REVIEW ARTICLE

Posttreatment Stability Following Facemask Therapy in Patients with Skeletal Class III Malocclusion: A Systematic Review

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Abstract

Background: Skeletal class III malocclusion is a challenging condition that orthodontists frequently come across. The facemask (FM) is a device commonly used to treat this malocclusion. However, the stability of this orthopedic correction remains unclear, and collective documentation of the short-, mid-, and long-term stability after FM therapy is necessary.

Aim: The aim of the systematic review was to assess posttreatment stability following FM therapy in patients with skeletal class III malocclusion.

Materials and methods: Through a predefined search strategy, electronic searching was conducted in PubMed, Latin American and Caribbean Health Sciences Literature (LILACS), Cochrane, Ovid, Embase, Scopus, and Web of Science until 30th June 2022. Eligible study selection, data extraction, and evaluation of the risk of bias were performed independently by two review authors according to the Cochrane tool for assessing the risk of bias in randomized trials (RoB 2.0 tool) and the Risk of Bias in Nonrandomized Studies–of Interventions (ROBINS-I) tool for nonrandomized trials. A total of 14 studies were finally considered eligible. The systematic review revealed that the maxillo-mandibular differential reverted to class III. The maxillary changes achieved were variable, with SNA angles ranging between –0.7° and 1.9°. Changes in the mandible were greater with an increase in the SNB angle ranging between 0.33° and 3.62°. The lower anterior facial height increased. The maxillary and mandibular incisors were proclined, and the overjet and overbite decreased. The soft tissue changes were insignificant.

Conclusion: The effects of FM therapy were found to be stable in the short-term follow-up period. The long-term follow-up revealed that the effects of FM therapy remained stable for the maxilla. However, the mandible continued to grow in a horizontal and unfavorable direction until the adolescent growth spurt.

Clinical significance: The major variable that determines the long-term success of FM therapy is the amount and direction of mandibular growth during the adolescent growth spurt. More focus on restricting unfavorable mandibular growth and duration of retention is needed for post-FM therapy.

Others: PROSPERO (CRD42021218960).

Keywords: Facemask, Protraction facemask, Relapse, Stability.

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Introduction

Class III skeletal malocclusion is a difficult condition that orthodontists frequently come across.[1] It most commonly manifests solely as a retrognathic maxilla without mandibular prognathism, and it is imperative to note that this phenomenon transpires in a significant proportion of patients, ranging from 20 to 30%.[2,3] However, a combination of deficient maxillary growth and excessive mandibular growth can also be found in class III patients.[4,5]

Treatment of class III malocclusions renders a psychological advantage to the child by reducing the facial disfigurement and reducing the malocclusion severity by inducing compensating growth.[5] Studies have shown that treating patients early in the mixed dentition stage is more effective in promoting maxillary growth compared to treatment during the late-mixed dentition stage.[6–8] Intervention for maxillary retrognathism subjects involves growth modification with protraction headgear, chin cup, functional regulator, Bionator III and other modification of functional appliances. The most frequently used orthopedic appliance to treat skeletal class III in growing patients is a facemask (FM). FM, apart from having a predominant effect on the maxilla, also affects the mandible, dentition, and dentoalveolar structures.[9–11]

Several studies indicate that following active treatment, class III disharmony may either reestablish or remain stable. Westwood et al.[12] showed a stable sagittal intermaxillary relationship 5.5 years postprotraction. Shanker et al.[13] assessed the changes in the position of point A during the 12-month posttreatment period and reported no significant differences in the treated group compared with the untreated group. Ngan et al.[14] assessed the maxillary and mandibular changes of patients who underwent treatment with a maxillary expander and FM. They reported an overall improvement

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in the maxillomandibular relationship and positive overjet despite some relapse at the end of 2 years of follow-up.

The stability of these orthopedic corrections remains unclear, and collective documentation of the short-, mid-, and long-term stability after orthopedic treatment is lacking in the orthodontic literature. Hence, it was deemed essential to conduct a comprehensive review of the existing literature.

This systematic review aimed to assess the posttreatment stability following FM therapy in patients with class III skeletal malocclusion.

Materials and Methods

Protocol and Registration

The systematic review was registered in PROSPERO (registration number CRD42021218960; http://www.crd.york.ac.uk/prospero). This review adhered to the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) 2020 guidelines.[15]

Eligibility Criteria

The clinical question was formulated precisely using the PICOS format, with defined inclusion and exclusion criteria (Table 1).

Information Sources and Search Strategy

PubMed, Latin American and Caribbean Health Sciences Literature (LILACS), Cochrane, Ovid, Embase, Scopus, and Web of Science databases were searched until 30th June 2022. Studies published only in English were included (Table 2).

Study Selection Process

The search with the chosen keywords was conducted across the databases independently by two reviewers. The studies were streamlined in accordance with the framed eligibility criteria and assessment of the relevance and suitability of the titles and abstracts of the articles in question. Then, two researchers independently screened the full-text articles to determine their eligibility for inclusion.

