The long-term efficacy of rapid maxillary expansion and facemask therapy in Class III malocclusion

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Aim: The aim of the present study was to investigate the long-term efficacy of rapid maxillary expansion (RME) and facemask (FM) therapy in the treatment of Class III malocclusions by comparing Class III subjects treated by RME/FM mechanics with untreated Class III controls at the Western Australian public dental hospital.

Materials and methods: The lateral cephalograms of 42 (26 males, 16 females) Class III patients treated by RME/FM therapy were analysed and compared with a control sample comprised of 23 (14 males, 9 females) untreated Class III patients. Evaluations were carried out prior to facemask therapy and at a long-term follow-up period of approximately eight to nine years post-treatment. Statistical comparisons were performed using *t*-tests for unpaired data.

Results: At long-term follow-up, there were no statistically significant differences between the treated and control groups except in overjet, which was greater in the treated group ($p < 0.05$).

Conclusions: These results suggest that the short-term effects on the maxilla in RME/FM therapy are not maintained in the long term. Success in treatment is largely dependent on the patient's skeletal growth pattern.

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Introduction

Facemask therapy is a commonly used form of interceptive treatment for the management of a Class III malocclusion in the growing child. The fundamental principles of Class III early treatment are based on the premise that growth of the dentofacial skeleton can be manipulated. The goal of RME/FM therapy is firstly to improve the Class III skeletal discrepancy by influencing the increment and direction of facial growth.[1] Secondly, therapy aims to improve occlusal function by the elimination of a functional shift and to simplify phase II conventional treatment.[2] Lastly, it aims to provide more pleasing facial aesthetics, thereby improving the psychological development of the child,[3] although there is previous evidence that Class III early intervention does not appear to confer a significant psychosocial benefit.[4]

The ability to alter basal skeletal relationships by interceptive treatment is largely based on work by Melsen, who showed in histological findings that the midpalatal suture is broad and smooth during infancy (8–10 years) and eventually becomes more squamous and interdigitated in the juvenile stage (10–13 years).[5] Moreover, several animal studies have shown that the maxillary complex can be displaced anteriorly with significant changes noted in the facial sutures associated with the nasomaxillary complex.[6-10]

The treatment effect of RME/FM therapy is primarily to orthopaedically advance the maxilla. This occurs with an associated concurrent maxillary rotation, which depends on the direction of the applied force vector in relation to the centre of resistance of the maxilla. This can be adjusted according to the desired clinical effect planned for the specific case. For example, maintaining a force vector of approximately 5–20 mm above the occlusal plane facilitates a parallel movement of the maxilla that is suited to patients with a hyperdivergent skeletal pattern and/or an anterior open bite tendency. Alternatively, maintaining a force vector angle of 20–30 degrees below the occlusal plane would generate a counter-clockwise rotation of the maxilla.[11] The downward vertical movement of the maxilla results in a downward and backward rotation of the mandible leading to dental changes that are favourable for the correction of a Class III malocclusion and deep overbite.[12]

There have been several studies reporting the effectiveness of facemask therapy in the early management of a Class III malocclusion in a growing child.[12-17] Nonetheless, there is still uncertainty related to the long-term stability of the dental and skeletal changes as a result of facemask therapy.

Despite being shown to be effective in the initial stages of treatment, the reported results are not maintained in the long term in 30% of Class III patients.[4,13,16] The most common cause of failure following facemask therapy is late mandibular growth in a horizontal direction, often indicated by the presence of an increased posterior vertical height, length of the mandibular ramus, angulation of the cranial base and the inclination of the mandibular plane to the cranial base.[12,13,18]

The purpose of this retrospective observational study was to investigate the long-term efficacy of RME/FM mechanics in the treatment of Class III malocclusions. By comparing Class III patients treated using RME/FM with untreated Class III controls, it was expected that a greater insight into the dental and facial changes would be revealed through long-term follow-up.

Material and methods

Approval was obtained from the Human Research Ethics Committee of Western Australia in accordance with the requirements from the *National Statement on Ethical Conduct in Human Research* (National Statement) and the policies and procedures of the University of Western Australia.

The lateral cephalograms of 42 (26 males, 16 females) Class III patients, with a mean age of 8.8 years, treated using RME/FM therapy were analysed and compared with a control sample comprised of 23 (14 males, 9 females) untreated Class III patients, with a mean age of 10.3 years. The records of the treated group were obtained from a private practice in Perth, Australia and the untreated group from the dental school clinic in Western Australia.

