ORIGINAL ARTICLE

Effects of the pendulum appliance, cervical headgear, and 2 premolar extractions followed by fixed appliances in patients with Class II malocclusion

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Introduction: In this retrospective study, we compared the cephalometric effects, the dental-arch changes, and the efficiency of Class II treatment with the pendulum appliance, cervical headgear, or extraction of 2 maxillary premolars, all associated with fixed appliance therapy. **Methods:** The sample of 82 patients with Class II malocclusion was divided into 3 groups: group 1 patients (n = 22; treatment time, 3.8 years) were treated with the pendulum appliance and fixed orthodontic appliances. Group 2 patients (n = 30; treatment time, 3.2 years) were treated with cervical headgear followed by fixed appliances; group 3 patients (n = 30; treatment time, 2.1 years) were treated with 2 maxillary premolar extractions and fixed appliances. The average starting ages of the groups ranged from 13.2 to 13.8 years. Data were obtained from serial cephalometric measurements and dental casts. The dental casts were analyzed with the treatment priority index. The treatment efficiency index was also used. **Results:** The 3 treatment protocols produced similar cephalometric effects, especially skeletally. Comparisons among the 2 distalizing appliances (pendulum and cervical headgear) and extraction of 2 maxillary premolars for Class II treatment showed changes primarily in the maxillary dentoalveolar component and dental relationships. The facial profile was similar after treatment, except for slightly more retrusion of the upper lip in the extraction patients. The treatment priority index demonstrated that occlusal outcomes also were similar among the groups. The treatment efficiency index had higher values for the extraction group. **Conclusions:** The effects of treatment with the pendulum appliance or cervical headgear and extraction of 2 maxillary premolars associated with fixed appliances were similar from both occlusal and cephalometric standpoints. Class II treatment with extraction of maxillary teeth was more efficient because of the shorter treatment time. Differences in maxillary incisor retraction should be noted, but these differences might have been due to greater maxillary dentoalveolar protrusion in the extraction group before treatment. (Am J Orthod Dentofacial Orthop 2009;136:833-42)

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The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.

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Submitted, June 2007; revised and accepted, December 2007.
0889-5406/$36.00

doi:10.1016/j.ajodo.2007.12.032

Treatment of Class II malocclusion is one of the most investigated and controversial issues in contemporary orthodontics, because of the extensive variability of treatment strategies addressing the morphologic characteristics of this malocclusion. The therapeutic approaches for correcting it include tooth extractions, orthopedic appliances, and extraoral or intraoral distalizing appliances.

Clinicians frequently select a treatment protocol based on their knowledge of the specific effects of each appliance on the dentoskeletal components—ie, directing the treatment to correct the maxilla and maxillary teeth or the mandible and mandibular teeth.[1] For example, distalizing appliances commonly are indicated for patients with maxillary dentoalveolar protrusion, as is treatment with extraction of 2 maxillary premolars. Orthopedic appliances are used more often for dentoskeletal corrections with maxillary skeletal protrusion

(maxillary splint, cervical headgear) or mandibular skeletal retrusion (Herbst, bionator, Twin-block).

According to Graber,[2] extraction of the maxillary first premolars or distalization of the posterior dentition is indicated when the patient has completed growing and has good alignment in the mandibular arch, but maxillary extraction or distalization can also be used in growing patients. The treatment protocol with tooth extractions requires retraction of the maxillary anterior teeth to reduce the overjet and correct the canine relationship; these patients have Class II molar relationships after treatment.[3-7]

The treatment of Class II malocclusion without extractions usually requires patient compliance, either for bodily distalization of molars (headgear) or for distalization of molar roots after use of intraoral distalizing appliances (pendulum). Bryk and White,[3] Kessel,[6] and Janson et al[5] agreed that extraction of maxillary premolars with maintenance of the initial molar relationship is an effective treatment option and requires less patient compliance. Proffit et al[8] stated that the occlusal and esthetic outcomes achieved with this treatment protocol usually are satisfactory, even when residual growth does not contribute to the treatment outcome significantly. Janson et al[9] and Pinzan-Vercelino[10] also observed that treatment with extraction of 2 maxillary premolars provided better occlusal outcomes with shorter treatment times, thus with higher efficiency than a nonextraction protocol with the pendulum appliance.

The orthodontic literature, however, is lacking about the dentoskeletal and soft-tissue effects of various therapeutic approaches (orthodontic appliances, intraoral and extraoral distalizing appliances, and tooth extractions), especially considering the outcomes after treatment with fixed appliances.[7] Burkhardt et al[1] compared the effects of the Herbst and pendulum appliances after fixed orthodontic treatment. These 2 treatment options for the correction of Class II malocclusion theoretically are diametrically opposed: distalization of maxillary teeth with the pendulum, and presumably increasing mandibular growth with the Herbst appliance. The investigators, however, found no differences in mandibular growth between groups, although they noted slightly greater increases in lower anterior facial height (LAFH) in the pendulum group. Treatment success with both appliances occurred primarily from dentoalveolar changes. Angelieri[11] compared the cephalometric effects of cervical headgear and the pendulum, and found few significant changes in the dentoskeletal component, with no difference in the soft-tissue profile.

