Original Article

Long-term Efficacy of Reverse Pull Headgear Therapy

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ABSTRACT

Objective: To add to the data for long-term reverse pull headgear (RPHG) outcomes and further explore possible variables that could be predictors of long-term failure.

Materials and Methods: Cephalometric radiographs of 41 Class III malocclusion children treated with RPHG (face mask) were evaluated before and immediately after treatment; at 5 years post-treatment; and, for 18 patients, at 10 years posttreatment. Patients were assigned to success or failure groups according to positive or negative overjet at the longest available recall.

Results: Seventy-five percent of the patients maintained positive overjet, whereas 25% outgrew the correction. In a stepwise discriminant analysis, a large mandible and vertical positioning of the maxilla and mandible so that mandibular growth would be projected more horizontally were the major indicators of unfavorable later mandibular growth. Patients who experienced downward-backward rotation of the mandible during RPHG treatment were more likely to be categorized in the failure group. The age at which treatment began had no effect on long-term success and failure for patients younger than 10 years, but the percentage of successful treatment decreased after that age.

Conclusions: When RPHG treatment is used for all but the most obviously prognathic children to correct anterior cross-bite in the early mixed dentition, positive overjet is maintained long-term in 70%–75% of cases, whereas 25%–30% of cases relapse into reverse overjet mainly because of increased horizontally directed and often late mandibular growth. Up to age 10, the time at which RPHG treatment began does not appear to be a major factor in long-term success in maintaining positive overjet.

KEY WORDS: Face mask; Class III

INTRODUCTION

In recent years, many studies have documented that reverse pull headgear (RPHG) (face mask) treatment before adolescence produces an orthopedic effect to bring the maxilla forward, often accompanied by a downward-backward rotation of the mandible and dental changes that are favorable to correction of reverse overjet and Class III malocclusion. However, short-term improvement does not always mean significant long-term improvement. For patients who had early RPHG treatment, growth at adolescence is a critical indicator for long-term outcomes. Today, there is a growing body of data of long-term recall for patients with RPHG.

Recent publications have documented generally favorable outcomes regarding 5 or more years posttreatment in patients in Michigan and Hong Kong who had early RPHG treatment.[1–4] In both the Michigan and Hong Kong samples, however, 25%–30% of the patients had a return of their skeletal problem as mandibular growth exceeded maxillary growth. Baccetti et al[3] reported that in the Michigan patients, initial findings of increased posterior facial height, an acute cranial base angle, and a steep mandibular plane were indicators of unfavorable long-term outcomes. In the Hong Kong patients, indicators of unfavorable growth after face-mask treatment were a forward position of

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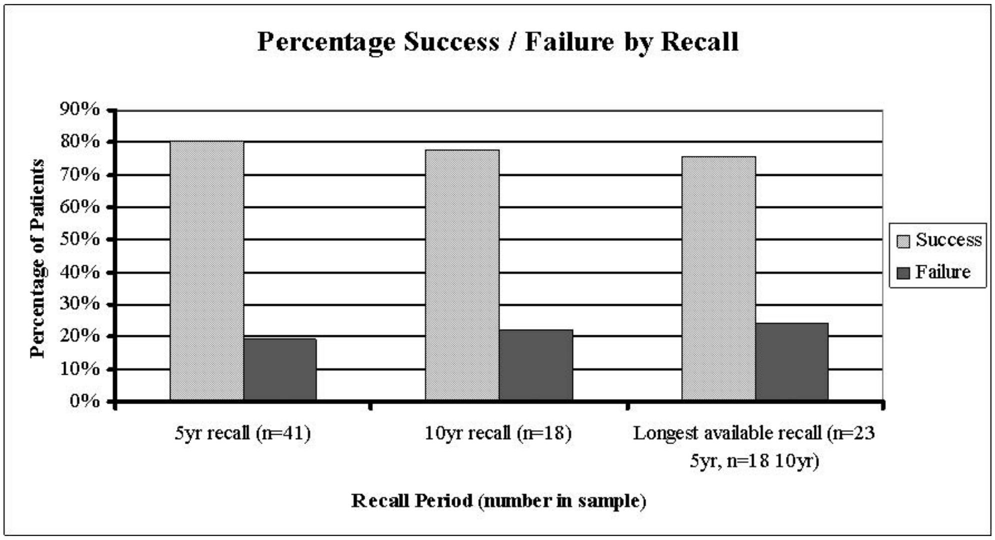