The sample selection criteria for the treatment group included

- A Class III malocclusion at the first observation (Ti) characterised by an anterior crossbite or edge-to-edge incisal relationship and a Wits appraisal of -2 mm or less
- Interceptive treatment with RME/FM therapy
- No permanent or congenitally missing teeth
- Cephalograms of adequate quality available at Ti before RME/FM and at the long-term observation (Tf), at least six years after RME/FM

The untreated Class III control group was screened by similar criteria except that RME/FM therapy was not undertaken, and this cohort was followed longitudinally. Early interceptive treatment was not commenced in these patients because the families could not afford, or alternatively refused, treatment.

The treatment protocol involved the use of a bonded RME and a facemask, with a forward force vector directed approximately 30 degrees below the occlusal plane. The treatment was continued until the initial negative overjet was overcorrected by at least 2 mm, as suggested by previous studies.[18-25] The expansion regime involved two turns per day for one week, followed by two turns per week until the desired overexpanded width was achieved.

An analysis of 32 cephalometric variables was conducted of predetermined cephalometric points. All radiographs were hand traced and analysed by the principal investigator (BL). The landmarks and reference planes used are illustrated in Figures 1 and 2, respectively. Changes in the skeletal and dental measurements were recorded in relation to the occlusal plane superior (OLs) and the occlusal plane perpendicular (OLsp) according to the method of Pancherz.[26,27]

Patients who experienced significant growth resulting in a recurrence or development of a significant negative overjet and/or self-perceived deterioration of their facial aesthetics were considered for surgery.

Statistical analysis

Sample means were calculated for each variable at the initial (Ti) and final visit (Tf), in addition to changes for each variable during this time period. Subsequently, the treatment group was divided into patients who required surgery and those who were treated non-surgically after RME/FM treatment. Independent samples *t*-tests were applied to determine any significant differences between the two groups in the cephalometric variables obtained at the initial and final visits. Bonferroni corrections were carried out on the *t*-tests to reduce the possibility that any significance was due to chance. The relationship between the change in maxillary base and each group was investigated using linear mixed effects models after adjusting for a change in age between visits.

The method error was measured by repeating the cephalometric measurements of pre- and post-treatment lateral cephalograms on a random selection of 10 patients (N = 20). Statistical analysis was undertaken using statistical software (R for Windows 2.15.2, R Foundation for Statistical Computing, Vienna, Austria),[28] testing at the 95% confidence level ($p < 0.05$).

Results

There were no statistically significant differences in the cephalometric values between the treated and control subjects at baseline (Ti) (Table I). At the long-term follow-up, the only statistically significant difference in cephalometric values between the treated and control groups was overjet, with the overjet greater in the treated group ($p < 0.05$, Table I). There was a significant difference in age between the untreated and treated groups at baseline (Ti) and at the final visit (Tf). At baseline, the untreated group was on average approximately 1.5 years older, whilst at Tf, untreated subjects were younger (Table II). Nonetheless, the relationship between a change in the maxillary base and each group was investigated using a longitudinal analysis with linear mixed models. This was done because of the number of complex predictors with variations in distribution that revealed no significant differences between the control and treated groups, even when age was taken into consideration (Figure 3, Tables III–V).

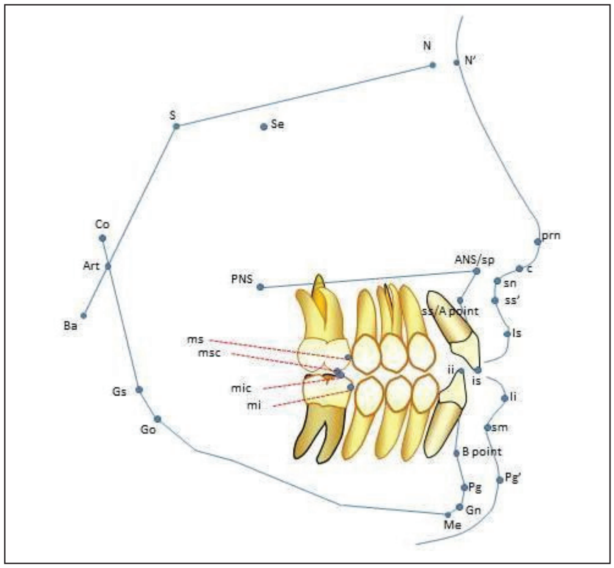

Figure 1. Cephalometric reference points used in the study.

