*Original Article*

# Long-term stability of rapid maxillary expansion combined with chincup protraction followed by fixed appliances

**Juan Carlos Palma[a]; Natalia Tejedor-Sanz[b]; M. Dolores Oteo[c]; José Antonio Alarcón[d]**

**ABSTRACT**

**Objective:** To analyze the long-term stability of rapid maxillary expansion (RME) and protraction from chincup therapy in girls with Class III malocclusion.

**Materials and Methods:** Twenty-two girls (mean age = 9.1 ± 0.6 years) with Class III malocclusion were treated with combined RME and protraction from a chincup, followed by fixed appliances. Lateral cephalograms were evaluated before treatment, at the end of a two-phase treatment protocol (mean age = 15.1 ± 1.1 years), and 10.9 ± 0.5 years after the end of treatment (mean age = 27.5 ± 0.5 years). The control group consisted of 22 matched girls with skeletal Class I malocclusion.

**Results:** After treatment, the Class III group showed significant improvement of the Class III malocclusion, mainly due to changes in the mandible (ie, SNB angle decreased 1.8 ± 1.6°) and significant improvement of the sagittal maxillomandibular relationship (Wits appraisal increased 2.6 ± 2.1 mm; ANB angle increased 1.0 ± 0.3 mm). These changes remained stable for an average of 10 years after the end of therapy. No tendency toward relapse was detected, and the mandibular position showed favorable outcomes.

**Conclusions:** RME and protraction from chincup therapy led to successful long-term outcomes in 18 of 22 patients (81.8%). This treatment approach can be considered an efficient therapy in growing girls with mild skeletal Class III malocclusion caused by maxillary retrusion and mandibular protrusion. (*Angle Orthod.* 2015;85:270–277.)

**KEY WORDS:** Class III; Chincup; Maxillary protraction; Long-term; Stability

## INTRODUCTION

Maxillary protraction from the use of a facemask after rapid maxillary expansion (RME) is the most extended treatment for Class III malocclusion.[1–4] When a patient's problems include a combination of maxillary retrusion and mandibular protrusion, combined treatment with maxillary protraction and a chincup has been demonstrated to be effective for correcting the skeletal discrepancy.[5–7] Yoshida et al.[7] found that the combined use of a maxillary protraction appliance and a chincup was effective in correcting intermaxillary and interarch discrepancies, although moderate rebound-like changes occurred in mandibular size and position at the end of pubertal growth. Masucci et al.[8] evaluated the long-term stability of RME and face mask therapy after active circumpubertal growth; in the long term, approximately 73% of the Class III patients achieved successful outcomes. Skeletal changes were mainly due to improvements in the sagittal position of the mandible, and initial maxillary changes reverted in the long term.

Using RME and facial mask therapy, Westwood et al.[9] described a success rate of over 76% at a follow-up observation 5 years after treatment. Baccetti et al.[10] found that the favorable dentoskeletal outcomes achieved after mandibular cervical headgear and fixed appliances remained stable in the long term (5 years) at a postpubertal stage. The studies by Sugawara et al.[11] and Sugawara and Mitani[12] concluded that the skeletal profile was greatly improved during the initial

[a] Adjunct Professor, Department of Orthodontics, Faculty of Odontology, University Complutense, Madrid, Spain.
[b] Research Fellow, Department of Orthodontics, Faculty of Odontology, University Complutense, Madrid, Spain.
[c] Assistant Professor, Department of Orthodontics, Faculty of Odontology, University Complutense, Madrid, Spain.
[d] Assistant Professor, Department of Stomatology, School of Dentistry, University of Granada, Granada, Spain.
Corresponding author: Dr Juan Carlos Palma, Department of Orthodontics, Faculty of Odontology, University Complutense, Madrid, Plaza Ramón y Cajal s/n. 28040 Madrid, Spain (e-mail: carlosc@odon.ucm.es)

Accepted: April 2014. Submitted: January 2014.
Published Online: June 3, 2014

stages of treatment with a chincup, but such changes were often not maintained for a long time thereafter. Deguchi et al.[13] found that the long-term (>5 years) application of a moderate and continuous orthopedic force with a chincup could improve severe skeletal Class III deformities in patients with dolichofacial features and that the treatment-induced changes persisted in the long term (nearly 4 years 8 months).

The literature does not contain data concerning the stability of combined RME and maxillary protraction from chincup therapy after the end of circumpubertal growth. Therefore, the aim of the present study was to analyze the long-term stability of combined RME and maxillary protraction from chincup therapy in girls with Class III malocclusion. Patients were reevaluated an average of 10 years after the end of treatment, long after the end of circumpubertal active craniofacial growth.

