5	3.5
3. Maxillary base *ss/OLp*	78.3	4.8	78.7	5.3
4. Mandibular base *pg/OLp*	80.4	5.5	83.5	6.0
5. Maxillary incisor *is/OLp*	85.9	5.3	84.8	5.3
6. Mandibular incisor *ii/OLp*	79.0	5.3	85.6	5.3
7. Maxillary molar *ms/OLp*	57.1	5.4	55.9	5.5
8. Mandibular molar *mi/OLp*	55.3	4.7	60.3	4.7

[a] SD indicates standard deviation.
[b] Upper/lower molar relationship: +, mi distal to ms; 0 mi = ms (1/2 cw distal occlusion); − mi mesial to ms.

Table 4. Sagittal Occlusion (SO) Analysis Treatment Changes (T2-T1) of 100 Class II Patients Treated with Reduced Mandibular Splint (RMS)-Herbst Appliance[a]

Variable (mm)	Mean	SD	*P* value
9. Overjet *is/OLp(d) − ii/OLp(d)*	−7.7	3.3	***
10. Molar relation *ms/OLp(d) − mi/OLp(d)*	−6.3	2.5	***
11. Maxillary base *ss/OLp (d)*	0.4	1.7	**
12. Mandibular base *pg/OLp (d)*	3.1	2.4	***
13. Maxillary incisor *is/OLp(d) − ss/OLp(d)*	−1.5	3.3	***
14. Mandibular incisor *ii/OLp(d) − pg/OLp(d)*	3.5	2.0	***
15. Maxillary molar *ms/OLp(d) − ss/OLp(d)*	−1.7	1.9	***
16. Mandibular molar *mi/OLp(d) −pg/OLp(d)*	1.9	1.8	***

[a] SD indicates standard deviation.
*** $P < .001$; ** $P < .01$.

study showed a statistically significant difference of 3.5°. Possible explanations for this difference are (1) the larger number of patients in the present study and (2) the fact that Class II division 1 and Class II division 2 patients were included. The latter might be relevant, as a larger mandibular incisor protrusion during Herbst treatment has been reported[16] for Class II division 2.

The amount of lower incisor proclination during RMS-Herbst treatment ranged from 11.9° (pre-peak) to 14.3° (young adult). However, the difference was not statistically significant. Lower incisor proclination of more than 20° could be seen not only in the young adult group but also in the peak group, in which the skeletal reaction capacity is anticipated to be best. In addition, earlier larger amounts of proclination with increasing age have been reported.[18,25,26] Although RMS-Herbst patients showing extreme proclination values (≥20°) were exclusively seen in the postgraduate student group, no statistically significant group differences (compared with values in the patients treated by certified orthodontists) were noted.

In the present study, the dental changes contributing to both molar and overjet correction were relatively larger (58–65%) than the skeletal changes (35–42%).