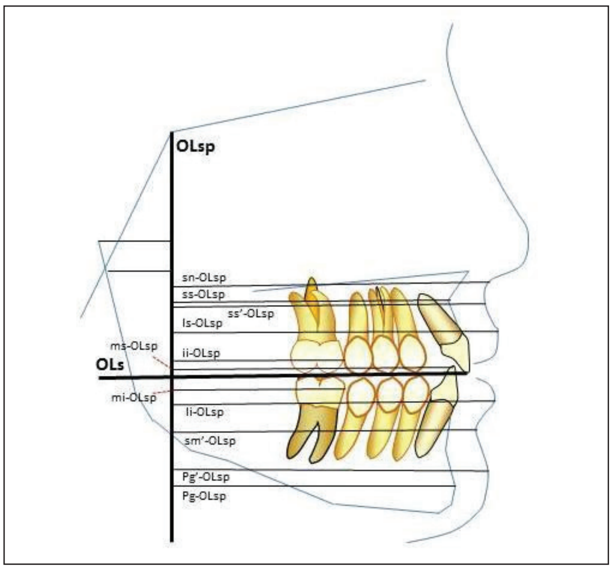

Figure 2. Cephalometric reference lines related to OLsp used in the study.

When the treatment group was subdivided into surgical and non-surgical groups, at Ti the surgical group presented with a greater AB distance discrepancy and greater soft tissue convexity ($p < 0.05$). Although the overbite was detected as statistically different between groups, it was not clinically significant ($p < 0.05$, Table VI). At long-term follow-up, the Class III skeletal pattern worsened in the surgical group with cephalometric variables Mx/Mn relationship ($p < 0.01$), ANB ($p < 0.01$), AB distance ($p < 0.01$), Wits ($p < 0.01$), soft and hard tissue convexity ($p < 0.05$), overjet ($p < 0.01$), molar relation ($p < 0.01$) and inclination of the mandibular incisors ($p < 0.01$)

Table I. Comparison between treatment and control groups at Ti and Tf.

Cephalometric variable	Control (CG) at Ti N=23		Treated (TG) at Ti N=42		Control (CG) at Tf N=23		Treated (TG) at Tf N=42		CG vs TG at Ti	CG vs TG at Tf
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Maxillary skeletal										
Maxillary Base (ss/OLsp)	66.2	5.6	65.4	4.4	70.6	5.0	70.4	5.5	NS	NS
SNA	79.2	3.4	79.2	3.8	80.1	3.5	80.9	4.1	NS	NS
Mandibular skeletal										
Md base (Pg/OLsp)	76.2	7.8	75.8	6.9	85.5	7.4	83.9	8.7	NS	NS
Md length (Pg-co/OLsp)	82.3	7.1	82.9	6.1	93.8	7.5	94.3	8.7	NS	NS
SNB	80.5	3.3	80.8	3.4	82.6	5.0	83.2	4.2	NS	NS
B point/Olsp	74.1	7.2	73.0	5.0	80.7	6.5	79.1	7.6	NS	NS
SNPg	81.0	3.4	81.4	3.7	83.7	5.0	84.3	4.3	NS	NS
Maxillomandibular										
Mx/Mn relationship (ss-Pg/OLsp)	-10.1	5.1	-10.4	4.2	-14.9	6.1	-13.6	6.4	NS	NS
ANB	-1.3	3.3	-1.7	2.5	-2.4	3.6	-2.1	3.4	NS	NS
AB distance	-1.2	4.1	-0.3	2.7	-4.1	6.0	-2.5	5.4	NS	NS
Wits	-7.9	4.2	-7.5	2.2	-10.1	4.8	-8.8	5.2	NS	NS
Hard tissue convexity (n-ss-Pg)	-4.9	7.6	-4.3	5.3	-7.8	6.4	-7.1	7.7	NS	NS
Vertical skeletal										
Nasal plane angle (NL/NSL)	7.3	2.9	6.6	3.1	6.8	3.1	6.7	3.3	NS	NS
Md plane angle (ML/NSL)	36.1	3.7	35.5	4.2	35.1	5.0	34.3	4.8	NS	NS
Vertical jaw relation (ML/NL)	28.7	4.5	28.6	3.6	28.1	5.5	27.3	5.0	NS	NS
LAFH (sp-gn/NSL)	56.5	2.6	56.2	2.0	57.9	2.2	57.0	2.3	NS	NS
Skeletodental										
Mx incisor horizontal (is/OLsp)	73.3	6.5	71.5	5.2	79.7	6.1	79.1	7.0	NS	NS
ls.OLsp	85.3	7.3	83.3	5.0	92.1	5.5	90.1	7.3	NS	NS
Mx molar horizontal (ms/OLsp)	47.5	6.0	45.4	3.8	54.3	5.5	52.5	5.0	NS	NS
Md incisor horizontal (ii/OLsp)	74.4	5.9	72.5	4.9	81.2	5.9	78.9	7.5	NS	NS
li.OLsp	88.0	8.0	86.0	5.3	96.0	6.4	92.9	8.1	NS	NS
Md molar horizontal (mi/OLsp)	51.0	6.3	48.5	4.2	60.2	7.1	57.4	6.4	NS	NS
Dentoalveolar										
Inclination max. inc. to NSL (ILis-NSL)	112.0	6.5	112.4	8.7	117.1	5.7	117.4	6.3	NS	NS
Inclination mand. inc. to ML (ILii-ML)	85.4	6.6	84.0	6.4	83.9	7.8	82.3	8.6	NS	NS
Interdental										
Overjet	-1.1	2.5	-1.0	2.2	-1.5	3.4	0.3	2.7	NS	*
Molar relation (ms/OLsp-mi/OLsp)	-3.6	3.1	-3.0	2.0	-5.9	4.1	-4.8	2.8	NS	NS
Overbite (is-ii/OLsp)	2.0	3.3	1.0	2.1	0.8	2.4	1.0	2.3	NS	NS
Soft tissue										
Soft tissue convexity w/out nose (n′-ss′-pg)	8.8	8.1	6.4	7.6	7.7	6.6	6.3	7.4	NS	NS
Soft tissue convexity with nose (n′-pro-Pg′)	41.6	6.3	41.7	4.5	42.2	6.1	43.9	6.0	NS	NS
ss′/OLsp	80.4	6.3	78.7	4.8	87.0	5.4	85.5	6.9	NS	NS
pg′/OLsp	87.2	8.0	85.2	6.1	96.8	8.0	94.6	8.9	NS	NS