Figure 1. Percentages of long-term success and failure by timing of recall.

the mandible relative to the cranial base, increased length of the mandibular body and ramus, and an increased gonial angle.[4]

The goal of this study was to add to the data for long-term RPHG outcomes and further explore possible variables that could be predictors of long-term failure, using a sample of patients from the southeastern United States.

MATERIALS AND METHODS

The parent sample for this investigation included all children with Class III malocclusion treated with RPHG before 1998 at the University of North Carolina (UNC) graduate orthodontic clinic, the UNC dental faculty practice, and the private orthodontic practice of Dr David M. Sarver in Birmingham, Ala. The final sample was composed of 41 children (40 Caucasian, 1 Asian) who had cephalometric radiographs before and after RPHG treatment and a recall radiograph at least 5 years posttreatment. Of these children, 18 who had additional cephalograms at or near 10 years post-RPHG were of particular interest.

All patients were treated with a RPHG face mask attached to a maxillary appliance via heavy elastics. In 39 of the patients, a fixed maxillary appliance was used and transverse expansion was performed simultaneously with protraction. In 2 of the patients, a removable splint was used during protraction and transverse expansion was performed after protraction was completed. Initial treatment for all patients corrected their anterior and posterior cross-bites. The median time in treatment was 0.8 years (interquartile scores, 0.4–1.3 years). Of the 41 patients, 29 had a second phase of comprehensive edgewise treatment (which included additional RPHG), Class III elastics, and further expansion as indicated in an attempt to maintain normal occlusion and jaw relationships as additional growth occurred.

An experienced research technician traced all cephalograms and subsequently scanned and digitized them with the UNC 139-point model. The cephalograms, which were taken on three different units, were standardized during digitization by using either a known 13% magnification factor or a ruler that was visible within the image. The error of landmark identification and digitization in our laboratory varies with the landmark but has been shown to be less than 2 mm for all points.

For data analysis, the sample was categorized into long-term success and failure groups, with negative overjet on follow-up as the indication of failure. Unpaired *t*-tests were performed to compare differences in 24 cephalometric variables between success and failure groups before treatment and to compare changes in the two groups from initial to post-RPHG and from post-RPHG to follow-up. Equality of variance was verified by analysis of variance. A discriminant analysis was performed on initial cephalometric variables to elucidate key variables that differentiated the failure and success groups. A Pearson correlation was performed to compare age at the start of treatment with treatment success or failure.

RESULTS

Percentages for Long-Term Success and Failure

The success and failure rates at each recall time point are shown in Figure 1. Note that the percentage of unsuccessful outcomes rose slightly from 20% at 5