Thus, it is questioned whether it is possible to distinguish the cephalometric effects produced by the pendulum and cervical headgear appliances or by treatment with extraction of 2 maxillary premolars with fixed appliances. In addition, which of these protocols is most efficient—ie, with better occlusal outcomes in shorter treatment times?

MATERIAL AND METHODS

In this retrospective clinical study, we evaluated 164 lateral cephalograms and 164 dental casts of 82 patients with Class II malocclusion from the files of Bauru Dental School at the University of São Paulo. All patients were treated by residents from this university. The sample was divided into 3 groups (Table I).

Group 1 included 22 patients (7 boys, 15 girls) who had treatment with the pendulum appliance and fixed appliances for a mean treatment time of 3.8 ± 1.8 years with an initial mean age of 13.8 ± 1.9 years. The malocclusions were characterized by bilateral molar relationships of at least a half cusp toward Class II, a mean ANB angle of 4.5°, and a mean overjet of 4.4 mm. The molar relationship was corrected with the pendulum appliance, as described by Angelieri et al.[12] After distalization of the maxillary molars, alignment and leveling were achieved with round nickel-titanium archwires, and heavier rectangular stainless steel archwires were used when the anterior teeth were retracted. Anchorage reinforcement was provided by headgear at night and Class II elastics during anterior retraction.

Group 2, treated with cervical headgear with fixed appliances, comprised 15 boys and 15 girls, with an initial mean age of 13.3 ± 1.6 years and treated for a mean period of 3.2 ± 1.5 years. The malocclusions were characterized by bilateral Class II molar relationship of at least a half cusp, an average ANB angle of 4.2°, and an overjet of 5.3 mm. The cervical headgear (adapted to the tubes of the maxillary first molar bands) was used with the outer bows of the facebow tilted 15° to 20° upward from the occlusal plane and exerting 450 g of force on each side with an average wear time of 14 to 16 hours per day. In addition to the headgear, fixed orthodontic treatment was performed, and Class II elastics were used during retraction of the canines and the incisors.

The patients in group 3 had 2 maxillary first premolars removed during their comprehensive orthodontic treatment. This group included 15 boys and 15 girls, with an initial mean age of 13.6 ± 1.2 years and a treatment duration of 2.2 ± 1.1 years. The malocclusions were characterized by a bilateral molar relationship of at least a half cusp, a mean ANB angle of 3.9°, and an overjet of 7.6 mm. Class II elastics and cervical headgear at night were used during anterior retraction.

Table I. Descriptive statistics of the sample

	Mean values			*ANOVA* P		
Variable	*Group 1*	*Group 2*	*Group 3*	*1-2*	*1-3*	*2-3*
Age at T1 (y)	13.8	13.3	13.6	NS	NS	NS
Age at T2 (y)	17.6	16.5	15.7	*	†	NS
Average treatment (y)	3.8	3.2	2.1	†	†	†

NS, Not significant.
*$P \leq 0.05$; †$P \leq 0.01$.

Two lateral cephalograms of each patient were analyzed at the initial (T1) and final (T2) examinations. The cephalograms were traced by 1 investigator (R.R.A.P.) and checked by another examiner (J.F.C.H.) for accuracy of landmark placement and anatomic contours. Any disparities in landmark location were resolved by mutual agreement. The points on the tracings were digitized (Dentofacial Planner version 7.0, Dentofacial Software, Toronto, Ontario, Canada) with a digitizing table (model DT-11, Houston Instruments, Austin, Tex). However, since the lateral cephalograms were obtained from 3 machines (1 machine for each group), the radiographic image magnifications had to be corrected. The magnification factors were calculated, determined, and corrected to 9.8% for the pendulum group, 7.9% for the headgear group, and 6% for the extraction group. The cephalometric landmarks used in this study are shown in Figure 1.

The occlusal relationships in and between arches on the dental casts before and after treatment were evaluated quantitatively by an occlusal index, the treatment priority index (TPI) of Grainger.[13] The TPI provides subscores in weights to describe overjet, overbite or anterior open bite, buccal or lingual tooth displacement, and posterior crossbite in the classification of malocclusions as Class II, Class III, or neutral occlusion; the final score indicates the degree of severity of the malocclusion.