* $p < 0.05$; ** $p < 0.01$; #Significant with the Bonferroni correction; NS = not significant

Table II. Comparison between treatment and control groups at Tf.

Age	Control (N=23)		Treated (N=42)		
	Mean	SD	Mean	SD	*p*-value
Age at Ti	10.32	1.57	8.77	1.17	<0.001*
Age at Tf	16.97	2.03	18.12	2.30	0.049*

Table III. Mixed effects modelling of Maxillary Base considering only visit (categorical), group (Treated vs Control) and the interaction of group and visit as explanatory variables.

Mixed effect modelling of Maxillary Base Measurement			
Variable	Estimate	Standard Error	*P*-value
Intercept	71.21	2.46	<0.001
Visit	-5.54	0.92	<0.001
Group		NS	
Interaction of Group and Visit		NS	
Change in Age		NS	

Table IV. Mixed effects modelling of Maxillary Base considering only visit (categorical), group (Treated vs Control), the interaction of group and visit and change in age (from initial to final visit) as explanatory variables.

Mixed effect modelling of Maxillary Base Measurement			
Variable	Estimate	Standard Error	*P*-value
Intercept	70.77	2.374	<0.001
Visit	-4.839	0.649	<0.001
Group		NS	
Interaction of Group and Visit		NS	
Change in Age		NS	

significantly different compared with the non-surgical group (Table VI). However, no significant differences in maxillary change were observed (Figure 4).

Discussion

The objective of early orthodontic treatment is to create a favourable dentofacial environment to prevent the adaptations and limitations that are often associated with malocclusion later in life.[1] However, whether RME/FM therapy can modify and influence growth of the maxilla beyond its predetermined position and length is a contentious issue, particularly since many of the studies do not provide long-term data on whether the positional correction is maintained and is any different to that resulting from normal maxillary growth.

Despite being effective in the initial stages of treatment,[17,20, 29-32] the literature has demonstrated that the results are not maintained in the long term in 30% of patients who present with a Class III malocclusion. This group likely requires orthognathic surgical consideration and intervention.[4,13,16] In addition, a recent case report involving twins with identical Class III malocclusions demonstrated that, despite only one twin receiving facemask therapy, both patients achieved almost identical dentofacial results at the age of 18 years. However, both received a full course of full fixed appliances.[2] Even though this was a case report, it questioned whether facemasks are able to significantly alter the inherited craniofacial skeleton of the growing child on a permanent basis.[34]

More recently, Masucci et al. observed no statistically significant difference in the position of the maxilla between RME/FM treated and untreated groups at the completion of growth.[35] These findings are consistent with those found in the present study, in which no

Table V. Comparison between surgical and non-surgical groups at Ti and Tf.