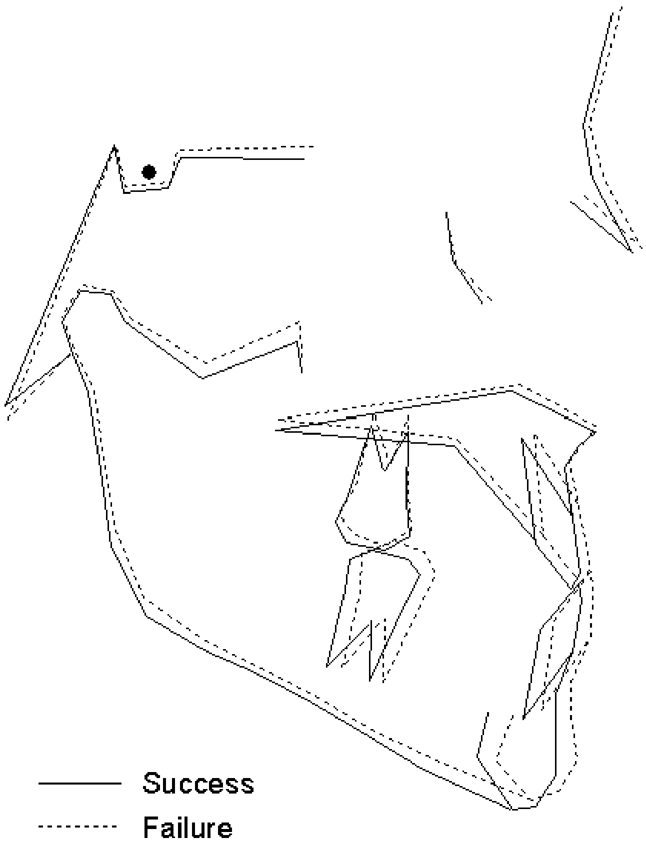

Figure 2. Composite cephalometric tracings for the success and failure groups, cranial base superimposition. Note the shorter facial height and greater horizontal projection of the chin in the failure group.

years (midadolescence for most of the patients) to 25% at longest recall. Of the 18 patients with both 5- and 10-year recall available, two boys who were successful at 5-year recall had late mandibular growth that took them to negative overjet at 10 years. For further evaluations, the success and failure groups were defined from patients' status at the longest available recall. Of the 10 patients in the failure group, five had completed a second phase of comprehensive fixed-appliance treatment that did not correct their malocclusion and were considered to need orthognathic surgery, and one did not have a second phase of treatment and would require surgery to correct late mandibular growth. Whether the other four patients would need surgery had not yet been determined.

Pretreatment Differences Between the Success and Failure Groups

A composite cephalometric superimposition of the patients in the pretreatment success and failure groups is shown in Figure 2. Note that before treatment, reverse overjet, maxillary length, and maxillary position were quite similar for the two groups, but the failure group had, on average, a slightly larger and more anteriorly positioned mandible. None of the individual cephalometric measures were significantly different for the two groups. The *P* values ranged from lows of .14 for y-axis and .16 for overbite to highs of .92 for overjet and .98 for the saddle angle.

In an effort to find a subset of variables that would be useful in distinguishing between patients destined to success or failure, a discriminant analysis was performed with all 51 variables typically evaluated with the UNC model. Four variables emerged after stepwise variable selection: the y (vertical)-coordinate of posterior nasal spine (PNS), the y-coordinate of gonion (Go), overbite, and mandibular unit length. Using these four variables in the discriminant analysis function shown in Table 1 correctly identified 30 (73%) of the 41 patients. This equation misidentified 9 of the 31 successes as potential failures and 2 of the 10 failures as potential successes.

Response to RPHG

Figure 3 shows composite superimpositions for changes during RPHG treatment for the success and failure groups. Note that the maxilla in both groups moved forward a similar amount. The success group had greater overjet correction and more proclination of the maxillary incisors. The failure group had a greater increase in the mandibular plane angle and lower anterior facial height, suggesting more downward-backward rotation of the mandible during treatment. For the individual cephalometric variables, only a more acute facial axis (defined by Ricketts as the angle between the N-Ba lines and a line connecting PT point and Gn) was significantly different for the failure group ($P = .04$). This also would reflect more downward-backward mandibular rotation during treatment in the failure group.

Growth Changes After RPHG

In Figure 4, which shows composite superimpositions for changes after RPHG treatment, it can be seen that the success group had more forward growth of the maxilla after treatment. Increases in mandibular unit length were quite similar for both groups, but the failure group had a greater increase in SNB and a greater decrease in ANB, reflecting a more horizontal pattern of mandibular growth.

As Figure 5 shows, there was a striking difference in growth between the ages of 5 and 10 years for the 18 patients with 10-year recall (13 successes, 5 failures). The patients in the failure group had much more late facial growth than those in the success group, with more forward growth of the mandible than the maxilla. The small sample size, however, must be kept in mind