Data Collection Process

The extraction of relevant data was independently executed by the two reviewers. The following data was analyzed from the finally selected articles: the author's name, the journal, year of publication, the type of study, sample size, categorization into study and control

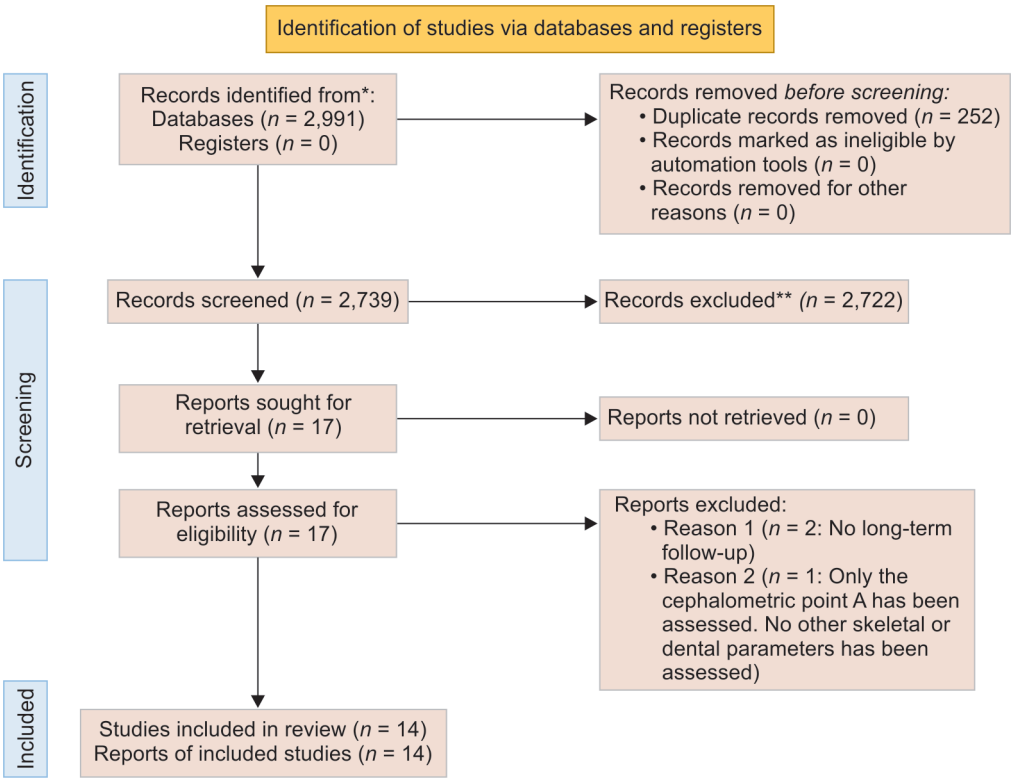
Table 1: Eligibility criteria

Field	*Inclusion criteria*	*Exclusion criteria*
Population (P)	Growing patients with skeletal class III malocclusion; growing or nongrowing patients during the follow-up period	Syndromic patients, adult patients, orthognathic surgery, cleft lip and palate, or existing pathological conditions
Intervention (I)	FM therapy; with or without rapid maxillary expansion preprotraction	Surgical technique or other orthodontic treatment modalities for correction of class III malocclusion
Comparison (C)	Posttreatment and follow-up evaluation with 2D or 3D diagnostic aid; with at least 1-year follow-up; with or without fixed appliance therapy postprotraction; with or without retainer	Studies with <1 year of follow-up
Outcome (O)	Posttreatment stability of skeletal structure; the dentoalveolar and soft tissue stability was also assessed additionally	Not applicable
Study design (S)	Randomized clinical trials (RCTs), nonrandomized trials, and prospective and retrospective studies were included	Systematic reviews, meta-analyses, case series, case reports, expert opinion, and editorials

Table 2: Search results across databases

Keywords	*Database*	*Results*
(Stability) (title/abstract) OR (retention) (title/abstract) OR (changes) (title/abstract) OR (relapse) (title/abstract) AND (FM) (title/abstract) OR (protraction FM) (title/abstract) OR (reverse pull headgear) (title/abstract) OR (protraction headgear) (title/abstract)	PubMed (from 1980 to 30th June 2022)	593
(Stability) OR (retention) OR (changes) OR (relapse) AND (FM) OR (protraction FM) OR (reverse pull headgear) OR (protraction headgear)	LILACS (from 1980 to 30th June 2022)	189
"Retention" in the title, abstract, keyword AND "FM" in the title, abstract, keyword, OR "protraction FM" in the title abstract keyword OR "reverse pull headgear" in the title, abstract, keyword, OR "protraction headgear" in the title, abstract, keyword—(word variations have been searched)	Cochrane (from 1945 to 30th June 2022)	24
"Retention" AND "FM" OR "protraction FM" OR "reverse pull headgear" OR "protraction headgear"	Ovid (from 1946 to 30th June 2022)	1085
("Stability": title, abstract, keyword OR "retention": title, abstract, keyword OR "changes": title, abstract, keyword OR "relapse": title, abstract, keyword) AND "FM": title, abstract, keyword OR "protraction FM": title, abstract, keyword OR "reverse pull headgear": title, abstract, keyword OR "protraction headgear": title, abstract, keyword	Embase (from 1966 to 30th June 2022)	398
[Title, abstract, keyword (stability) OR title, abstract, keyword (retention) OR title, abstract, keyword (changes) OR title, abstract, keyword (relapse) AND title, abstract, keyword (FM) OR title, abstract, keyword (protraction AND FM) OR title, abstract, keyword (reverse AND pull AND headgear) OR title, abstract, keyword (protraction AND headgear)]	Scopus (from 1960 to 30th June 2022)	425
All fields: (retention) AND all fields: (FM) OR all fields: (protraction FM) OR all fields: (reverse pull headgear) OR all fields: (protraction headgear)	Web of Science (from 1952 to 30th June 2022)	277

Flowchart 1: Preferred reporting items for systematic review and meta-analyses (PRISMA) study flow diagram



group, the type of intervention employed, the retention protocol, the duration of the follow-up period and cephalometric parameters to determine the long-term stability.