Except for rotation and buccal or lingual tooth displacement, all other components of the TPI are expressed along a continuous scale with positive and negative values. Then, subjects with mandibular overjet (Class III) or anterior open bite are expressed as negative overjet and overbite scores, respectively. A constant corresponding to the molar occlusion is added to the TPI score. The total score of the TPI scale ranges from 0 to 10 or more; higher scores represent more severe malocclusions. After all aspects of the malocclusion are scored, each is counted and added to a constant, the value of which corresponds to the molar relationship at T1.

Two TPI tables were used for each patient. One contained data on the initial dental casts and the other on the final dental casts. Analysis of final dental casts in group 3, treated with extraction of 2 premolars, considered the Class II molar relationship after treatment as normal.[3,4,6,7,9] Therefore, it was classified in the same column as the Class I molar relationship.

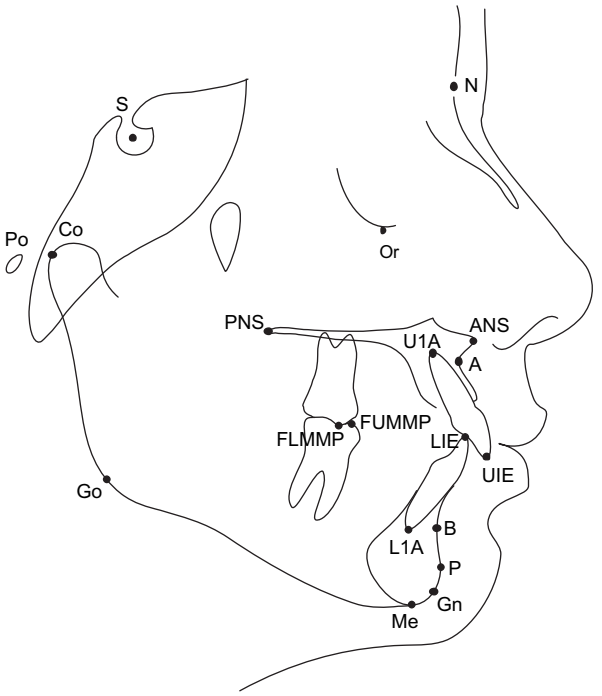

Fig 1. Cephalometric landmarks: sella (*S*), midpoint of sella turcica; nasion (*N*), most anterior point of frontonasal suture; porion (*Po*), uppermost point of the external auditory meatus; orbitale (*Or*) lowermost point of the orbit; subspinale (*A*), deepest concavity of the anterior maxilla; supramentale (*B*), deepest concavity of the anterior mandibular symphysis; anterior nasal spine (*ANS*); posterior nasal spine (*PNS*); menton (*Me*), most inferior point on the mandibular symphysis; gonion (*Go*), most posteroinferior point of the angle of the mandible; gnathion (*Gn*), most anteroinferior point on the mandibular symphysis; pogonion (*P*), most anterior point of the bony chin; condylion (*Co*), most posterosuperior point of the condyle; upper incisor edge (*UIE*); lower incisor edge (*LIE*); upper incisor apex (*U1A*); lower incisor apex (*L1A*); first upper molar mesial contact point (*FUMMP*); first lower molar mesial contact point (*FLMMP*).

Because treatment efficiency is related to better outcomes during a shorter interval, efficiency was evaluated by an index (the treatment efficiency index [TEI]), defined as the ratio between the percentage of improvement (Pc) in the TPI score (PcTPI) and the treatment time (Ttreat) in months,[9] as expressed by the following equation: TEI-TPI = PcTPI/Ttreat. The