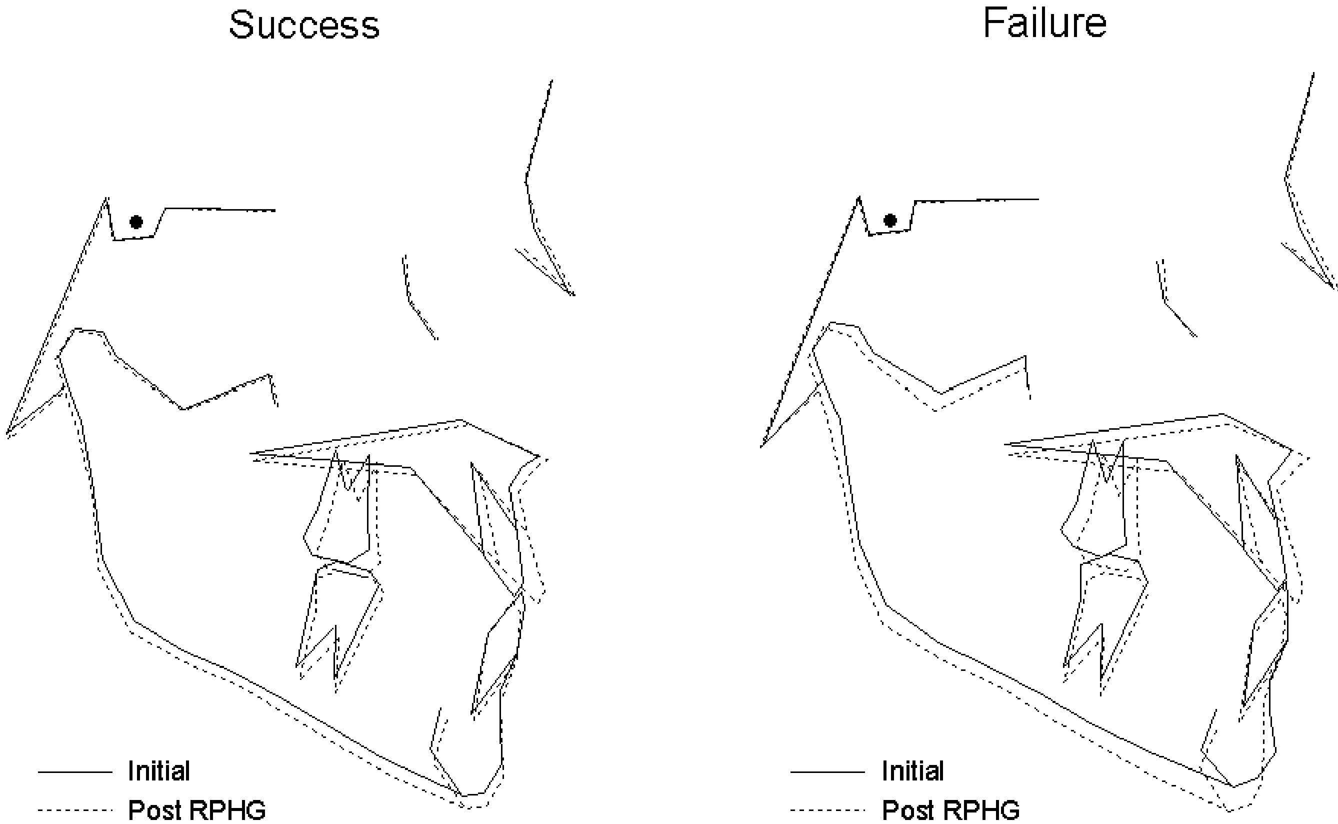

Figure 3. Composite superimpositions of changes during initial reverse pull headgear treatment for the success and failure groups. The horizontal maxillary change during treatment was almost identical in the two groups, but the failure group had more downward movement of the posterior maxilla and maxillary molars and more downward-backward rotation of the mandible.

when these composites are examined. Inferential statistics were not calculated for this group because the sample was so small.

Correlation Between Age at Start of Treatment and Long-Term Success

On average, treatment started 9 months earlier for the patients in the success group than for those in the failure group, but this difference was not statistically significant. Statistically significant but small correlations were found between age at the start of treatment and long-term changes in only 4 of the 24 cephalometric variables that were examined individually (Table 2).

Figure 6 shows the percentages of success and failure when the sample was categorized into four age segments with nearly the same number of patients in each group. The percentages are almost identical for the groups younger than age 10 years, but long-term success was lower in the patients whose RPHG treatment started later.