Data Items

The eligible outcome was the posttreatment stability of skeletal, dentoalveolar, and soft tissue structures in patients with skeletal class III malocclusion treated with FM therapy. The difference between the measurements taken posttreatment and follow-up of FM therapy was calculated.

Study Risk of Bias Assessment

Two reviewers independently evaluated the risk of bias for the studies included in the analysis according to the Cochrane tool for assessing the risk of bias in randomized trials (RoB 2.0 tool) for randomized trials and Risk of Bias in Nonrandomized Studies–of Interventions (ROBINS-I) tool for nonrandomized trials[16,17] The quality of evidence was also assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE).[18] Any disagreements were resolved through discussion or by a senior reviewer.

Results

Study Selection

A total of 2,991 records were obtained across all databases. After duplicate removal, 2,739 records were screened, out of which 2,722 articles were eliminated after reading the title and abstracts. Of the 17 full-text documents, 14 studies[9,11,12,14,19–28] have been included in this systematic review. The entire search selection process and the reasons for the exclusion of the three studies[7,13,29] are presented in the PRISMA flowchart (Flowchart 1).

Study Characteristics

Descriptive data on the characteristics of the final included studies is displayed in Table 3. There was a total of 305 participants across the included studies. All patients were treated with FM appliances with or without rapid maxillary expansion (RME). The total duration of treatment ranged from 4 to 8 months. The patients were instructed to wear the appliance 12–22 hours a day with a force ranging from 250 to 500 gm per side. In some studies, this was followed by 1-year retention with Frankel III,[20] Reverse activator,[14] or Bionator III.[11] Some authors used the "bedtime wear" of a FM without changing the force for another 2–3 months as part of the retention protocol.[9,24] In five studies, some patients underwent comprehensive fixed appliance treatment post-FM therapy.[12,20,22,23,25] The patients were recalled after a defined follow-up duration. All these studies had a follow-up duration ranging from 1 to 20 years.

All 14 studies evaluated the posttreatment and follow-up stability following FM therapy in patients with skeletal class III malocclusion using two-dimensional (2D) radiographs. Posttreatment and follow-up lateral cephalometric records were collected and assessed for the stability of skeletal and dentoalveolar structures post-FM therapy.

Risk of Bias in Studies

The follow-up study by Mandall et al. was an randomized controlled trials (RCTs).[26–28] The RoB 2.0 tool was used to evaluate bias risk and found a low risk of bias. The ROBINS-I tool was used in observational studies. Two studies were classified as having a serious risk of bias,[23,25] while five studies were deemed to have a moderate risk of bias.[9,12,19,20,22] The remaining four studies were graded as low risk of bias.[11,14,21,24] These results are depicted in Tables 4 and 5. The GRADE approach indicated a "low" certainty of the evidence for five

Table 3: Characteristics of the included articles

S. no	*Author*	*Study design*	*Treatment group (TG)*	*Sample size (TG)*	*Intervention characteristic*	*Preprotraction expansion*	*Second phase (Rx)*	*Retention duration*	*Follow-up duration*
1	Ngan et al., 1997	Prospective	Skeletal class III malocclusion	20; age: 6–9.2 years	12 hours a day—380 gm per side	Banded RME + FM	NA	NA	2 and 4 years
2	Williams et al., 1997	Retrospective	Class III malocclusions	41	NA	RME + FM	29–fixed appliance therapy + FM	NA	5 and 10 years
3	Ngan et al., 1998	Retrospective	Skeletal class III malocclusion	20 (8 males and 12 females) Age: 8.4 ± 1.8 years	12 hours a day—380 gm per side	Banded RME + FM	NA	10 patients—reverse activator for 1 year	2 years
4	Macdonald et al., 1999	Prospective	Skeletal class III malocclusion	24 (12 males and 12 females) Age: 7.4 years	18–22 hours a day—200–450 gm	Banded RME + FM	NA	FM–"bedtime only" wear for 3–4 months	10.3 years
5	Westwood et al., 2003	Retrospective	Class III malocclusions	34 (20 girls and 14 boys) Age: 8 years 3 months	14 hours per day—300–500 gm per side	Bonded or banded RME + FM	PEA therapy postprotraction	NA	5.5 years (CVM stage 4, 5, or 6)
6	Cozza et al., 2004	Prospective	Skeletal class III with maxillary retrognathism	30 (17 boys, 13 girls) Age: 4.1–9 years	14 hours a day—400 gm	No expansion	NA	Bionator III—1 year	1 year
7	Pangrazio et al., 2007	Retrospective	Skeletal class III with maxillary deficiencies	Protraction—17 (8 boys and nine girls) Age: 8 years and 7 months	14–16 hours a day–300–400 gm	Bonded RME + FM	7—fixed appliance therapy post protraction	10—Frankel III nighttime wear for 1 year	7 years and 6 months (CVM 5 or 6)
8	Masucci et al., 2011	Prospective	Dento-skeletal class III malocclusion	22 (nine boys and 13 girls) Age: 9.2 years ± 1.6 CS1-CS3	14 hours per day—400 to 500 gm per side	Bonded or banded RME + FM	19—PEA therapy	NA	8.5 years
9	Chen et al., 2012	Prospective	Class III malocclusions	22 (12 males and 1 0 females) Age: 11.38 ± 0.69 CVM of 2–4	12 hours per day—250–300 gm	7—banded RME + FM 15 - FM	Fixed appliance therapy post protraction	NA	3 years (CVM stage 5 or 6)
10	Nevzatoğlu et al., 2014	Retrospective	Skeletal and dental class III malocclusion	17 (nine males and eight females) Age: 11.26 ± 1.89 years	16 hours a day	RME + FM	NA	FM–nighttime wear for 3 months without changing the force	6.08 ± 0.61 years
11	Mandall et al., 2010 Mandall et al., 2012 Mandall et al., 2016	RCT	Skeletal class III with maxillary retrognathism	35 Age: 8.7 ± 0.9 years	14 hours per day—400 gm per side	Bonded RME + FM	NA	NA	15 months, 3 years 6 years
12	Wendl et al., 2017	Retrospective	Class III malocclusions	23 (males—15, females—8) Age: 7.8 ± 1.7	300 gm throughout a day	RME + FM	NA	NA	20 years