## MATERIALS AND METHODS

### Study Groups

A sample of 22 girls with skeletal Class III malocclusion treated with combined RME and maxillary protraction from a chincup followed by comprehensive preadjusted edge-wise therapy was consecutively recruited from the Orthodontic Clinic of the School of Dentistry, University Complutense, Madrid, Spain. Inclusion criteria at the beginning of the study (T0) included skeletal Class III malocclusion (ANB angle $< 0^\circ$ and Wits appraisal $< -2.0$ mm) caused by maxillary retrusion (SNA angle $< 80^\circ$) and mandibular protrusion (SNB angle $> 82^\circ$), a permanent first molar relationship of at least one-half cusp Class III, an anterior crossbite or edge-to-edge incisal relationship, no discrepancy between centric occlusion and centric relation, prepubertal skeletal maturation according to cervical vertebral maturation (CS1–CS3),[14] and white descent. Exclusion criteria included congenitally missing, supernumerary, or extracted teeth; craniofacial disorders; temporomandibular joint dysfunction; and previous or current orthopedic/orthodontic treatment.

A control group of 22 girls with skeletal Class I (ANB angle between $0^\circ$ and $3^\circ$; Wits appraisal between $-2.0$ and 2.0 mm) and mesofacial patterns (FMA between $20^\circ$ and $28^\circ$) treated only with fixed appliances for dental problems were recruited at the same clinic. All subjects were matched to the Class III group by age, origin, skeletal maturity at all observation periods, duration of observation intervals, and exclusion criteria.

A minimum sample of 20 subjects per group was established according to the method described by Mandall et al.[4] and the criteria used in the systematic review by Morales-Fernández et al.[15]

The study protocols were approved by the local ethics committee (University Complutense of Madrid, Spain). All subjects were informed of the characteristics of the study, and agreed to participate by signing an informed consent form.

### Two-Phase Treatment Protocol for Class III Malocclusion

Subjects with Class III malocclusion were treated through a two-phase process. Phase 1 treatment consisted of RME and maxillary protraction from chincup therapy. Treatment began with the placement of a Hyrax palatal expander (Dentaurum, Ispringen, Germany). Protraction soldered hooks (0.045 in) were placed in the canine region. The patient's parents were instructed to activate the screw one-quarter turn (0.2 mm) twice per day until an overcorrection of the transverse relationship of 3 mm was seen.

Immediately after expansion, the patient was given an occipital chincup with protraction hooks. Elastics were attached from the soldered hooks on the expander to the protraction hooks of the chincup in a downward forward vector of approximately $30^\circ$ to the occlusal plane. The elastics produced a protraction force of ~400 g per side, as determined by a force gauge. Patients were instructed to wear the chincup for 14 hours daily. Maxillary protraction was continued until a positive overjet of 4 to 5 mm and overcorrected Class II molar occlusion were achieved. The average duration of phase 1 was $1.6 \pm 0.4$ years. Compliance was appraised with a three-point Likert scale (in which 1 = poor, 2 = moderate, 3 = good).[16]

Orthodontic treatment was continued in phase 2, which involved the use of fixed appliances (0.018-inch-slot conventionally ligated Hilgers' edgewise bracket system; Ormco, Glendora, Calif) for 2 to 2.5 years, followed by a 2-year retention period with a removable standard Hawley-type retainer (12 months full time, 12 months night time). Orthopedic treatment was also continued with the chincup (force ~300 g per chin side). The mean period of use of the chincup (including both phases) was $5.2 \pm 0.6$ years.

### Cephalogram Imaging

Both groups were evaluated with a lateral cephalogram before treatment (T0), immediately after the end of the two-phase treatment/observation period (T1), and at an average of 10 years after T1 (T2). All subjects had completed active circumpubertal craniofacial growth (CS6) long before T2. Cephalograms were scanned and then digitized using Dolphin Imaging Software (Version 11.5, Dolphin Imaging & Management Solutions Software, Chatsworth, Calif). Radiograph magnifications were standardized to 8%

**Table 1.** Demographic Characteristics of the Class III and Control Groups

| | Treated Group (n = 22) | | Control Group (n = 22) | | |
|---|---|---|---|---|---|
| Period/Interval | Mean (y) | SD (y) | Mean (y) | SD (y) | *P*[a] |
| T0 | 9.1 | 0.6 | 9.3 | 0.7 | NS |
| T1 | 15.1 | 0.6 | 15.3 | 0.6 | NS |
| T2 | 25.7 | 0.5 | 25.0 | 0.7 | NS |
| T0-T1 | 6.2 | 0.6 | 5.9 | 0.6 | NS |
| T1-T2 | 10.9 | 0.5 | 10.8 | 0.6 | NS |

[a] There were no significant differences between the Class III group and the control group at any age or observation interval ($P < .05$). NS indicates not significant.

enlargement. Cephalometric analysis, including measurements from the analyses of Steiner,[17] Ricketts,[18] McNamara,[19] Jacobson,[20] and Siriwat and Jarabak,[21] generated 29 variables (14 angular and 15 linear).