Table 1. Prediction of Success and Failure Using a Four-Variable Discriminant Analysis Function*

	Actual	Potential Success	Potential Failure
Success	31	22	9
Failure	10	2	8

* $D = 1.29 - (.61)yPNS - (.29)yGo + (.30)OB + (.43)MdUL$

$D_{(success)} = 0.25$

$D_{(failure)} = 2.84$

Cutoff value $= [D_{(success)} + D_{(failure)}]/2 = 1.54$

DISCUSSION

Long-Term Success Percentages

Although this study followed most of the patients well into adolescence, it is certain that some patients with only 5-year recall had growth remaining. Growth between 5 and 10 years posttreatment was the biggest difference between our success and failure groups. In this study, two patients (12.5%) who were successful at 5 years grew enough to be rated as failures at 10 years posttreatment. Extrapolating this information to the 23 patients for whom we do not yet have 10-year recall data gives a theoretical 30% fail-

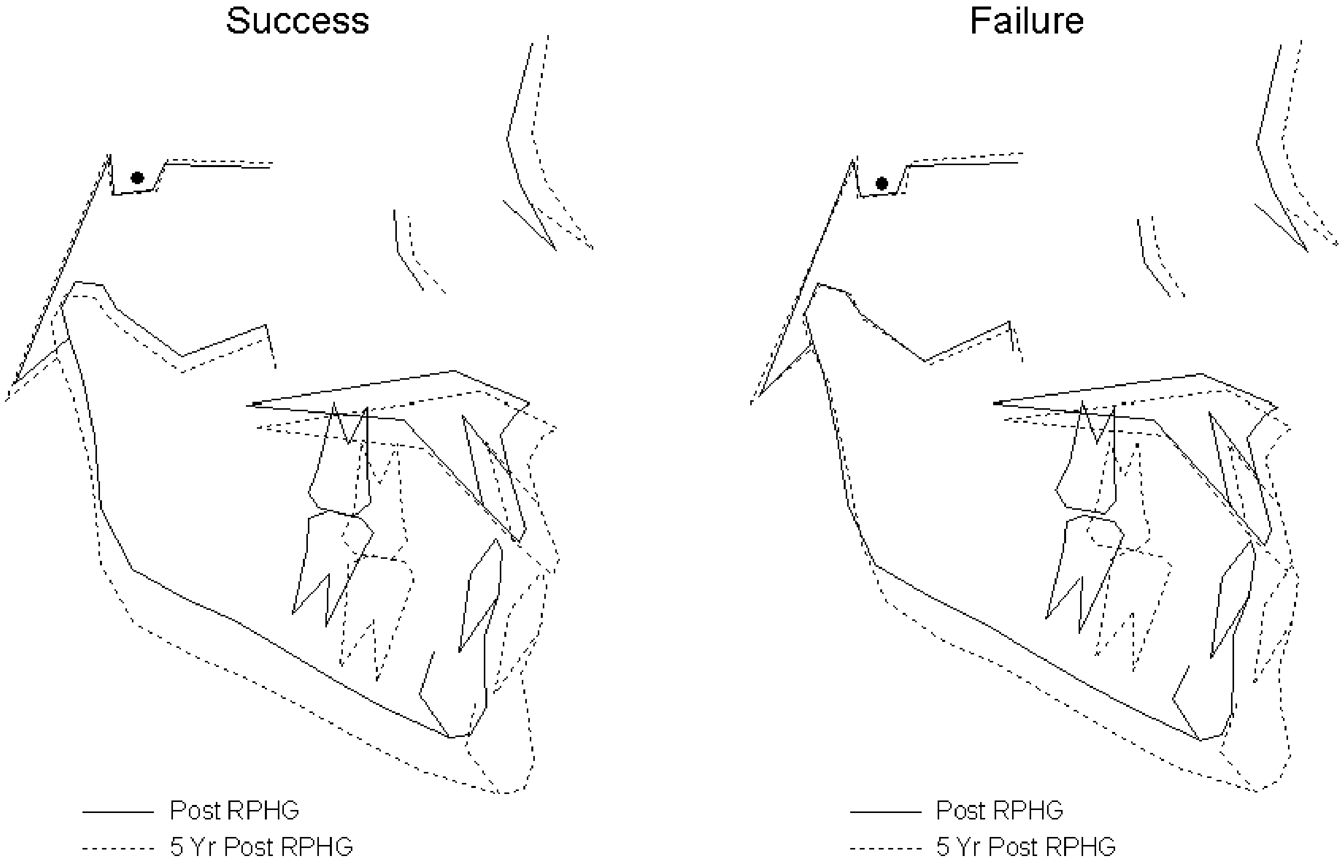

Figure 4. Composite superimpositions of changes from the end of reverse pull headgear treatment to 5-year recall for the success and failure groups. The success group had more maxillary and less mandibular growth than did the failure group, with mandibular growth projected more horizontally in the failure group.

ure rate at the completion of essentially all mandibular growth. This compares very closely with the other recent reports. Hägg et al[2] reported that 7 of 21 patients had negative overjet on an average 8-year recall. One patient had comprehensive orthodontics at that point, whereas the other six (29%) were considered to need surgery. Baccetti et al[3] reported that 12 of 41 patients (28%), all of whom had comprehensive orthodontics after RPHG, had negative overjet and Class III molar relationship on an average 6.5 years recall at a mean age of 15 years.