	Non-surgical (NG) at Ti N=23		Surgical (SG) at Ti N=19		Non-surgical (NG) at Tf N=23		Surgical (SG) at Tf N=19		NG vs SG at Ti	NG vs SG at Tf
Cephalometric variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Maxillary skeletal										
Maxillary Base (ss/OLsp)	65.7	4.1	64.8	4.8	71.3	5.5	69.2	5.5	NS	NS
SNA	79.0	4.2	79.5	3.3	81.8	4.8	80.3	2.7	NS	NS
Mandibular skeletal										
Md base (Pg/OLsp)	75.8	6.6	75.8	7.4	82.3	8.6	85.9	8.6	NS	NS
Md length (Pg-co/OLsp)	82.9	6.0	82.9	6.3	92.4	8.2	95.8	9.2	NS	NS
SNB	80.5	3.8	81.3	3.0	82.2	4.3	84.3	3.9	NS	NS
B point/Olsp	72.8	4.8	72.8	5.3	77.6	7.5	81.0	7.5	NS	NS
SNPg	81.2	4.1	81.8	3.2	83.5	4.5	85.3	4.0	NS	NS
Maxillomandibular										
Mx/Mn relationship (ss-Pg/OLsp)	-10.0	4.2	-10.9	4.3	-11.0	5.8	-16.7	5.8	NS	**
ANB	-1.4	2.6	-2.1	2.4	-0.5	3.0	-4.1	2.9	NS	**/#
AB distance	0.5	2.2	-1.2	2.9	0.3	4.4	-6.0	4.6	*	**/#
Wits	-7.1	2.3	-8.0	2.0	-6.3	4.5	-11.8	4.4	NS	**
Hard tissue convexity (n-ss-Pg)	-5.2	5.9	-3.2	4.3	-4.2	7.3	-10.7	6.5	NS	**
Vertical skeletal										
Nasal plane angle (NL/NSL)	6.9	3.5	6.2	2.5	6.1	3.6	7.5	2.7	NS	NS
Md plane angle (ML/NSL)	34.7	4.4	36.5	3.9	33.4	3.8	35.4	5.7	NS	NS
Vertical jaw relation (ML/NL)	27.7	3.6	29.7	3.3	27.0	4.7	27.7	5.4	NS	NS
LAFH (sp-gn/NSL)	55.9	1.9	56.6	2.0	56.6	1.9	57.4	2.6	NS	NS
Skeletodental										
Mx incisor horizontal (is/OLsp)	71.5	5.4	71.5	5.0	80.0	7.0	78.1	7.0	NS	NS
ls.OLsp	83.8	4.9	82.8	5.3	90.7	7.0	89.4	7.8	NS	NS
Mx molar horizontal (ms/OLsp)	45.5	3.8	45.2	4.0	52.4	4.8	52.8	5.4	NS	NS
Md incisor horizontal (ii/OLsp)	72.4	4.3	72.5	5.6	77.9	7.7	80.0	7.4	NS	NS
li.OLsp	86.2	4.9	85.8	6.0	92.4	7.7	93.6	8.3	NS	NS
Md molar horizontal (mi/OLsp)	48.5	.4.0	48.4	4.5	55.8	6.3	59.3	6.1	NS	NS
Dentoalveolar										
Inclination max. inc. to NSL (ILis-NSL)	111.9	7.0	113.0	10.5	116.9	6.3	118.1	6.4	NS	NS
Inclination mand. inc. to ML (ILii-ML)	85.3	7.4	82.6	4.6	85.7	9.0	78.3	6.1	NS	**
Interdental										
Overjet	-1.0	2.5	-1.0	1.8	2.1	1.7	-1.9	2.1	NS	**
Molar relation (ms/OLsp-mi/OLsp)	-3.0	2.3	-3.0	1.6	-3.4	2.3	-6.5	2.4	NS	**
Overbite (is-ii/OLsp)	1.7	1.9	0.2	2.2	1.3	1.7	0.7	2.8	*	NS
Soft tissue										
Soft tissue convexity w/out nose (n′-ss′-pg)	8.8	4.8	3.6	9.4	8.3	8.0	3.8	5.8	*	*
Soft tissue convexity with nose (n′-pro-Pg′)	42.2	3.8	41.0	5.2	45.3	4.9	42.1	6.9	NS	NS
ss′/OLsp	79.1	4.6	78.2	5.1	86.5	6.6	84.4	7.3	NS	NS
pg′/OLsp	85.2	6.3	85.3	5.9	94.1	8.8	95.3	9.1	NS	NS

*$p < 0.05$; **$p < 0.01$; #Significant with the Bonferroni correction; NS = not significant