### Statistical Analysis

Descriptive statistics were calculated for age at T0, T1, and T2 and for the T1-T0 and T2-T1 age intervals in both groups. Statistical comparisons of these data were performed with an independent samples *t*-test. Repeated-measures analysis of variance was used to assess the differences within groups between T1-T0 and T2-T1. The comparison between the Class III and control groups at every moment of the study (T0, T1, and T2) and the differences between the T1-T0 and T2-T1 intervals were analyzed by independent samples *t*-test. Significance was set at $P < .05$.

The prevalence of successful patients in the Class III group in the long term (at T2) was calculated. An unsuccessful treatment outcome was defined as a concurrent Class III permanent molar relationship and negative overjet.[22]

To assess method error, 15 randomly selected lateral cephalograms were retraced and measured after an interval of 10 days by the same operator. The intraclass correlation coefficient varied between 0.974 for the SNA angle and 0.993 for cranial flexure. Linear measurement errors varied between 0.15 and 0.56 mm and between 0.21° and 0.54°, indicating a high level of intraobserver agreement.

## RESULTS

Table 1 reports the demographic characteristics for the Class III and control groups. No significant differences were found between the groups at any age or observation interval ($P < .05$). Table 2 reports the descriptive statistics and comparisons between the groups for every period of the study. Before treatment (T0), compared with the control group, the Class III group showed significantly smaller values for the Co-point A distance, Wits appraisal, ANB angle, overjet, overbite, molar relationship, U1 to point A to Nasion perpendicular distance, and U1 to E plane distance and showed greater values for the SNB angle, gonial angle, FH to occlusal plane angle, and L1 to Pg to Nasion perpendicular distance.

Immediately after the end of two-phase treatment/observation period (T1), comparisons between the groups showed fewer differences. Compared with the control group, the Class III group at T1 showed greater values for Co-Gn distance and the SNB angle as well as smaller values for the Wits appraisal and ANB angle. At an average of 10 years after T1 (T2), compared with the control group, the Class III group showed greater values for the Co-Gn distance, SNB angle, maxillomandibular differential, and S to Go distance as well as smaller values for the Wits appraisal, overjet, overbite, and L1 to MPA angle. The long-term success rate (at T2) of the Class III group was 18 of 22 patients (81.8%).

Table 3 reports the comparison of T1-T0 changes between the Class III and control groups. The Class III group showed a significant improvement in Class III malocclusion (Co-point A increased 7.0 ± 4.3 mm; SNB angle decreased 1.8 ± 1.6°) as well as significant improvement of the sagittal maxillomandibular skeletal relationship (Wits appraisal increased 2.6 ± 2.1 mm; ANB angle increased 1.0 ± 0.3 mm). Compared with the control group, the Class III group exhibited significant improvements in the overjet (4.1 ± 2.9 vs −2.1 ± 3.5), molar relationship (2.4 ± 1.4 mm vs −1.1 ± 0.7 mm), and overbite (1.0 ± 1.6 mm vs −0.9 ± 1.9 mm). The upper incisor advanced and proclined significantly in the Class III group compared with the control group (U1 to point A to Nasion perpendicular, 3.6 ± 2.8 mm vs 0.5 ± 2.9 mm; U1 to FH, 12.3 ± 5.1° vs 2.4 ± 4.7°), and there was a significantly reduced amount of lower incisor advancement in the Class III group (L1 to Pg to Nasion perpendicular, 0.4 ± 1.7 mm vs 2.0 ± 2.2 mm).