CS, cervical stage; CVM, cervical vertebral maturation; FM, facemask; NA, not available; RME, rapid maxillary expansion

Table 4: Risk of bias assessment of randomized controlled trials evaluated using the Cochrane risk of bias (RoB 2.0) tool

S. no.	Author/year of publication	Selection bias	Selection bias	Performance bias	Detection bias	Attrition bias	Selective reporting	Overall bias
1	Mandall et al., 2010 Mandall et al., 2012 Mandall et al., 2016	Low	Low	Low	High	Low	Low	Fair

Table 5: Risk of bias assessment using the ROBINS-I tool

S. no.	Author	Bias due to confounding	Bias in the selection of participants in the study	Bias in the classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in the measurement of outcomes	Bias in the selection of the reported result	Overall bias
1	Ngan et al., 1997	Low	Low	Low	Low	Low	Low	Low	Low
2	Williams et al., 1997	Serious	Low	Low	Low	Low	Low	Low	Serious
3	Ngan et al., 1998	Low	Low	Low	Low	Low	Low	Low	Low
4	Macdonald et al., 1999	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate
5	Westwood et al., 2003	Low	Moderate	Low	Low	Low	Low	Low	Moderate
6	Cozza et al., 2004	Low	Low	Low	Low	Low	Low	Low	Low
7	Pangrazio et al., 2007	Low	Low	Low	Moderate	Low	Low	Low	Moderate
8	Masucci et al., 2011	Low	Low	Low	Moderate	Low	Low	Low	Moderate
9	Chen et al., 2012	Low	Low	Low	Low	Serious	Low	Serious	Serious
10	Nevzatoğlu et al., 2014	Low	Low	Low	Low	Low	Low	Low	Low
11	B. Wendl et al., 2017	Moderate	Low	Low	Low	Low	Low	Low	Moderate

Table 6: Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach indicating the overall certainty of evidence

	Certainty assessment						Effect				
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	No. of events	No. of individuals	Rate (95% confidence interval)	Certainty	Importance
Posttreatment stability with retainer											
5	Observational studies	Serious	Serious	Not serious	Not serious	None	108	108		⨁⨁◯◯ Low	
Posttreatment stability without a retainer											
6	Observational studies	Serious	Serious	Serious	Not serious	None	174	174		⨁◯◯◯ Very low	
Posttreatment stability without a retainer											
1	Randomized trials	Not serious	Not serious	Not serious	Not serious	None	35	35		⨁⨁⨁⨁ High	

studies with a retainer and a "very low" certainty of the evidence for six studies without a retainer (Table 6).

Synthesis of Result

Of the 14 studies[9,11,12,14,19–28] included in this review, three studies were RCTs,[26–28] five studies were prospective,[9,11,23] and six were retrospective studies.[12,14,19,20,24,25] The skeletal, dentoalveolar, and soft tissue structures were evaluated in the sagittal and vertical plane, the results of which are depicted in Tables 7 to 10.

Skeletal

Maxillo-mandibular Relationship

Among the six studies[9,11,12,19,20,25] which evaluated the maxillomandibular relationship with both ANB angle and Wit's appraisal, four studies[9,12,20,25] indicated relapse in the form of decreased ANB angle, and the BO was ahead of AO in Wit's appraisal. One study[19] found no significant changes in the ANB angle and Wit's appraisal during long-term follow-up, whereas Cozza et al.[11] reported a significant improvement in the maxillo-mandibular relationship

Table 7: Results of individual studies showing changes in the cephalometric measurements posttreatment (T2) and follow-up (T3)–skeletal (sagittal)