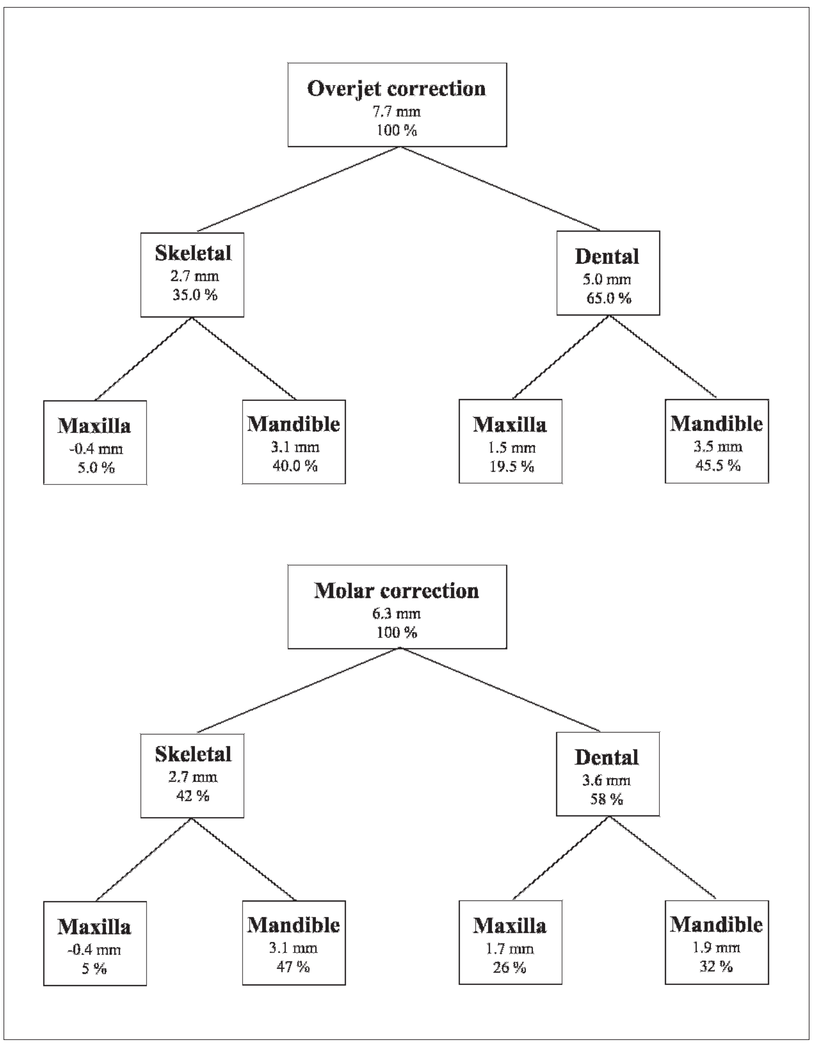

Figure 6. SO analysis: Maxillary and mandibular skeletal and dental changes contributing to overjet correction and molar correction in 100 Class II patients treated with a RMS-Herbst appliance.

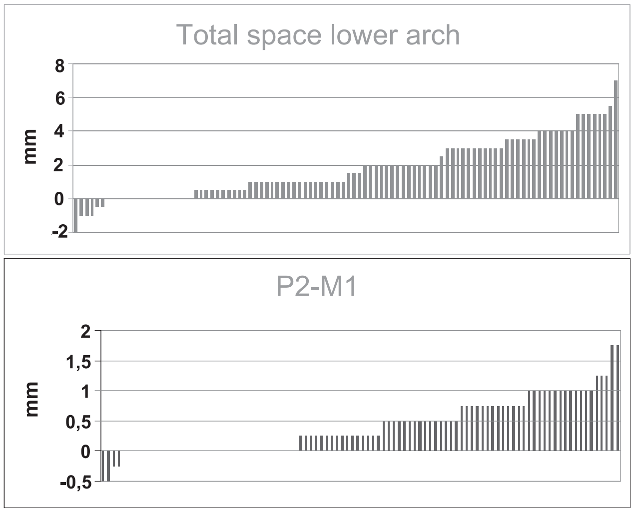

Figure 7. Individual treatment changes (T2-T1) in 100 Class II patients treated with a RMS-Herbst appliance. The values (mm) for the total available space and for the space between the second permanent premolar (P2) and the first permanent molar (M1) in the lower arch are given.

Nevertheless, the mandibular skeletal changes [*pg/OLp (d)*] remained acceptably large, contributing 40% and 47% to overjet and molar correction, respectively. These mandibular changes are most likely the result of an increase in mandibular length due to condylar growth stimulation in response to bite jumping.[7,26–29]

In particular, the contribution of lower incisor proclination to overjet correction (45.5%) during RMS-Herbst treatment was increased compared to previous TMS-Herbst studies. A relative contribution of 39–40% has been reported for Herbst treatment of hyper- or hypodivergent Class II division 1 adolescents[30] and Class II division 1 young adults,[31] while a mandibular incisor contribution to overjet correction of only 35% was seen in pre-peak Class II division 1 subjects.[7] Thus, regardless of skeletal maturity, RMS treatment resulted in larger dental changes.