The Class III group showed a similar increase in mandibular size (Co-Gn) compared with the control group as well as a significant reduction of the gonial angle (−5.9 ± 5.4 mm vs −1.6 ± 2.1 mm). The vertical skeletal dimensions—Nasion to Me, S to Go, and ANS to Me—were significantly more increased in the Class III group compared with the control group

**Table 2.** Descriptive Statistics and Comparisons Between Groups; Before Treatment (T0), Immediately After the End of Two-phase Treatment/ Observation Period (T1) and at an Average of 10 Years After T1 (T2) [a]

| | | | | | | | | | | | | | T0 | T1 | T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T0 | | | | T1 | | | | T2 | | | | TG vs | TG vs | TG vs |
| | TG | | CG | | TG | | CG | | TG | | CG | | CG | CG | CG |
| Cephalometric Measures | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | | (*t*-test) | |
| Cranial base | | | | | | | | | | | | | | | |
| Cranial flexure (°) | 27.8 | 2.6 | 28.9 | 2.3 | 28.2 | 2.0 | 29.3 | 2.3 | 29.0 | 2.2 | 30.2 | 1.8 | NS | NS | NS |
| Maxillary skeletal | | | | | | | | | | | | | | | |
| Co-point A (mm) | 76.2 | 3.5 | 78.3 | 2.9 | 83.2 | 5.1 | 82.7 | 3.2 | 86.5 | 3.4 | 84.8 | 4.6 | * | NS | NS |
| SNA (°) | 79.1 | 0.6 | 77.7 | 3.3 | 79.8 | 2.4 | 76.3 | 4.2 | 79.7 | 2.9 | 77.2 | 3.5 | NS | NS | NS |
| Point A to Nasion perp (mm) | −1.2 | 3.6 | −0.5 | 2.4 | −1.0 | 3.4 | −1.6 | 4.1 | 0.2 | 3.2 | 0.3 | 2.8 | NS | NS | NS |
| Mandibular skeletal | | | | | | | | | | | | | | | |
| Co-Gn (mm) | 105.1 | 4.8 | 103.0 | 6.7 | 117.3 | 5.2 | 112.8 | 3.8 | 123.8 | 6.8 | 117.4 | 4.9 | NS | * | * |
| SNB (°) | 82.6 | 0.5 | 75.4 | 4.0 | 80.1 | 0.9 | 75.0 | 4.7 | 80.0 | 3.8 | 75.8 | 4.6 | ** | ** | * |
| Pg to Nasion perp (mm) | 0.2 | 6.0 | −2.7 | 5.7 | 1.2 | 7.8 | −2.2 | 7.2 | 3.9 | 7.5 | 1.5 | 6.6 | NS | NS | NS |
| Gonial angle (°) | 128.7 | 5.6 | 124.0 | 4.8 | 122.8 | 5.7 | 122.4 | 4.7 | 123.1 | 5.1 | 120.7 | 5.2 | * | NS | NS |
| Maxillary/mandibular | | | | | | | | | | | | | | | |
| Wits appraisal (mm) | −7.0 | 3.3 | −0.7 | 2.9 | −4.3 | 2.9 | −1.2 | 2.3 | −4.1 | 3.4 | −0.5 | 2.2 | ** | ** | ** |
| ANB (°) | −1.7 | 0.7 | 2.3 | 1.6 | 1.0. | 0.4 | 1.3 | 1.9 | 0.3 | 0.5 | 1.3 | 1.8 | ** | * | NS |
| Maxillary/mandibular differential (mm) | 28.8 | 4.0 | 27.2 | 5.4 | 34.0 | 4.2 | 31.1 | 4.1 | 37.3 | 6.0 | 32.6 | 3.6 | NS | NS | * |
| Vertical skeletal | | | | | | | | | | | | | | | |