		Maxillary parameter				*Mandibular parameter*				*Maxillo-mandibular relationship*		
				Mx length (mm)				*Md length (mm)*				
S. no.	*Author*	*SNA (°)*	*N perp-A (mm)*	*2 years*	*4 years*	*SNB (°)*	*N perp–Pg (mm)*	*2 years*	*4 years*	*ANB (°)*	*Wits appraisal (mm)*	*Outcome*
1	Ngan et al., (Sem Orthod, 1997)	NA	NA	1.2	3.3	NA	NA	4.6	9.1	NA	NA	Skeletal base reverted to class III; significant forward position in the maxilla; significant forward position in the mandible
2	Williams et al., (Sem Orthod, 1997)	Superimpositional qualitative study with no numerical values given*										Skeletal base reverted to class III; more forward position of the maxilla; more forward growth of the mandible than the maxilla, reflecting the horizontal pattern of mandibular growth
3	Ngan et al., (EJO, 1998)	−0.3 ± 1.4	NA		NA	1.6 ± 1.8	NA		NA	−2.0 ± 1.3	NA	Skeletal base maintained as class I; no significant changes in the maxilla; no significant changes in the mandible
4	Macdonald et al., (AJODO, 1999)	−0.57 ± 0.47	−0.19 ± 0.31		NA	0.33 ± 0.36	1.42 ± 0.57		NA	−0.90 ± 0.24	−0.19 ± 0.25	Skeletal base reverted to class III; significant retroposition of the maxilla; significant forward position in the mandible
5	Westwood et al., (AJODO, 2003)	0.2 ± 1.9	0.2 ± 1.7		NA	1.9 ± 2.1	5.0 ± 4.1		NA	−1.6 ± 2.0	−0.2 ± 2.8	Skeletal base reverted to class III; significant forward position in the maxilla; significant forward position in the mandible
6	Cozza et al., (EJO, 2004)	0.65 ± 0.47	0.88 ± 0.36		NA	0.23 ± 0.44	0.08 ± 0.67		NA	0.38 ± 0.74	0.88 ± 0.30	Skeletal base progressed to class I; significant forward position in the maxilla; significant forward position in the mandible
7	Pangrazio et al., (AJODO, 2007)	0.35	0.35		NA	2.44	NA		NA	−2.18	−2.09	Skeletal base reverted to class III; significant forward position in the maxilla; significant forward position in the mandible
8	Macussi et al., (AJODO, 2011)	Data from baseline to follow-up were only available										The skeletal base reverted to class III; no significant changes in the maxilla; significant forward position in the mandible
9	Chen et al., (EJO, 2012)	−0.88	NA		NA	2.50	NA		NA	−2.0	NA	Skeletal base reverted to class III; significant retroposition of the maxilla; significant forward position in the mandible
10	Nevzatoğlu et al., (Angle Orthod, 2014)	−0.7	−0.5		NA	3.62	NA		NA	−2.44	NA	Skeletal base reverted to class III; no significant changes in the maxilla; significant forward position in the mandible
11	Mandall et al., (J Orthod, 2010)	Data from baseline to 15 months follow-up were only available										Skeletal base progressed towards class I; significant forward position in the maxilla; significant retroposition of the mandible
	Mandall et al., (J Orthod, 2012)	Data from baseline to 3-year follow-up were only available										Skeletal base progressed towards class I; no significant changes in the maxilla; no significant changes in the mandible
	Mandall et al., (J Orthod, 2016)	Data from baseline to 6-year follow-up were only available										Skeletal base maintained as class I; no significant changes in the maxilla; no significant changes in the mandible
12	Weldl et al., (J Orofac Orthod, 2017)	−0.6	NA		NA	1.3	NA		NA	−0.7	−0.6	Skeletal base maintained as class I; significant retroposition of the maxilla; significant forward position in the mandible

Md, mandibular; Mx, maxillary; NA, not available

Table 8: Results of individual studies showing changes in the cephalometric measurements posttreatment and follow-up–dental (sagittal)

S. no.	*Author*	*U1-SN*	*U1-FH*	*Impa*	*Overjet*	*Molar relationship*	*Outcome*
1	Ngan et al., (Semin Orthod, 1997)	NA	NA	NA	−0.5	−0.8	Significant decrease in the overjet; significant change in the molar relationship
2	Williams et al., (Sem Orthod, 1997)	Superimpositional qualitative study with no numerical values given* .					Positive overjet is maintained in the long term in 70–75% of cases, whereas 25–30% of cases relapse into reverse overjet
3	Ngan et al., (EJO, 1998)	5.6 ± 6.0	NA	3.3 ± 5.5	−0.9 ± 2.1	−1.9 ± 2.5	Significant increase in the upper incisor proclination; significant increase in the lower incisor proclination; no significant changes in the overjet; no significant change in the molar relationship
4	Macdonald et al., (AJODO, 1999)	NA	NA	NA	−0.58 ± 0.04	NA	Significant decrease in the overjet
5	Westwood et al., (AJODO, 2003)	NA	5.9 ± 5.8	2.5 ± 6.7	−1.4 ± 1.7	2.7 ± 2.6	Significant increase in the upper incisor proclination; significant increase in the lower incisor proclination; significant decrease in the overjet; significant change in the molar relationship
6	Pangrazio et al., (AJODO, 2007)	3.77	NA	3.71	−2.04	NA	Significant increase in the upper incisor proclination; significant increase in the lower incisor proclination; significant decrease in the overjet
7	Macussi et al., (AJODO, 2011)	Data from baseline to follow-up were only available					No significant change in the upper incisor inclination; no significant change in the lower incisor inclination; no significant changes in the overjet; significant change in the molar relationship
8	Mandall et al., (J Orthod, 2010)	Data from baseline to 15 months follow-up were only available					Significant retroclination of lower incisor
	Mandall et al., (J Orthod, 2012)	Data from baseline to 3-year follow-up were only available					No significant change in the incisor inclination
	Mandall et al., (J Orthod, 2016)	Data from baseline to 6-year follow-up were only available					No significant change in the incisor inclination
9	Nevzatoğlu et al., (Angle Orthod, 2014)	4.23	NA	4.45	NA	NA	Significant increase in the upper incisor proclination; significant increase in the lower incisor proclination
10	Weldl et al., (J Orofac Orthod, 2017)	2.7	NA	2.6	NA	NA	No significant change in the upper incisor inclination; no significant change in the lower incisor inclination