Therefore, it appears that unless the selection criteria for RPHG treatment are modified to exclude patients likely to have excessive mandibular growth, one-fourth to one-third of these patients will relapse into negative overjet as subsequent mandibular growth considerably exceeds maxillary growth. The similarity in the Hong Kong and Michigan-UNC studies indicates little or no difference in this regard between patients of Asian and European descent.

Cephalometric Characteristics Indicating Possible Long-Term Success vs Failure

To improve long-term success rates, it is important to develop criteria for young Class III patients that are indicators of probable long-term success and failure. In the study by Baccetti et al,[3] the cranial base angle (between the middle and posterior cranial fossae) was an important component of the authors' discriminant function. An acute angle, which would project the mandible forward, favored eventual treatment failure. The other characteristics of their discriminant function were mandibular length and ramus height, with greater length of both favoring failure. Their equation successfully identified 83% of the patients in the sample from which it was derived. The discriminant function derived by Ghiz et al[4] identified a more forward position of the mandible relative to the cranial base, a longer mandible and shorter ramus, and an increased gonial angle as indicators of eventual failure.

In our study, stepwise regression showed decreased posterior vertical facial height as indicated by the vertical position of both PNS and Go, mandibular length, and overbite as indicators of possible failure. We did not measure the cranial base angle exactly as Baccetti et al[3,5] did, but we found no differences in the saddle angle (N-S-Ar) between patients in the success and failure groups. In our patients, posterior facial height (S-Gn) was shorter in the failure group.