The available space in the lower arch increased significantly, by an average of 1.8 mm, and a space opened between the lower second premolars and lower permanent first molars in 62% of the present RMS-Herbst patients. This spacing amounted to an average of 0.4 mm per side. Thus, the total space gain was slightly larger than the interproximal P2-M1 spacing seen. While both are the result of the increased amount of anchorage loss during RMS-Herbst treatment, the difference is most likely due to spacing in the lower anterior segment as a result of the increased incisor proclination.[20]

Because the aforementioned results clearly demonstrate that RMS-Herbst treatment results in a larger amount of anchorage loss, we have returned to the use of TMS-Herbst appliances as a general standard.

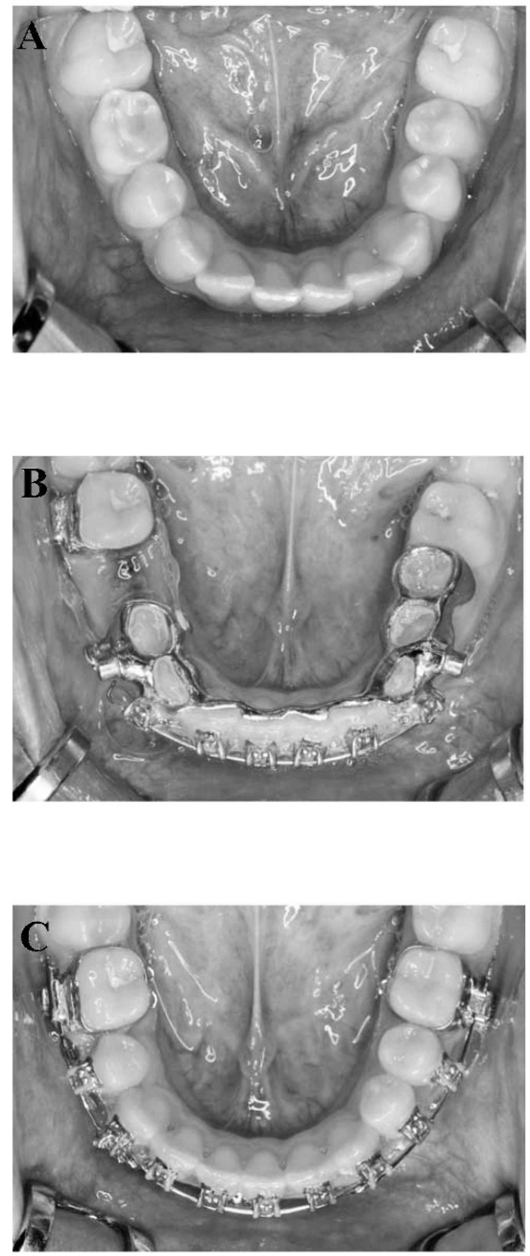

Figure 8. Intraoral photographs of a 12-year, 7-month-old girl with a Class II division 1 malocclusion and an aplasia of tooth 45. (A) Before treatment. (B) Space closure during RMS-Herbst treatment—note that in such a case it is useful to place an additional attachment in the area of the lower first premolar. (C) After Herbst treatment.

However, in Class II patients with unilateral or bilateral aplasia of the lower second premolars (Figure 8), RMS remains the appliance of choice, because in these cases the Herbst appliance counteracts the posterior inclination tendency of the lower incisors during space closure.

CONCLUSIONS

- Treatment with RMS-Herbst appliances leads to higher proclination of the lower incisors than does treatment with TMS-Herbst appliances; it also leads to an overall larger amount of anchorage loss.
- Thus, RMS-Herbst treatment can only be recommended in indicated cases.

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