NA, not available

in the form of an increase in ANB angle and AO ahead of BO in Wit's appraisal. Six studies[14,21,22,30–32] evaluated only the ANB angle, out of which two studies[23,24] showed a significant decrease in the ANB angle and four studies[14,26–28] showed no significant changes. Thus, the difference in the ANB angle ranged from −2.4° to 0.38°.

Maxilla

Six studies[9,11,12,20,24,25] evaluated both SNA angle and point A relative to the nasion perpendicular. Of these, one study[9] showed a notable reduction in the SNA angle and point A relative to nasion perpendicular. One study[24] showed no significant changes during follow-up, whereas four studies[11,12,20,25] showed a significant increase in the SNA angle and point A relative to the nasion perpendicular. Macdonald et al.[9] showed relapse in the form of a decrease in the SNA angle, while no significant changes were found in point A relative to the nasion perpendicular. Only the SNA angle was assessed in six studies,[14,19,23,26–28] of which two studies[19,23] showed relapse due to a decrease in the SNA angle, and four studies[14,26–28] found no significant changes. Therefore, the changes with SNA angle were on both ends of the spectrum, ranging between −0.7° and 1.9°.

Mandible

Four studies[9,11,12,25] which used both SNB angle and the nasion perpendicular to pogonion showed relapse due to a significant increase in the SNB angle and forward movement of point B during the follow-up. Eight studies,[14,19,20,23,24,26–28] which evaluated only the SNB angle, also showed relapse due to a significant increase in the SNB angle during follow-up. Hence, a significant increase in the SNB angle ranging between 0.33° and 3.62° was reported.

Lower Anterior Facial Height (LAFH)

Of the nine studies[12,14,20–22,24,26–28] which evaluated the lower anterior facial height (ANS-Me), four studies[12,20,21,24] showed a net

Table 9: Results of individual studies showing changes in the cephalometric measurements posttreatment and follow-up–skeletal and dental (vertical)

S. no.	*Author*	*Lafh (ANS-Me)*	*MPA*	*Overbite*	*Outcome*
1	Ngan et al. (Semin Orthod, 1997)	2.3	NA	0.2	Significant increase in the lower anterior facial height; significant increase in the overbite
2	Ngan et al., (EJO, 1998)	2.4 ± 2.2	NA	0.4 ± 1.1	No significant change in the lower anterior facial height; no significant change in the overbite
3	Westwood et al., (AJODO, 2003)	6.4 ± 4.0	−1.9 ± 2.6	−1.4 ± 1.7	Significant increase in the lower anterior facial height; significant decrease in the mandibular plane angle; significant decrease in the overbite
4	Pangrazio et al., (AJODO, 2007)	7.35	−2.84	0.83	Significant increase in the lower anterior facial height; significant decrease in the mandibular plane angle; significant increase in the overbite
5	Macussi et al., (AJODO, 2011)	Data from baseline to follow-up were only available			No significant change in the lower anterior facial height; significant decrease in the mandibular plane angle; no significant change in the overbite
6	Mandall et al., (J Orthod, 2010)	Data from baseline to 15 months follow-up were only available			No significant change in the lower anterior facial height; significant increase in the mandibular plane angle
	Mandall et al., (J Orthod, 2012)	Data from baseline to 3-year follow-up were only available			No significant change in the lower anterior facial height; no significant change in the mandibular plane angle
	Mandall et al., (J Orthod, 2016)	Data from baseline to 6-year follow-up were only available			No significant change in the lower anterior facial height; no significant change in the mandibular plane angle
7	Nevzatoğlu et al., (Angle Orthod, 2014)	1.44	−5.41	NA	Significant increase in the lower anterior facial height; significant decrease in the mandibular plane angle

NA, not available

Table 10: Results of individual studies showing changes in the cephalometric measurements posttreatment and follow-up–soft tissue (sagittal)

S. no.	*Author*	*Soft tissue profile*	*NLA*	*UL-EL*	*LL-EL*	*Outcome*
1	Macdonald et al., (AJODO, 1999)	NA	−3.35 ± 2.99	NA	NA	Significant decrease in the nasolabial angle; no significant changes in the soft tissue profile
2	Westwood et al., (AJODO, 2003)	NA	NA	−3.3 ± 2.4	−2.0 ± 2.2	There is a significant increase in the distance between the upper lip and the E-line; there is a significant increase in the distance between the lower lip and the E-line; no significant changes in the soft tissue profile
3	Nevzatoğlu et al., (Angle Orthod, 2014)	NA	−4.88	NA	NA	Significant decrease in the nasolabial angle
4	Weldl et al., (J Orofac Orthod, 2017)	NA	NA	−2.4	−1.6	There is no significant change in the position of the lip to the E-line

NA, not available

increase in the LAFH with a minimum of 1.44 mm to a maximum of 9.8 mm. Whereas five studies[14,22,26–28] reported no significant changes.