| FH to occlusal plane (°) | 9.9 | 2.6 | 7.2 | 3.1 | 6.3 | 3.4 | 6.2 | 4.5 | 4.5 | 4.0 | 3.6 | 4.1 | * | NS | NS |
| SN to palatal plane (°) | 7.7 | 2.9 | 8.0 | 3.0 | 7.4 | 3.6 | 9.4 | 4.0 | 8.1 | 3.6 | 8.4 | 2.5 | NS | NS | NS |
| MPA (°) | 25.8 | 3.6 | 25.1 | 4.5 | 25.0 | 4.5 | 25.1 | 5.4 | 24.4 | 5.0 | 22.9 | 6.0 | NS | NS | NS |
| Nasion to Me (mm) | 110.8 | 8.0 | 112.3 | 8.4 | 120.1 | 5.3 | 118.7 | 5.7 | 126.0 | 7.7 | 122.1 | 6.3 | NS | NS | NS |
| S to Go (mm) | 71.1 | 3.6 | 70.2 | 6.7 | 77.9 | 3.0 | 74.6 | 5.4 | 82.3 | 3.7 | 78.4 | 5.0 | NS | NS | * |
| ANS to Me (mm) | 62.1 | 6.0 | 64.2 | 5.3 | 67.9 | 5.6 | 67.7 | 5.0 | 71.9 | 7.4 | 69.6 | 5.6 | NS | NS | NS |
| Facial pattern | | | | | | | | | | | | | | | |
| S-Go/ N-Me (%) | 63.3 | 2.9 | 62.6 | 4.6 | 64.9 | 2.7 | 63.0 | 5.2 | 65.5 | 3.4 | 64.4 | 5.5 | NS | NS | NS |
| Facial axis (°) | 91.9 | 5.0 | 88.9 | 4.5 | 90.9 | 5.4 | 88.1 | 5.3 | 90.4 | 6.2 | 88.9 | 5.4 | NS | NS | NS |
| Interdental | | | | | | | | | | | | | | | |
| Overjet (mm) | −1.4 | 2.7 | 4.2 | 1.1 | 2.8 | 0.8 | 2.9 | 1.0 | 2.3 | 1.3 | 3.2 | 0.6 | ** | NS | * |
| Overbite (mm) | 0.4 | 1.6 | 2.3 | 2.2 | 1.4 | 0.9 | 1.4 | 0.8 | 0.9 | 1.6 | 2.3 | 1.1 | * | NS | * |
| Interincisal angle (°) | 144.0 | 13.6 | 135.7 | 9.1 | 130.3 | 7.2 | 128.8 | 8.1 | 129.3 | 8.0 | 127.9 | 8.6 | NS | NS | NS |
| Molar relationship (mm) | −4.0 | 2.5 | −0.5 | 1.1 | −1.6 | 1.1 | −1.6 | 0.6 | −2.0 | 1.6 | −1.5 | 0.6 | ** | NS | NS |
| Dentoalveolar | | | | | | | | | | | | | | | |
| U1 to point A to Nasion perp (mm) | 3.4 | 2.3 | 5.4 | 2.3 | 7.0 | 1.5 | 5.9 | 2.5 | 8.1 | 2.2 | 7.0 | 2.1 | * | NS | NS |
| U1 to FH (°) | 107.6 | 9.0 | 113.4 | 6.8 | 119.9 | 5.0 | 115.8 | 9.3 | 120.2 | 5.7 | 117.1 | 9.3 | NS | NS | NS |
| L1 to Pg to Nasion perp (mm) | 2.9 | 1.8 | 0.7 | 2.2 | 3.3 | 1.9 | 2.6 | 1.7 | 4.0 | 2.4 | 3.0 | 2.1 | ** | NS | NS |
| L1 to MPA (°) | 82.3 | 6.9 | 85.9 | 5.8 | 84.8 | 7.6 | 90.3 | 6.2 | 86.2 | 8.2 | 92.1 | 4.5 | NS | NS | * |
| Soft-tissue relationship | | | | | | | | | | | | | | | |
| U1 to E plane (mm) | −4.4 | 1.9 | −2.7 | 2.1 | −4.3 | 2.5 | −4.3 | 1.9 | −6.8 | 2.3 | −6.1 | 1.8 | * | NS | NS |
| L1 to E plane (mm) | −0.8 | 2.4 | −0.7 | 1.8 | −1.5 | 3.3 | −1.5 | 2.3 | −3.2 | 2.9 | −2.9 | 2.8 | NS | NS | NS |
| Nasolabial angle (°) | 107.5 | 8.9 | 103.6 | 8.5 | 100.9 | 10.6 | 102.0 | 0.1 | 104.2 | 7.2 | 101.5 | 11.3 | NS | NS | NS |