Table II. Comparison of starting forms

	Group 1, pendulum (n = 22)		*Group 2, headgear (n = 30)*		*Group 3, extraction (n = 30)*		*Significance*		
Cephalometric measurement	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*1-2*	*1-3*	*2-3*
Maxillary skeletal									
SNA (°)	82.2	3.1	82.1	3.2	80.6	3.9	NS	NS	NS
Nperp-A (mm)	2.0	2.8	2.0	2.9	–1.0	4.0	NS	*	*
Co-A (mm)	86.5	5.2	85.7	4.5	85.7	6.4	NS	NS	NS
Mandibular skeletal									
SNB (°)	77.7	2.6	77.8	3.4	76.7	2.9	NS	NS	NS
Co-Gn (mm)	109.1	4.8	107.7	5.9	108.8	6.2	NS	NS	NS
Maxillomandibular									
ANB (°)	4.5	1.6	4.2	2.2	3.9	2.6	NS	NS	NS
Vertical									
FMA (°)	23.6	5.1	22.7	3.9	26.5	4.9	NS	NS	*
SN.GoGn (°)	31.3	5.7	30.4	4.7	32.8	4.9	NS	NS	NS
SN.PP (°)	6.4	3.6	7.3	3.2	4.9	2.9	NS	NS	*
LAFH (mm)	62.7	4.6	61.1	4.3	65.3	5.5	NS	NS	*
Maxillary dental									
U1.NA (°)	21.0	9.0	24.4	7.8	28.9	10.1	NS	*	NS
U1-NA (mm)	3.7	2.9	4.1	2.7	6.5	4.0	NS	*	NS
U1-PP (mm)	27.7	2.6	26.5	2.3	29.0	3.0	NS	*	*
U1.PP (°)	109.6	6.8	113.7	8.1	114.4	8.8	NS	NS	NS
Mandibular dental									
L1.NB (°)	29.9	6.0	27.2	6.3	24.8	6.2	NS	*	NS
L1-NB (mm)	5.0	2.2	4.1	2.1	4.9	2.5	NS	NS	NS
L1-GoMe (mm)	38.7	2.5	37.0	2.7	39.2	3.2	NS	NS	*
L6-GoMe (mm)	28.5	2.1	27.3	2.4	28.1	2.3	NS	NS	NS
IMPA (°)	98.7	5.0	96.7	6.5	93.3	5.9	NS	*	NS
Dentoalveolar relationships									
Overjet (mm)	4.4	1.4	5.3	3.0	7.6	2.6	NS	*	*
Overbite (mm)	4.5	1.9	3.4	1.5	3.9	2.8	NS	NS	NS
Molar relationship (mm)	0.8	0.7	0.3	1.3	3.7	0.8	NS	*	*
Soft tissue									
Nasolabial (°)	106.6	12.2	107.8	11.4	111.0	16.0	NS	NS	NS
Mentolabial (°)	6.4	1.5	5.9	1.5	6.1	1.7	NS	NS	NS
Ls-E (mm)	–0.9	2.1	–2.1	2.4	–2.1	2.3	NS	NS	NS
Li-E (mm)	0.2	2.9	–1.1	2.8	–0.0	2.7	NS	NS	NS

NS, Not significant.
*$P \leq 0.01$.

Pc is related directly to the TEI. Therefore, the value of the TEI is increased because higher Pc values are associated with shorter treatment times.

Statistical analysis

All statistical analyses were performed with Statistica software (Statistical Software for Windows, version 5.0, Statsoft, Tulsa, Okla). To evaluate the data distribution, the data were analyzed with the Kolmogorov-Smirnov test. In considering a normal distribution of the data, analysis of variance (ANOVA) was performed.

The reliability of the measurements was assessed by randomly selecting 20 lateral cephalograms and 20 dental casts from the 3 study groups; these were traced and digitized (radiographs) or measured (dental casts) by the same examiner a second time a month after the first evaluation. The difference between the first and second evaluations of each cephalogram and dental cast was determined to establish the casual error (Dahlberg's formula)[14] and systematic error (paired *t* test).

The casual error of the method did not exceed 0.8° or 0.6 mm, whereas the paired *t* test did not show any statistically significant difference for the systematic error. Due to the ease of reproducibility of the TPI, the occlusal evaluations had no casual or systematic errors.

The initial analysis among groups addressed the means of initial age, final age, and treatment time, and the initial means of the cephalometric measurements

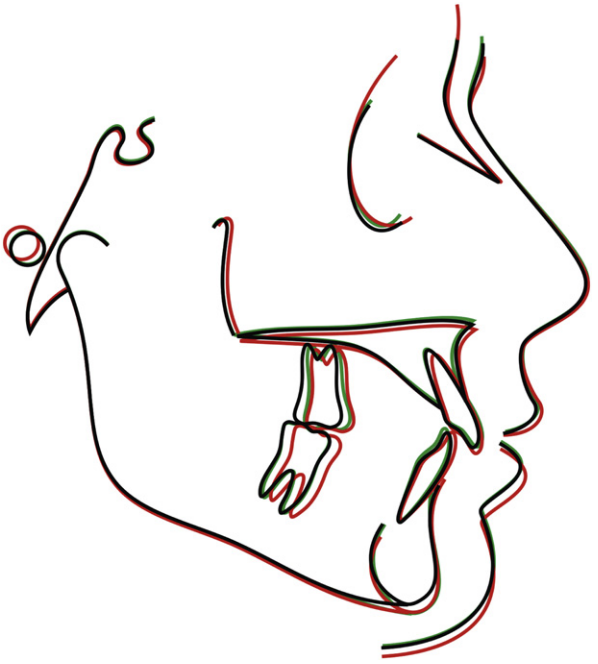

Fig 2. Superimposition of the average cephalometric tracings obtained at T1 of the 3 groups. Pendulum group (*red line*), headgear group (black line), and extraction group (*green line*).

of each group; ANOVA was applied to investigate the similarity between groups.