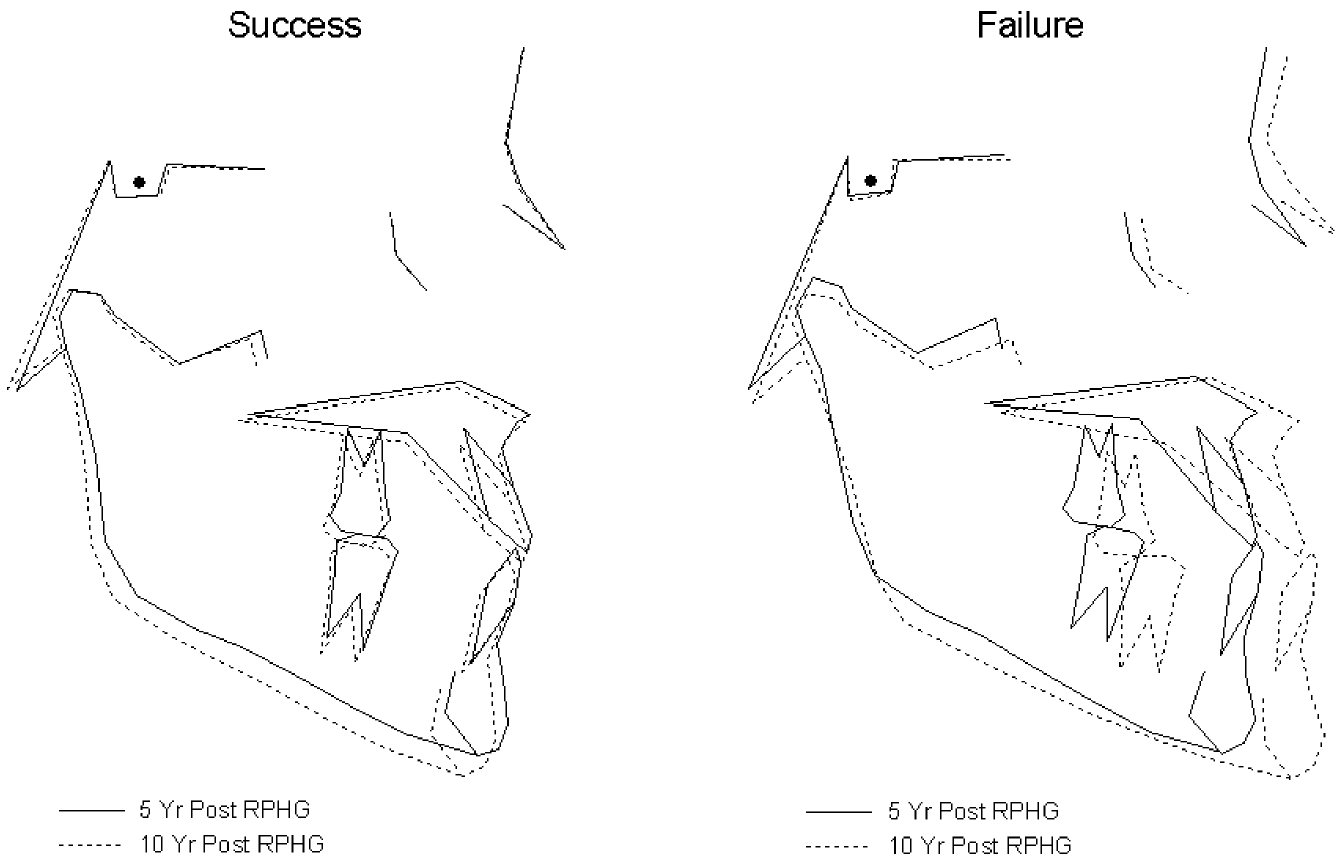

Figure 5. Composite superimpositions of changes from 5 to 10 years posttreatment. The failure group had dramatically more growth, which was projected horizontally rather than vertically. The small sample size—only five patients in the failure group—must be kept in mind.

Table 2. Significant Pearson Correlation Coefficients Between Age at Start of Treatment and Long-Term Changes*

Measurement	Correlation Coefficient	*P* Value
Maxillary unit length	−0.30	.05
Mandibular unit length	−0.37	.02
Overbite	−0.40	.01
Maxillary incisor/SN	−0.41	.01

* Correlations for the other 20 variables evaluated were not significant.

All the studies[1–5] agree that the length of the mandible is a major difference between long-term success and failure. The major variable that determines long-term success with RPHG is not the response of the maxilla to forward traction but the amount and direction of mandibular growth during and after adolescence.

Treatment Response as a Factor in Long-Term Success

It is interesting that downward-backward rotation of the mandible during RPHG treatment increases the chance of long-term failure of treatment. This was observed both in our study and by Hägg et al[2] with Chinese children in Hong Kong. Because maxillary deficiency often includes a vertical component—the maxilla has not grown down as much as would normally be expected—the face mask usually is adjusted so that the force direction is somewhat downward. Downward movement of the posterior maxilla and maxillary molar teeth that rotate the mandible down and back seems to be associated with a more horizontal expression of subsequent mandibular growth, and this would increase the chance of relapse into anterior cross-bite.