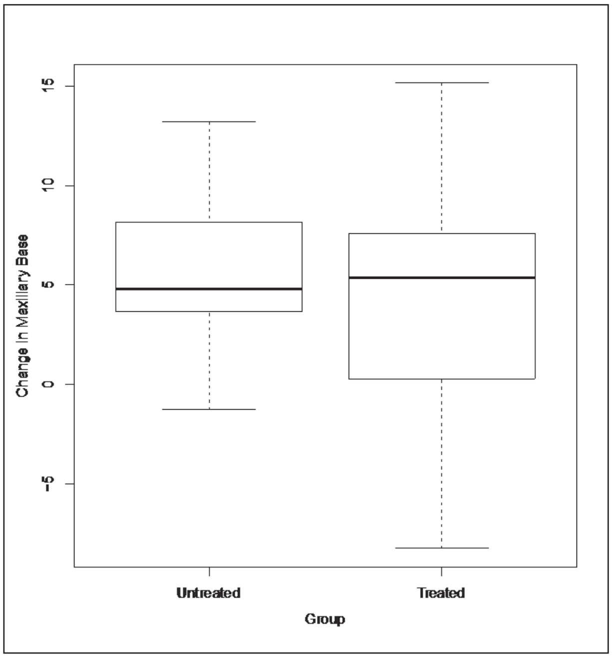

Figure 3. Distribution of Change in Maxillary Base separated by group.

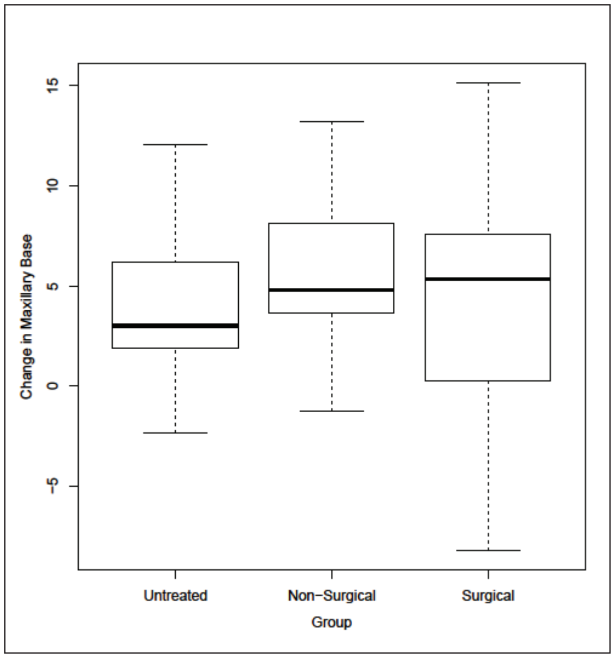

Figure 4. Distribution of Change in Maxillary Base separated by group.

significant difference in maxillary base values were observed between the treated and control groups.

In comparison with the RME/FM failure rate of 30% reported in previous studies,[4,13,16] the failure rate within the current treated sample was increased at 45%. This may be due to selection bias within the sample, as patients who required orthognathic surgery had more complete records and were over-represented in the present sample. Nonetheless, the greater long-term failure rate observed in the current study questions whether the maxilla may be manipulated, and adds validity to the theory that the dimensions of the craniofacial skeleton are genetically predetermined, as described many years ago by Martinek[36] and Brodie.[37]

In a comparison of the non-surgical and surgical groups, the Class III skeletal discrepancy at Ti was greater in the surgical group, as indicated by the AB distance ($p < 0.05$) and soft tissue convexity ($p < 0.05$). This worsened with growth, as the variables describing the Mx/Mn relationship ($p < 0.01$) (ANB ($p < 0.01$), AB distance ($p < 0.01$), Wits ($p < 0.01$), soft and hard tissue convexity ($p < 0.05$), overjet ($p < 0.01$), molar relation ($p < 0.01$) and inclination of the mandibular incisors ($p < 0.01$)) were significantly different compared with the non-surgical group at Tf. The variables were consistent with those found by Stellzig-Eisenhauer et al.,[38] and served as indicators determining whether individuals with a Skeletal Class III relationship can be treated surgically or non-surgically. However, at Ti the variables suggested as predictors of successful RME/FM therapy, such as the molar relationship,[39] upper incisor inclination to the maxillary plane, horizontal distances of labrale superioris to soft tissue nasion and labrale inferioris to sella vertical,[40] were not significantly different in either group and possibly due to the different phenotypic expressions of Class III skeletal discrepancy within a given population.[41]

There are limitations associated with the present study. Firstly, the nature of the study is retrospective and longitudinal, which comes with inherent concerns. Secondly, although reflective of Australia's multicultural population, the small sample size of mixed ethnicity is a confounding factor that adds comparison variability. Additionally, obtaining an untreated longitudinal Class III sample proved challenging and this group was fewer in number than the treated group.

New techniques involving novel expansion protocols have been proposed to expand and protract the maxilla,[42] using a facemask with temporary anchors in the growing child.[43-47] The treatment effects on the maxilla appear to be enhanced in the short term by applying the technique of alternating expansion and contraction. However, the long-term outcomes are yet to be reported.