The changes from the 3 treatment protocols were assessed by the difference between the means of the T1 and T2 measurements and were compared with ANOVA to investigate the null hypothesis that the treatment effects were equal in the 3 groups. When statistical differences were found between the groups, the mean changes were assessed by the Tukey post-hoc test to investigate which aspects were related to rejection of the null hypothesis of equality among groups. The TPI, Pc, and TEI also were evaluated by ANOVA and the Tukey test. Results with $P \leq 0.05$ and $P \leq 0.01$ were considered statistically significant for all analyses.

RESULTS

The 3 groups were similar in age at the start of treatment but not at the end. The mean final ages and mean treatment times had statistical differences among the groups, thus preventing direct statistical comparisons (Table I). The substantial difference in treatment times indicated the need to standardize the treatment time (a variation on the concept of annualizing data) to make the groups comparable.[15] To conduct direct and meaningful statistical comparisons, therefore, all cephalometric increments of the pendulum and the headgear patients were adjusted to the time interval of the extraction sample: 2.1 years (the raw data are available from the authors on request).

Table III. Comparison of the TPI and the TEI among the 3 groups

	Mean values			*ANOVA* P		
Variable	*Group 1*	*Group 2*	*Group 3*	*1-2*	*1-3*	*2-3*
TPI (T1)	6.28	6.37	7.32	NS	NS	NS
TPI (T2)	0.84	0.95	0.77	NS	NS	NS
TPI difference	5.44	5.41	6.55	NS	NS	NS
PcTPI	86.62	84.91	89.48	NS	NS	NS
Treatment average (months)	46.4	38.0	25.6	*	*	*
TeI	1.9	2.2	3.5	NS	*	*

NS, Not significant.
*$P \leq 0.01$.

Table II presents the results of the ANOVA for comparisons among the groups at the pretreatment stage to establish the initial morphologic similarity among the groups. General similarity was observed in the pretreatment cephalometric values among groups, as shown by the overall superimpositions in Figure 2.

Among the 26 variables, however, 12 measurements had significant differences among groups (Table II). The sagittal positions of the maxilla and mandible were comparable among the 3 groups, as well as the ANB angle. The maxilla was more retruded in group 3 (A-Nperp, –1.0 mm) compared with groups 1 and 2 (both, 2.0 mm). LAFH was greater in group 3, as were the palatal plane and the FMA angle. The maxillary incisors were tipped more lingually and retruded in group 1, yet with a statistical difference only when compared with group 3. Overjet for group 3 was significantly greater than for the other 2 groups, as was the molar relationship (Class II). The characteristics of the soft-tissue profile were similar among the groups.

Analysis of the dental casts with the TPI did not show a statistically significant difference among the groups at T1 and T2, demonstrating that, from an occlusal standpoint, the malocclusions were similar among groups and were corrected in a quantitatively similar manner (Table III).

A statistical difference was found for the TEI, with greater efficiency for group 3 (3.5) than for the pendulum (1.9) and headgear (2.2) groups.

The results of this comparison (Table IV) indicated statistically significant differences in several measurements related to the maxillary, vertical, dentoalveolar, and soft-tissue components and in the maxillomandibular and dental relationships.

Table IV. Differences in mean changes standardized to 2.1 years (T1-T2)

	Group 1, pendulum (n = 22)		Group 2, headgear (n = 30)		Group 3, extraction (n = 30)		Significance		
Cephalometric measurement	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*1-2*	*1-3*	*2-3*
Maxillary skeletal									
SNA (°)	0.2	0.7	–0.8	1.0	–1.2	2.2	NS	†	NS
Nperp-A (mm)	0.3	1.4	–0.7	1.5	–2.0	2.5	NS	†	†
Co-A (mm)	1.2	1.8	0.9	1.5	–0.3	2.5	NS	*	*
Mandibular skeletal									
SNB (°)	0.2	0.9	0.4	0.9	0.5	1.3	NS	NS	NS
Co-Gn (mm)	2.3	2.9	3.6	2.5	3.2	3.0	NS	NS	NS
Maxillomandibular									
ANB (°)	0.0	0.9	–1.2	0.8	–1.7	2.2	†	†	NS
Vertical									
FMA (°)	–0.2	1.2	–0.6	1.6	0.6	1.6	NS	NS	†
SN.GoGn (°)	–0.1	1.3	–0.6	1.3	–0.2	1.5	NS	NS	NS
SN.PP (°)	0.1	1.0	0.4	0.9	0.2	1.8	NS	NS	NS
LAFH (mm)	1.8	2.2	2.1	1.4	2.7	1.9	NS	NS	NS
Maxillary dental									
U1.NA (°)	0.8	6.0	1.2	6.7	–3.7	9.7	NS	NS	*
U1-NA (mm)	–0.1	1.9	0.3	2.0	–0.6	2.1	NS	NS	NS
U1-PP (mm)	0.3	1.0	0.9	1.1	–0.1	1.8	NS	NS	*
U1.PP (°)	1.1	5.7	0.8	6.9	–4.7	9.1	NS	†	†
Mandibular dental									
L1.NB (°)	3.7	4.0	1.8	4.4	1.7	5.8	NS	NS	NS
L1-NB (mm)	0.9	1.2	0.5	1.0	0.7	1.3	NS	NS	NS
L1-GoMe (mm)	0.5	1.2	0.6	1.3	1.0	2.3	NS	NS	NS
L6-GoMe (mm)	0.9	0.9	1.2	1.0	2.0	1.3	NS	†	†
IMPA (°)	3.6	4.2	2.0	4.3	1.4	6.0	NS	NS	NS
Dentoalveolar relationships									
Overjet (mm)	–0.9	0.7	–1.6	1.7	–4.6	2.5	NS	†	†
Overbite (mm)	–1.2	0.9	–0.7	1.1	–2.0	2.7	NS	NS	*
Molar relationship (mm)	–1.3	0.9	–1.3	1.1	0.4	0.7	NS	†	†
Soft tissue									
Nasolabial (°)	1.0	6.2	–2.0	7.3	2.4	15.1	NS	NS	NS
Mentolabial (°)	–0.1	0.7	–0.2	0.7	–0.4	1.1	NS	NS	NS
Ls-E (mm)	–1.0	0.6	–1.1	1.1	–2.6	1.8	NS	†	†
Li-E (mm)	–0.2	1.1	–0.3	1.2	–1.0	1.9	NS	NS	NS