Age at Start of Treatment as an Indicator of Long-Term Success

From the beginning of RPHG treatment, it has been recognized that treatment must begin quite early relative to most other orthodontic treatment, but the cutoff age beyond which treatment probably would not succeed has been controversial. The original guideline by Delaire[6] was to start treatment before age 8 years. Another study compared treated children in Michigan with untreated controls in Italy and concluded that maxillary skeletal change was greater in children treated in the

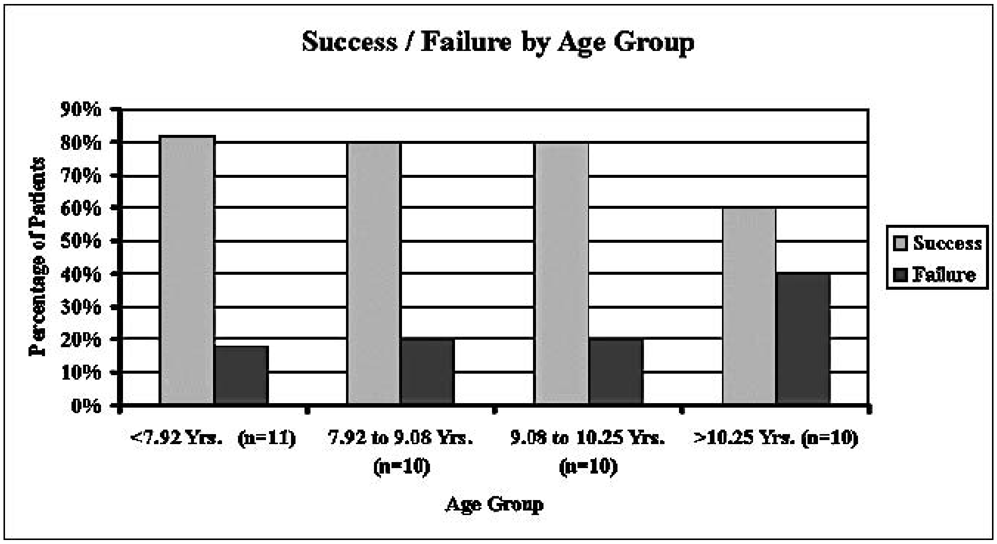

Figure 6. Percentages of long-term success and failure by age at the start of treatment, with the sample categorized into four nearly equally sized groups. There is no difference related to age younger than 10 years, whereas the chance of success declined at older ages.

early mixed dentition than in the late mixed dentition.[5] A number of recent reports have suggested that positive responses to RPHG treatment can occur in older children, perhaps up until the beginning of adolescence.[7–10]

In our sample, there was no difference in the chance of long-term success with treatment starting at any age younger than 10 years, but the percentage of successful outcomes dropped after that age. It is quite likely that a patient's maturational rather than chronologic age is the determinant of whether skeletal change can be obtained. Radiographic evaluation of cervical vertebrae can now be used to determine a patient's status relative to the peak of the adolescent growth spurt. However, this is much less accurate relative to the later stages of development that were of interest in this study; therefore, we did not use this method.

Changes in the position of teeth and the vertical position of the chin contribute to reduction of negative overjet, so clinical success in older children does not contradict the finding by Baccetti et al[5] that maxillary skeletal changes are most likely in children younger than age 8 years. Treatment responses to RPHG are greater than just forward movement of the maxilla. It is now possible to use RPHG to bone anchors in the maxilla, which should decrease forward movement of the maxillary teeth. The result may well be an increased emphasis on treatment by age 8 or 9 years when skeletal anchorage is used so that a maximal skeletal response can be obtained.

CONCLUSIONS

- When RPHG treatment is used for all but the most obviously prognathic children to correct anterior cross-bite in the early mixed dentition, positive overjet is maintained long-term in 70%–75% of cases, whereas 25%–30% of cases relapse into reverse overjet mainly because of increased horizontally directed and often late mandibular growth. The same conclusion was reached in similar studies in Hong Kong and Michigan.
- Downward-backward rotation of the mandible during RPHG treatment seems to increase the chance that subsequent mandibular growth will be expressed more in a horizontal than vertical direction.
- Up to age 10, the age at the start of RPHG treatment does not seem to be a major factor in long-term success in maintaining positive overjet. After age 10, the long-term success rate decreases for treatment started later.

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