[a] TG indicates treated group; CG, control group; SD, standard deviation; NS, not significant.
* $P < .05$; ** $P < .01$; *** $P < .001$; independent *t*-test.

(12.3 ± 5.4 vs 6.4 ± 5.9; 9.8 ± 2.9 vs 4.4 ± 4.7; 6.8 ± 2.6 vs 3.5 ± 3.5 mm, respectively). However, there were no significant differences between the groups for facial pattern or soft tissue changes.

Table 4 reports the comparison of the T2-T1 (long-term) changes between groups. Compared with the control group, the Class III group showed reductions in the facial axis (−0.4 ± 1.3° vs 0.8 ± 1.4°) and overbite (−0.5 ± 1.1 mm vs 0.8 ± 1.3 mm). No other significant differences were found between the groups.

Figures 1 and 2 show a representative superimposition of T0 to T1 and to T2 for the Class III and control groups, respectively.

**Table 3.** Analysis of Treatment Effects (T1-T0) and Comparisons of T1-T0 Changes in the Class III Group vs T1-T0 Changes in the Control Group[a]

| | TG | | CG | | T1-T0 | | |
|---|---|---|---|---|---|---|---|
| | | | | | Intragroup Difference (ANOVA) | | TG vs |
| Cephalometric Measures | Mean | SD | Mean | SD | TG | CG | CG (*t*-test) |
| Cranial base | | | | | | | |
| Cranial flexure (°) | 0.4 | 2.5 | 0.4 | 1.7 | NS | NS | NS |
| Maxillary skeletal | | | | | | | |
| Co-point A (mm) | 7.0 | 4.3 | 5.4 | 2.5 | *** | ** | ** |
| SNA (°) | 0.4 | 1.9 | −1.4 | 2.1 | NS | NS | NS |
| Point A to Nasion perp (mm) | 0.2 | 2.6 | −1.1 | 2.4 | NS | NS | NS |
| Mandibular skeletal | | | | | | | |
| Co-Gn (mm) | 12.2 | 4.9 | 10.9 | 4.4 | *** | *** | NS |
| SNB (°) | −1.8 | 1.6 | −0.4 | 2.3 | * | NS | * |
| Pg to Nasion perp (mm) | 1.1 | 3.9 | 0.5 | 3.6 | NS | NS | NS |
| Gonial angle (°) | −5.9 | 5.4 | −1.6 | 2.1 | ** | * | * |
| Maxillary/mandibular | | | | | | | |
| Wits appraisal (mm) | 2.6 | 2.1 | −0.4 | 1.8 | ** | NS | *** |
| ANB (°) | 1.6 | 0.8 | −1.0 | 1.4 | * | * | * |
| Maxillary/mandibular differential (mm) | 5.2 | 2.8 | 3.9 | 2.2 | *** | *** | NS |
| Vertical skeletal | | | | | | | |
| FH to occlusal plane (°) | −3.6 | 3.5 | −0.9 | 3.1 | ** | NS | NS |
| SN to palatal plane (°) | −0.2 | 2.4 | 1.4 | 3.4 | NS | NS | NS |
| MPA (°) | −0.8 | 3.7 | 0.0 | 2.4 | NS | NS | NS |
| Nasion to Me (mm) | 9.3 | 4.1 | 6.4 | 3.9 | *** | ** | * |
| S to Go (mm) | 6.8 | 2.9 | 4.4 | 3.6 | *** | ** | ** |
| ANS to Me (mm) | 5.8 | 2.1 | 3.5 | 2.4 | *** | ** | ** |
| Facial pattern | | | | | | | |
| S-Go/N-Me (%) | 1.6 | 2.2 | 0.4 | 3.5 | * | NS | NS |
| Facial axis (°) | −1.0 | 2.8 | −0.8 | 1.8 | NS | NS | NS |
| Interdental | | | | | | | |
| Overjet (mm) | 4.1 | 2.9 | −2.1 | 3.5 | *** | * | *** |
| Overbite (mm) | 1.0 | 1.6 | −0.9 | 1.9 | NS | NS | ** |
| Interincisal angle (°) | −13.7 | 6.4 | −6.8 | 5.7 | ** | NS | NS |
| Molar relationship (mm) | 2.4 | 1.4 | −1.1 | 0.7 | ** | * | *** |
| Dentoalveolar | | | | | | | |
| U1 to point A to Nasion perp (mm) | 3.6 | 2.1 | 0.5 | 1.9 | *** | NS | * |
| U1 to FH (°) | 12.3 | 5.1 | 2.4 | 4.7 | ** | NS | * |
| L1 to Pg to Nasion perp (mm) | 0.4 | 1.7 | 2.0 | 2.2 | NS | ** | * |
| L1 to MPA (°) | 2.5 | 1.9 | 4.4 | 2.1 | NS | * | NS |
| Soft-tissue relationship | | | | | | | |
| U1 to E plane (mm) | 0.1 | 1.0 | −1.5 | 1.2 | NS | * | NS |
| L1 to E plane (mm) | −0.7 | 1.1 | −0.8 | 1.3 | NS | NS | NS |
| Nasolabial angle (°) | −6.5 | 7.2 | −1.5 | 7.2 | NS | * | NS |

[a] TG indicates treated group; CG, control group; ANOVA, analysis of variance; SD, standard deviation; NS, not significant.
* $P < .05$; ** $P < .01$; *** $P < .001$; independent *t*-test.

The analysis of the compliance of the Class III group during orthopedic therapy showed that none had a poor degree of cooperation; 5 had moderate compliance, and 17 had good compliance.

## DISCUSSION

This study examined the long-term effects of early RME and protraction from chincup treatment in a sample of girls with Class III malocclusion caused by a combination of maxillary retrusion and mandibular protrusion. Favorable changes in the maxillomandibular relationship were observed after treatment. These changes remained stable for an average period of 10 years, and the success rate was 81.8%.