NS, Not significant.
*$P \leq 0.05$; †$P \leq 0.01$.

In the maxilla, there were statistically significant reductions in the variables SNA and Nperp-A in groups 2 and 3 and a mild increase in group 1, indicating a difference only between groups 1 and 3. Effective midfacial length (Co-A) was increased in groups 1 and 2 and reduced in group 3.

There were no significant differences in themandibular measurements (SNB and Co-Gn).

For the maxillomandibular relationships, there were reductions in the ANB angles in the headgear (–1.2°) and extraction (–1.7°) groups; no change was observed in the pendulum group (0.0°).

With regard to the vertical component, no measurement had a statistical difference among the groups.

The maxillary incisors were tipped lingually (1.NA = –3.7° and 1.PP = –4.7°) and retruded (–2.4 mm) in group 3. Groups 1 and 2 nearly maintained their initial values.

In the mandibular dentition, only the variable 1-GoMe had a statistical difference among the groups, with greater extrusion of the mandibular molars (2.0 mm) in group 3.

Overjet and overbite were reduced significantly in group 3 ($P < 0.01$ for overjet; $P < 0.05$ for overbite) compared with the other groups, yet there was statistical difference between groups 1 and 3, and 2 and 3, for overjet, and only between groups 2 and 3 for overbite.

The molar relationship showed an increase (0.4 mm) in group 3 (toward a Class II relationship) with

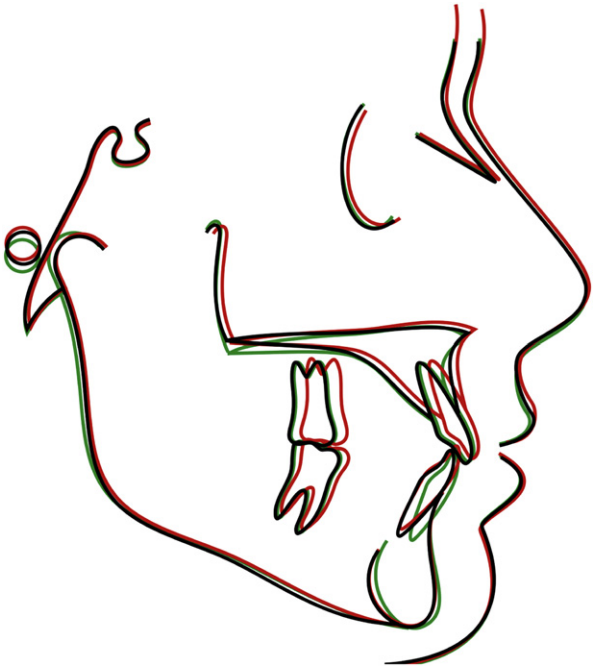

Fig 3. Superimposition of the average cephalometric tracings obtained at T2 of the 3 groups. Pendulum group (*red line*), headgear group (*black line*), and extraction group (*green line*).

statistical difference ($P < 0.01$) among the groups, because 2 maxillary teeth were extracted in this group.

In the soft-tissue profile among the 4 variables, only 1 (Ls-E) had statistical differences among the groups. The upper lip was significantly more retruded in group 3. Relative to the esthetic plane, the upper lip of the extraction patients was retruded (–2.6 mm) compared with the pendulum group (–1.0 mm) and the headgear group (–1.1 mm).