Table VI. Baseline comparison between surgical and non-surgical groups at Ti.

Cephalometric variable	Non-surgical (N=23) Mean	SD	Surgical (N=19) Mean	SD	*P*-value	Significant
Age	8.76	1.06	8.79	1.32	0.926	NS
Maxillary skeletal						
Maxillary Base (ss/OLsp)	65.73	4.07	64.85	4.76	0.522	NS
SNA	79.04	4.18	79.45	3.31	0.735	NS
Mandibular skeletal						
Mandibular base (Pg/OLsp)	75.75	6.61	75.77	7.39	0.995	NS
Mandibular length 1 (Pg-co/OLsp)	82.88	6.01	82.86	6.27	0.995	NS
Mandibular length 2 (Pg-ar/OLsp)	81.90	5.87	81.58	5.87	0.867	NS
SNB	80.46	3.78	81.32	2.95	0.424	NS
B point/Olsp	72.83	4.82	72.84	5.33	0.995	NS
SNPg	81.15	4.07	81.79	3.22	0.583	NS
Maxillomandibular						
Mx/Mn relationship (ss-Pg/OLsp)	-10.02	4.20	-10.91	4.33	0.503	NS
ANB	-1.41	2.60	-2.11	2.36	0.376	NS
AB distance	0.49	2.23	-1.24	2.93	0.036	*
Wits	-7.10	2.33	-7.99	1.95	0.192	NS
Hard tissue convexity (n-ss-Pg)	-5.15	5.93	-3.21	4.32	0.242	NS
Vertical skeletal						
Nasal plane angle (NL/NSL)	6.89	3.48	6.16	2.54	0.449	NS
Mandibular plane angle (ML/NSL)	34.72	4.35	36.45	3.93	0.188	NS
Vertical jaw relation (ML/NL)	27.70	3.63	29.71	3.26	0.069	NS
LAFH (sp-gn/NSL)	55.94	1.89	56.56	2.03	0.310	NS
Skeletodental						
Maxillary incisor horizontal (is/OLsp)	71.47	5.40	71.46	5.01	0.995	NS
Is.OLsp	83.80	4.86	82.77	5.28	0.516	NS
Maxillary molar horizontal (ms/OLsp)	45.53	4.02	45.24	4.46	0.813	NS
Mandibular incisor horizontal (ii/OLsp)	72.44	4.30	72.47	5.65	0.985	NS
Ii.OLsp	86.24	4.91	85.80	5.96	0.792	NS
Mandibular molar horizontal (mi/OLsp)	48.52	3.77	48.40	3.99	0.932	NS
Dentoalveolar						
Inclination max. inc. to NSL (ILis-NSL)	111.94	7.00	112.97	10.51	0.704	NS
Inclination mand. inc. to ML (ILii-ML)	85.26	7.38	82.55	4.61	0.155	NS
Interdental						
Overjet	-0.97	2.52	-1.00	1.79	0.959	NS
Molar relation (ms/OLsp-mi/OLsp)	-2.99	2.27	-3.01	1.57	0.975	NS
Overbite (is-ii/OLsp)	1.70	1.86	0.15	2.17	0.017	*
Soft tissue						
Soft tissue convexity w/out nose (n′-ss′-Pg)	8.78	4.80	3.55	9.36	0.036	*
Soft tissue convexity with nose (n′-pro-Pg′)	42.17	3.80	41.03	5.22	0.415	NS
ss′/OLsp	79.11	4.57	78.22	5.12	0.556	NS
Pg′/OLsp	85.16	6.33	85.28	5.91	0.952	NS

**p* < 0.05; ***p* < 0.01; #Significant with the Bonferroni correction; NS = not significant

Table VII. Baseline comparison between surgical and non-surgical groups at Tf.