The sample size was not sufficient to include both sexes, and only girls were included to avoid the influence of sexual dimorphism.[23] Another limitation of

**Table 4.** Analysis of Long-Term Treatment Effects (T2-T1) and Comparisons of T2-T1 Changes in the Class III Group vs T2-T1 Changes in the Control Group[a]

| | | | | | T2-T1 | | |
|---|---|---|---|---|---|---|---|
| | TG | | CG | | Intragroup Difference (ANOVA) | | TG vs CG (*t*-test) |
| Cephalometric Measures | Mean | SD | Mean | SD | TG | CG | TG |
| Cranial base | | | | | | | |
| Cranial flexure (°) | 0.8 | 2.1 | 0.9 | 1.3 | NS | * | NS |
| Maxillary skeletal | | | | | | | |
| Co-point A (mm) | 3.2 | 4.0 | 3.1 | 2.4 | * | ** | NS |
| SNA (°) | −0.1 | 2.1 | 0.8 | 2.5 | NS | NS | NS |
| Point A to Nasion perp (mm) | 1.2 | 2.0 | 1.8 | 2.2 | NS | * | NS |
| Mandibular skeletal | | | | | | | |
| Co-Gn (mm) | 6.5 | 6.3 | 4.6 | 3.7 | ** | ** | NS |
| SNB (°) | −0.1 | 1.9 | 0.8 | 2.2 | NS | NS | NS |
| Pg to Nasion perp (mm) | 2.7 | 2.8 | 3.7 | 4.4 | ** | * | NS |
| Gonial angle (°) | 0.3 | 3.4 | −1.7 | 3.1 | NS | NS | NS |
| Maxillary/mandibular | | | | | | | |
| Wits appraisal (mm) | 0.2 | 1.3 | 0.7 | 1.4 | NS | NS | NS |
| ANB (°) | 0.0 | 1.6 | 0.1 | 0.9 | NS | NS | NS |
| Maxillary/mandibular differential (mm) | 3.2 | 3.0 | 1.5 | 1.9 | ** | * | NS |
| Vertical skeletal | | | | | | | |
| FH to occlusal plane (°) | −1.8 | 2.3 | −2.5 | 2.7 | * | ** | NS |
| SN to palatal plane (°) | 0.7 | 2.0 | −1.0 | 2.8 | NS | NS | NS |
| MPA (°) | −0.6 | 1.5 | −2.2 | 2.8 | NS | * | NS |
| Nasion to Me (mm) | 5.8 | 5.6 | 3.4 | 2.3 | ** | ** | NS |
| S to Go (mm) | 4.4 | 2.9 | 3.7 | 3.6 | ** | ** | NS |
| ANS to Me (mm) | 4.0 | 3.2 | 1.9 | 2.0 | ** | ** | NS |
| Facial pattern | | | | | | | |
| S-Go/N-Me (%) | 0.6 | 1.8 | 1.4 | 2.8 | NS | NS | NS |
| Facial axis (°) | −0.4 | 1.3 | 0.8 | 1.4 | NS | NS | * |
| Interdental | | | | | | | |
| Overjet (mm) | −0.4 | 1.0 | 0.3 | 1.2 | NS | NS | NS |
| Overbite (mm) | −0.5 | 1.1 | 0.8 | 1.3 | NS | NS | ** |
| Interincisal angle (°) | −1.0 | 6.1 | −0.9 | 6.9 | NS | NS | NS |
| Molar relationship (mm) | −0.4 | 1.2 | 0.1 | 0.8 | NS | NS | NS |
| Dentoalveolar | | | | | | | |
| U1 to point A to Nasion perp (mm) | 1.1 | 1.6 | 1.1 | 0.9 | * | NS | NS |
| U1 to FH (°) | 0.3 | 3.8 | 1.2 | 5.6 | NS | NS | NS |
| L1 to Pg to Nasion perp (mm) | 0.7 | 1.2 | 0.4 | 1.2 | NS | NS | NS |
| L1 to MPA (°) | 1.4 | 2.1 | 1.8 | 2.3 | NS | NS | NS |
| Soft-tissue relationship | | | | | | | |
| U1 to E plane (mm) | −2.4 | 1.4 | −1.8 | 2.1 | ** | NS | NS |
| L1 to E plane (mm) | −1.6 | 1.4 | −1.4 | 2.3 | *** | NS | NS |
| Nasolabial angle (°) | 3.3 | 9.2 | −0.4 | 8.3 | ** | * | NS |

[a] TG indicates treated group; CG, control group; ANOVA, analysis of variance; SD, standard deviation; NS, not significant.
* $P < .05$; ** $P < .01$; *** $P < .001$; independent *t*-test.

the study was the control group; although the use of a Class III untreated control group in addition to a Class I control group would have been desirable, it was not possible for ethical reasons.