Figure 3 shows the differences among groups, highlighting the changes achieved for each treatment protocol.

DISCUSSION

In this retrospective clinical study, we compared the effects of the pendulum appliance, cervical headgear, and extraction of 2 premolars, all followed by fixed orthodontic appliances, to correct Class II malocclusions. Only a few studies have evaluated the cephalometric effects of the pendulum appliance and cervical headgear,[11] the pendulum and Herbst,[1] and the extraction of 2 premolars compared with extraction of 4 premolars[16] for the treatment of Class II malocclusion. Also with regard to these treatment protocols, other studies have compared the occlusal outcomes of the pendulum and extraction of 2 maxillary premolars,[10] treatment of Class II malocclusion without extractions and with extraction of 2 maxillary premolars,[9] and treatment with extraction of 2 vs 4 premolars.[17] To our knowledge, no previous investigation has compared directly the 3 treatment protocols examined in this study.

The results of comparison of the TPI at T1 showed that all 3 groups had similar malocclusions at T1 from an occlusal standpoint, even though the initial cephalometric characteristics indicated some discrepancies in the dentoalveolar component (Table II).

The TPI at T2 showed that, even though different treatment protocols were used for the same malocclusion, the occlusal outcomes were similar and clinically satisfactory, with the average TPI scores below 1.0 mm, indicating nearly perfect occlusions. These results corroborated the study of Pinzan-Vercelino,[10] who found no difference in final TPI when comparing the pendulum appliance and the extraction of 2 maxillary premolars for correcting Class II malocclusions. These findings compare with those of Angelieri,[11] who also observed similar occlusal outcomes for treatment with cervical headgear and the pendulum associated with fixed appliances. On the other hand, Janson et al[5,9] observed better occlusal outcomes for treatment with extraction of 2 premolars compared with treatment of Class II malocclusion without extractions or with extraction of 4 premolars, respectively.

The higher the TEI score, the more efficient the treatment. Larger TEI values were found for the extraction group (4.3) than for the pendulum (2.1) and cervical headgear (2.3) groups. Total treatment times differed significantly among the 3 groups for obvious reasons. In both the headgear and pendulum groups, the first part of the protocol was to move the maxillary posterior teeth distally, a step that was unnecessary in the extraction patients because the molar relationship remained Class II. Anterior retraction was necessary in all groups, and Class II elastics were used similarly in all patients. Thus, since a step was skipped in the extraction group, its total treatment time was substantially shorter than for the other 2 groups.

The few studies that evaluated the efficiency of treatment of Class II malocclusion with the TEI unanimously indicated that treatment with extraction of 2 maxillary premolars is more efficient than that with extraction of 4 first premolars or distalization of molars from a duration-of-treatment perspective.[5,9,10,17] This greater efficiency reported in the literature is related to the shorter treatment time when 2 maxillary teeth are extracted, since the Class II molar relationship is maintained, thus requiring less patient compliance during treatment and less tooth movement.[5,9,10,16]

Most studies of the pendulum appliance analyzed only the distalization time. The mean distalization treatment time was 6 to 12 months. Similarly to our study, Burkhardt et al[1] also found a longer treatment time for the pendulum group followed by fixed appliance (31.6 months) compared with the acrylic and crowned Herbst groups (29.5 and 28.0 months, respectively).

The protocols evaluated in this study, especially the extraction of 2 maxillary premolars, caused changes in the anterior contour of the maxilla (analyzed by the movement of Point A). These results demonstrated statistically significant differences among the groups. The SNA angle and the linear measurement Nperp-A, both of which establish the position of the maxilla relative to the cranial base, were reduced in groups treated with headgear (–0.8° and –0.7 mm) and extractions (–1.2° and –2.0 mm), with smaller reductions in the group treated with extractions, which had slight increases in these measurements (0.2° and 0.3 mm). The results for group 3 are understandable and similar to a previous study, because this group had greater overjet at T1 and thus underwent the greatest retraction of the incisors and consequently of Point A.[16]

The orthopedic effect of headgear treatment on the maxilla (restriction of forward maxillary displacement) during the growth period has been reported widely in the literature.[6,18-24] Kopecky and Fishman,[22] however, demonstrated that headgear worn by patients treated after the pubertal growth spurt did not produce such effective maxillary treatment outcomes. The changes in group 1 corroborate previous findings in the literature that showed no restrictive effects on the maxilla secondary to this type of therapy.[1,11,12,25-33]

With regard to effective midfacial length (Co-A), there was a similar increase for the groups treated with the headgear (0.9 mm) and the pendulum (1.2 mm) and once again a reduction for the group with extractions (–0.3 mm), with statistically significant differences between group 3 and the others. The maxillary changes in all 3 groups were a combination of the normal downward and forward growth of the maxilla during the treatment period combined with adaptations in maxillary dentoalveolar structures, especially at Point A.