Mandibular Plane Angle

Of the eight studies[12,20,22,24,26–28] which evaluated the mandibular plane angle (SN-MP), four studies[12,20,22,24] showed a significant decrease in the MPA ranging between −1.2° and −5.41°. Whereas four studies[26–28] reported no significant changes in the MPA during follow-up.

Dental

Upper Incisors

Of the six studies[12,14,19,20,22,24] which evaluated the upper incisor inclination, four studies[12,14,20,24] showed a significant proclination of the upper incisors ranging between 1.91° and 3.1° during the follow-up. Two studies[19,22] reported no significant change.

Lower Incisors

Among six studies[12,14,19,20,22,24] which evaluated the IMPA, four studies[12,14,20,24] found a significant proclination of lower incisor with

a minimum of 0.6° to a maximum of 4.45°. Two studies[19,22] reported no significant changes in the lower incisor inclination.

Overjet

Of the seven studies[9,12,14,20,21,22,25] which evaluated the overjet, five studies[9,12,20,21,25] reported a significant change in the overjet ranging between –1.4 mm and 1.1 mm during the posttreatment phase. Two studies[14,22] reported no significant changes.

Overbite

Among the five studies[12,14,20–22] that evaluated the overbite relationship, two studies[20,21] reported a significant increase in the overbite, whereas Westwood et al.[12] reported a significant decrease in the overbite. Two studies[14,22] reported no significant changes during follow-up. Thus, the change in the overbite from a minimum of –1.4 mm to a maximum of 1.2 mm has been reported.

Molar Relationship

Four studies[12,14,19,20] evaluated the posttreatment changes in a molar relationship, of which three studies[12,21,22] reported a significant change in the molar relationship ranging between –1.9 and 2.7 mm. Whereas Ngan et al.[14] reported that the molar relationship showed no significant differences during follow-up.

Soft Tissue

The soft tissue profile evaluated by two studies[9,12] reported no significant changes during follow-up. Macdonald et al.[9] and Nevzatoğlu et al.[24] reported that the nasolabial angle decreased during the follow-up. Among the two studies,[12,19] which evaluated the relationship of the upper and lower lip to E-line (UL-EL and LL-EL), one study[12] reported that the distance between the UL-EL and LL-EL increased during the follow-up significantly. Whereas Wendl et al.[19] reported no significant increase in the distance between the UL-EL and LL-EL.

Discussion

Facemask (FM) therapy is a common approach to the treatment of skeletal class III growing subjects with maxillary retrognathism. An optimal timing for the orthopedic approach to class III malocclusion correction is at either a prepubertal or a pubertal phase of growth because greater skeletal changes are possible during these phases. However, the long-term efficacy of FM therapy, with respect to posttreatment stability, is still questionable.

Yavuz et al.,[30] and Yüksel et al.,[31] Takada et al.,[32] examined early and a late treatment group and concluded that a greater orthopedic effect was observed when FM therapy was applied before or during the acceleration of pubertal growth spurt. Westwood et al.,[12] Pangrazio et al.,[20] and Franchi et al.,[33] conducted a study to observe the effects of FM therapy on patients over a long period of time and reported that early orthopedic treatment during the prepubertal stage resulted in positive long-term outcomes.

However, Behrents[34] reported that craniofacial development doesn't cease in early adulthood but rather persists as an ongoing process that can extend into later stages of life. He concluded that craniofacial changes endured over the past 17 years. Bjork and Palling[35] found that during the adolescent period, growth of the mandible exceeds that of the maxilla, and the mandibular growth continued until 16–18 years. Foley and Mamandras[36] determined that mandibular growth was significant between 14 and 16 years in females and 16 and 20 years in males. Hence, the exact age at which the growth potential has been completed remains ambiguous.

Two systematic reviews have previously been published regarding long-term changes following maxillary protraction. Kakali et al.,[37] included only studies with follow-up of >6 years or until the end of puberty, whereas, in our systematic review, studies with a minimum of 1-year follow-up were also included with the intention of evaluating both short-, mid-, and long-term stability post-FM therapy. Lee et al.[38] have assessed only one parameter, which is the SNA angle. Hence, this systematic review is to update the collective data on the short-, mid-, and long-term stability of the skeletal, dentoalveolar, and soft tissue changes in both the sagittal and vertical planes following FM therapy.

Skeletal Parameters

The majority of studies showed that the maxillomandibular relationship was unstable during follow-up. Most of the studies pointed toward an increase in SNB and mandibular unit length. Williams et al.,[25] found that some patients on 5-year follow-up had growth remaining. The patients experienced the greatest relapse during the adolescent growth spurt, with increased horizontally-directed and late mandibular growth between 5 and 10 years of follow-up. Similar results were reported by Ngan et al.,[14] in which the postprotraction effects were found to be stable 2 years after removal of the appliance, and greater relapse occurred during the 4-year follow-up. Mandall et al.,[26–28] evaluated the stability at three time periods: 15 months, 3 years, and 6 years. At 3-year follow-up, 75% of patients had a positive overjet, whereas, at the end of 6 years, the treatment-related improvement was not maintained. Therefore, it must be noted that the class III skeletal growth is reestablished in the long-term.