Significant improvements in dentoskeletal Class III malocclusion were recorded in the Class III group during the T1-T0 interval (ie, short-term treatment outcomes). The Wits appraisal improved by 2.6 mm, and the ANB angle improved by 1.6°. These skeletal results were mainly due to changes in the mandible (no significant differences were found between groups in the Co-Gn distance increments, and the SNB angle decreased significantly in the Class III group). In the maxilla, the Co-point A distance increased by 7.0 mm, but no significant changes were found in the SNA angle and Point A to Nasion

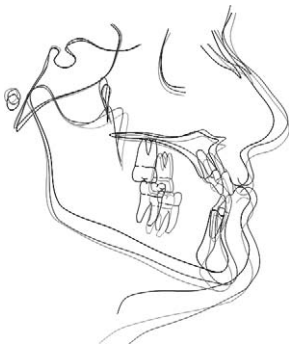

**Figure 1.** Class III group. Representative superimposition of T0 (before treatment, black lines) to T1 (end of the two-phase treatment, dark grey lines) to T2 (an average of 10 years after treatment, light grey lines).

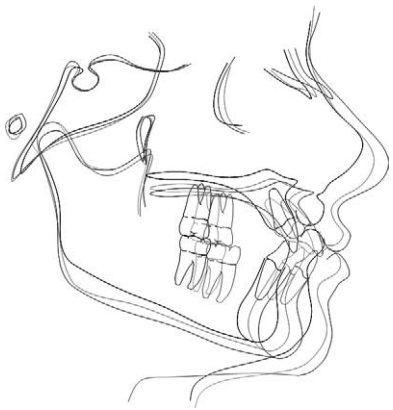

**Figure 2.** Control group. Representative superimposition of T0 (before treatment, black lines) to T1 (end of the 2-phase treatment, dark grey lines) to T2 (an average of 10 years after treatment, light grey lines).

perp. The gonial angle decreased in the Class III group, due to the effect of the chincup,[24,25] and the L1 to IMPA increased slightly due to the effects of the fixed appliances.

Analysis of the T2-T1 results (postpubertal changes) revealed the long-term stability of the treatment outcomes. Posttreatment changes in the facial axis and overbite were reduced slightly in the Class III group. No other differences were found between the groups. In the maxilla, Co-point A increased similarly in both groups, although the control group also showed a significant increase in the Point A to Nasion perpendicular distance. Therefore, there was no apparent tendency to relapse in the sagittal position of the maxilla, as was described in Masucci et al.[8] In the study by Pangrazio-Kulbersh et al.,[26] the positive changes found in the anteroposterior position of the maxilla remained stable over time.

The mandibular position showed favorable outcomes in the Class III group, similar to the findings of previous studies.[8,12,25] The final sagittal mandibular dimension was greater in the Class III group compared with the control group; nevertheless, it was not expressed completely anteroposteriorly. This condition, which can be attributed to gonial angle closure and changes in the mandible shape[24] and glenoid fossa[27] after chincup use, helped to maintain the improved intermaxillary relationship. Different results were described by Yoshida et al.,[7] who found that the effects on the maxilla persisted, while changes in the mandible reverted almost completely for an excessive rebound-like growth.

The improvement in the intermaxillary skeletal relationship remained stable in the long term. The increase in the maxillomandibular differential was greater in the Class III group than in the control group, mainly because of the greater increase in the Co-Gn distance. Similar to Ferro et al.,[25] our Class III sample showed a more negative value for the Wits appraisal than the control group at the end of the study. Masucci et al.[8] also found favorable long-term intermaxillary sagittal skeletal relationship outcomes, mainly because of mandibular changes.

There was slightly backward mandibular rotation in the Class III group in the long-term period, which helped to maintain the sagittal improvement. In contrast, Masucci et al.[8] observed no tendency toward an increased vertical skeletal relationship in the Class III group after treatment with RME and facemask therapy.

The long-term treatment success rate was 81.8%, higher than those reported in other studies after RME and facemask therapy (73% in Masucci et al.[8] and 76% in Westwood et al.[9]) or after reverse pull headgear therapy (75% in Wells et al.[28]).

## CONCLUSIONS

- RME and protraction from chincup therapy led to favorable long-term outcomes in the sagittal dentoskeletal relationship.
- This treatment approach can be considered an efficient therapy in growing girls with mild skeletal Class III malocclusion caused by maxillary retrusion and mandibular protrusion.

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