	Non-surgical (N=23)		Surgical (N=19)			
Cephalometric variable	Mean	SD	Mean	SD	*P*-value	Significant
Age	18.02	2.41	18.24	2.23	0.758	NS
Maxillary skeletal						
Maxillary Base (ss/OLsp)	71.28	5.47	69.23	5.46	0.234	NS
SNA	81.76	4.85	80.26	2.74	0.217	NS
Mandibular skeletal						
Mandibular base (Pg/OLsp)	82.28	8.61	85.89	8.59	0.183	NS
Mandibular length 1 (Pg-co/OLsp)	92.42	8.21	95.80	9.17	0.216	NS
Mandibular length 2 (Pg-ar/OLsp)	91.81	8.01	94.82	9.09	0.261	NS
SNB	82.24	4.27	84.32	3.89	0.110	NS
B point/Olsp	77.58	7.50	81.03	7.51	0.146	NS
SNPg	83.50	4.54	85.34	3.97	0.174	NS
Maxillomandibular						
Mx/Mn relationship (ss-Pg/OLsp)	-11.00	5.83	-16.66	5.75	0.003	**
ANB	-0.48	3.01	-4.05	2.88	0.0004	**/#
AB distance	0.31	4.36	-5.97	4.60	<.0001	**/#
Wits	-6.30	4.47	-11.80	4.41	0.0003	**
Hard tissue convexity (n-ss-Pg)	-4.15	7.34	-10.74	6.54	0.004	**
Vertical skeletal						
Nasal plane angle (NL/NSL)	6.09	3.58	7.47	2.71	0.172	NS
Mandibular plane angle (ML/NSL)	33.41	3.77	35.37	5.66	0.188	NS
Vertical jaw relation (ML/NL)	27.02	4.71	27.71	5.44	0.662	NS
LAFH (sp-gn/NSL)	56.64	1.95	57.37	2.57	0.302	NS
Skeletodental						
Maxillary incisor horizontal (is/OLsp)	79.98	7.67	78.10	7.36	0.394	NS
ls.OLsp	90.74	6.97	89.35	7.76	0.546	NS
Maxillary molar horizontal (ms/OLsp)	90.74	4.84	89.35	5.40	0.546	NS
Mandibular incisor horizontal (ii/OLsp)	77.91	7.67	80.00	7.36	0.377	NS
li.OLsp	92.44	7.69	93.56	8.25	0.653	NS
Mandibular molar horizontal (mi/OLsp)	55.81	6.28	59.28	6.14	0.079	NS
Dentoalveolar						
Inclination max. inc. to NSL (ILis-NSL)	116.85	6.33	118.05	6.42	0.545	NS
Inclination mand. inc. to ML (ILii-ML)	85.65	8.98	78.26	6.10	0.004	**
Interdental						
Overjet	2.07	1.68	-1.89	2.13	<.0001	**
Molar relation (ms/OLsp-mi/OLsp)	-3.41	2.28	-6.48	2.45	0.0001	**
Overbite (is-ii/OLsp)	1.29	1.70	0.68	2.83	0.420	NS
Soft tissue						
Soft tissue convexity w/out nose (n′-ss′-Pg)	8.28	7.98	3.79	5.83	0.047	*
Soft tissue convexity with nose (n′-pro-Pg′)	45.33	4.90	42.13	6.90	0.088	NS
ss′/OLsp	86.51	6.61	84.38	7.32	0.329	NS
Pg′/OLsp	94.13	8.83	95.26	9.10	0.686	NS

*$p < 0.05$; **$p < 0.01$; #Significant with the Bonferroni correction; NS = not significant

De Clerk et al. utilised titanium miniplates as anchorage to apply pure bone-borne orthopaedic forces between the maxilla and mandible by the application of intermaxillary elastics.[43-47] De Clerk et al.,[44] Cevidanes et al.[45] and Hino et al.[47] have reported the treatment effects of bone-anchored maxillary protraction to include significant maxillary protraction and repositioning of the condyle posteriorly with associated fossa remodelling. Compared with RME/FM treatment, bone-anchored maxillary protraction produced a greater amount of maxillary advancement, improved vertical control, an inhibition of clockwise mandibular rotation and an absence of lower incisor retroclination. Moreover, the mandible exhibited a degeree of counter-clockwise rotation, a decrease in gonial angle flexure and more parallel lowering of the mandibular border than obsereved in facemask-only treatment.[45,47]

A three-dimensional assessment of the effects of bone-anchored maxillary protraction reported zygomatic advancement as well.[48,49] However, this was subject to individual variation described in Hino et al.'s [47] study, which compared the growth and treatment effects on the midface and maxillary dentition produced by RME/FM and bone-anchored maxillary protraction in the three dimensions. Although the skeletal changes were greater in the bone-anchored group, there were several individuals in whom little change occurred.

At present, the long-term efficacy of bone-anchored maxillary protraction compared with facemask therapy and normal growth is yet to be clarified. Therefore, caution is recommended in using these approaches, particularly as the placement of bone plates is an invasive surgical procedure in a growing child.

Conclusion

1. At long-term follow-up, there were no statistically significant differences between RME/FM treated and control groups except in overjet, which was greater in the treated group ($p < 0.05$).
2. AB distance and soft tissue convexity may be indicators of an unfavourable Class III growth pattern.
3. The Mx/Mn relationship, ANB angle, AB distance, Wits value, soft and hard tissue convexity, overjet, molar relation and the inclination of the mandibular incisors are indicators of the need for orthognathic surgery at growth cessation.

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