The skeletal pattern of the subjects should also be considered while evaluating the stability of the FM therapy. Macdonald et al.[9] have found significant differences in the way class I and class III subjects grow. A point and ANS tend to move anteriorly in class I subjects, whereas B point moves more anteriorly in class III subjects.

The crucial factor that determines the long-term success of FM therapy is the magnitude and direction of mandibular growth during and after adolescent growth. Therefore, it must be noted that the length and position of the mandible determine the long-term success and failure of FM therapy.

Regarding maxilla, conclusive results could not be drawn due to conflicting results on both ends of the spectrum. This could be attributed to the heterogeneity in the intervention and retention protocols among the studies included. However, the majority of the studies stated that the maxilla remained stable during the follow-up with minimal relapse.

Though there is a lack of literature evidence regarding the retention post-FM therapy, some studies followed a retention protocol with Frankel III,[20] Reverse activator,[14] or Bionator III.[11] Some authors used the "bedtime wear" of FMs without changing the force for another 2–3 months as part of the retention protocol.[9,24] Garattini et al.[39] proved that the Bionator III is effective in treating class III malocclusions in growing patients with midfacial deficiency, producing both skeletal and dentoalveolar effects. Similarly, the myofuctional appliances that have been used as a retention appliance in the aforementioned studies could have aided in the continued forward movement of point A. Some patients also underwent comprehensive fixed appliance treatment post-FM therapy, which could have affected the results of the study and limited their interpretation and generalization. Therefore, the results from these studies should be interpreted with caution.

Even though the follow-up period among the studies varied widely, ranging from 1 to 20 years, the common findings were that the skeletal base tended to relapse, the primary reason being the increased horizontally directed and late mandibular growth.

Dental Parameters

In spite of the different cephalometric parameters that were used to assess the upper incisor inclination, all studies showed a significant proclination of the upper incisors to compensate for the skeletal imbalance. This supports the dentoalveolar compensatory mechanism of the dentition.[40] A significantly lower incisor proclination and relapse in the molar relationship were reported. Most of the studies reported a significant decrease in the overjet despite the increase in axial inclination of the upper and the lower incisors. This could also be attributed to the late growth of the mandible in a horizontal direction. Williams et al.[25] reported that a positive overjet is maintained in 70–75% of cases, whereas 25–30% of cases relapse into reverse overjet mainly because of the growth of the lower jaw directed horizontally over a long period of time. A significant decrease in the overbite was reported by Westwood et al., which could be due to an increase in lower anterior facial height.

Soft Tissue Parameters

The decrease in the nasolabial angle during follow-up could be due to the increase in axial inclination of the upper incisors and the continued growth of the nose. The change in mandibular position due to the continuing mandibular sagittal growth pattern and the nose could be the reason for the increase in distance between the upper and lower lips and the E-line. In spite of these, the soft tissue changes observed during active treatment remained long-term, demonstrating the ability of the soft tissue profile to conceal the underlying growth pattern.

Limitations

Ethnicity, Gender, and Growth Status

- Among the included studies, the ethnicity of the subjects was unclear.
- The sample had a heterogenous gender distribution, and the results reported were not gender specific.
- Only two studies evaluated the growth status of the participants preprotraction, whereas it is unclear in other studies. Furthermore, only three studies had mentioned the growth status of the participants during the follow-up period.

Retention Protocol

- The retention protocol followed varied widely among the studies. Five studies had mentioned the retention protocol that has been followed post protraction, while it was unclear in the rest of the studies.
- The varied cephalometric analysis and the skeletal and dentoalveolar parameters assessed among the studies made comparison difficult.
- The information sources were searched with restrictions to studies published only in English.

Scope for Further Research

- From this systematic review, it is evident that the continued and late mandibular growth during the pubertal growth spurt is accountable for the failure of FM therapy in patients with class III malocclusion. Hence, future emphasis should be made on restricting mandibular growth until growth completion. Since there is a lack of literature evidence on the ideal retention protocol post-FM therapy, further research to standardize the type and duration of the retention period is deemed appropriate.
- The use of biomarkers as a new aid in assessing the relapse during the posttreatment period has been proposed recently. With further research, a quantitative study on the increasing level of biomarkers in gingival crevicular fluid or saliva can be used as a potential indicator for posttreatment relapse.
- All studies evaluated the stability only using a 2D diagnostic aid. Further research is justified using standardized methods and three-dimensional (3D) diagnostic aids to reduce bias and improve the generalizability of results.

Conclusion

The effects of FM therapy were found to be stable for a short time in patients with class III skeletal malocclusion and maxillary retrognathism. The long-term follow-up revealed that the effects of FM therapy remained stable for the maxilla. However, the mandible continued to grow in a horizontal and unfavorable direction until the adolescent growth spurt. The upper and the lower incisors proclined. The combined contributions of skeletal imbalance led to a decrease in overjet and overbite.

Therefore, the major variable that determines the long-term success of the FM therapy is the amount and direction of mandibular growth during the adolescent growth spurt. The lower anterior facial height increased, and the mandibular plane angle decreased.

Future research should be based on high-quality RCTs, focusing more on restricting the unfavorable mandibular growth and duration of retention that is needed after FM therapy.

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