The changes in mandibular skeletal effects were similar among the groups, without statistical differences. The SNB angle was nearly unchanged by the therapies evaluated, in agreement with the literature.[6,11,12,16,18-20,26,27,34-36] This lack of difference was expected since our protocols did not incorporate orthopedic appliances for forward mandibular displacement.

As a consequence of the maxillary changes, the sagittal relationship between the bone bases (ANB) was reduced mildly and only in the groups treated with headgear (–1.2°) and extractions (–1.7°), demonstrating the modest influence of these treatment protocols on the maxillomandibular component, as shown previously.[3,11,12,16]

The changes in overall growth patterns during treatment were similar in the 3 groups; this shows that the growth pattern was not changed by the therapies, confirming the minimum repercussion of these treatment protocols on the craniofacial complex. The mandibular plane exhibited minimal counterclockwise rotation, confirmed by the slight reduction in the SN.GoMe and FMA angles. There was a tendency of clockwise rotation of the palatal plane (SN.PP) during treatment. LAFH had an approximate increase of 2 mm secondary to the extrusive mechanics inherent in fixed orthodontic treatment; these effects also are corroborated in the literature.[3,11,18,26,35,36]

The maxillary incisors exhibited significant changes among groups with regard to buccolingual tipping (1.NA and 1.PP) and anteroposterior positioning (1-NA). In the extraction group, the anterior teeth had greater incisor flaring and overjet than did the other 2 groups. The incisors in the pendulum and headgear groups generally were maintained in their initial orientation, with only mild buccal crown tipping, probably due to tooth alignment and leveling with fixed appliances. Burkhardt et al[1] and Angelieri et al[12] also observed mild buccal tipping of these teeth during orthodontic treatment with pendulum and fixed appliances. Sagittally, the retraction of the maxillary incisors in the pendulum and headgear groups was modest, and their magnitude was statistically different compared with the extraction group.

Other studies of treatment effects produced by headgear and fixed appliances reported significant retraction of incisors.[18,37] The anteroposterior changes of the maxillary molars (6-PTV) were similar among the 3 groups, with mild mesialization of these teeth (0.3, 1.1, and 1.9 mm, respectively), despite the distalization mechanics used in groups 1 and 2. Angelieri[11] also observed similar outcomes for molars after fixed orthodontic treatment associated with distalization with the pendulum (1.8 mm) and cervical headgear (1.7 mm). These findings confirm that the distal movement achieved by these distalizing appliances is temporary and rebounds presumably with the normally occurring downward and forward movement of the maxillary posterior teeth during the active growth period. Only the study of Burkhardt et al[1] demonstrated the net distalization of molars after treatment with the pendulum and fixed appliances (–0.8 mm).

The statistically significant changes in the mandibular dentition were limited to the vertical development of

the molars (6-GoMe). In the 3 treatment protocols, these teeth exhibited extrusion presumably because of fixed orthodontic mechanics, including Class II elastics.[11,16,18,28,35] The group with extractions had greater extrusion, however, indicating a difference compared with the other groups. Despite the significant extrusion of the mandibular molars in the extraction group, the increase in LAFH was not greater than in the other groups.

With regard to the anteroposterior positioning of the incisors and the molars, there were similar increases in angular (IMPA and 1.NB) and linear (1-NB and 6-PTV) measurements in the groups by mesial tooth movement, buccal tipping and protrusion to correct crowding, or leveling of the curve of Spee. Janson[16] and Angelieri[11] also observed similar results when evaluating extractions of 2 maxillary premolars and the pendulum and cervical headgear appliances with fixed orthodontic mechanics. Concerning the vertical displacement of the mandibular incisors, there was a similar change in the measurement 1-GoMe, without statistical difference.

Is it possible to distinguish the soft-tissue changes in patients treated with extractions compared with those treated without extractions and with distalization of the molars? Evaluation of the changes in angular and linear measurements related to the soft-tissue profile showed a statistically significant difference among the groups only for the position of the upper lip, which had greater retrusion in the extraction group because of removal of the maxillary premolars, the subsequent retraction of anterior teeth, and the resulting greater change in overjet. The nasolabial angle and mentolabial angle and the position of the lower lip showed slight changes without statistical differences among groups during treatment.

CONCLUSIONS

The effects of treatment with the pendulum appliance and cervical headgear and extraction of 2 maxillary premolars associated with fixed appliances generally are similar from both occlusal and cephalometric standpoints. Treatment of a Class II malocclusion with extraction of maxillary teeth was more efficient than the other 2 protocols because of the shorter treatment time. Slightly more retraction of the upper lip relative to the esthetic plane was noted after treatment in the extraction group; however, this difference might have been related to the slightly greater maxillary dentoalveolar protrusion in this group at the beginning of treatment.

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