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ASSESSMENT OF DENTOSKELETAL EFFECTS CONCOMITANT WITH SKELETALLY ANCHORED MAXILLARY PROTRACTION IN ORTHODONTIC SKELETAL CLASS III PATIENTS

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ABSTRACT

Objective: The current prospective study evaluated the dentoskeletal effects subsequent to maxillary protraction with facemask in skeletal Class III malocclusion with or without skeletal anchorage. **Materials and methods:** Fourteen pre-pubertal patients with comparable chronological age, 9 boys and 5 girls, were randomly allocated to a control group and skeletally anchored facemask (SAFM) group. All patients were treated for 6 months with maxillary protraction via facemask attached to an intra-oral appliance comprising an acrylic splint without palatal expander. In SAFM group, the intraoral appliance was connected to palatal miniscrews of 1.6 mm diameter and 10 mm length to obtain skeletal anchorage. Dentoskeletal variables were analyzed and compared within and between both groups via lateral cephalometric radiographs before (T1) and after maxillary protraction (T2). **Results:** Within each group; facemask therapy resulted in a significant maxillary skeletal advancement in group I ($P \leq 0.05$)highly significant maxillary advancement in group II ($P \leq 0.01$) and non-significant maxillary incisor proclination and retroclination in group I and II respectively ($P \geq 0.05$). Regarding the mandible, it was non-significantly backward positioned in both groups ($P \geq 0.05$). However, the inclination of the lower incisor underwent a highly significant decrease in both groups ($P \leq 0.01$). The vertical dimension was significantly increased in both groups after treatment ($P \leq 0.05$). Moreover, a comparison of dentoskeletal changes between the two groups revealed a significant difference in the anteroposterior maxillary skeletal changes only in favour of group II ($P \leq 0.05$). **Conclusions:** The use of palatal miniscrews in conjunction with a facemask for maxillary protraction revealed a more favourable maxillary skeletal effect.

KEYWORDS: Skeletal Class III malocclusion, Maxillary protraction, Skeletally anchored facemask, Palatal miniscrews.

INTRODUCTION

Skeletal Class III is a challenging problem that is confronting orthodontists in their everyday orthodontic practice. The prevalence of this malocclusion varies globally among and within populations with the greatest incidence among Asian countries. It was reported that Class III malocclusion represents 3.98% and 5.93% of malocclusions in mixed and permanent dentitions respectively. Among Egyptians, the prevalence of Class III malocclusion during mixed dentition was found to be 5.9 % according to the sample studied by Fsifis et al [1–3].

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The typical Class III with convex or straight profile develops from a variety of skeletal elements. These elements can be a combination of maxillary retrognathism and mandibular prognathism in relation to other craniofacial structures, or they can be just one or the other. In the sample Ellis and Macnamara examined, they discovered that 65% to 67% of skeletal Class III was brought about by maxillary skeletal retrusion [4].

The potential treatment options depend on the growth and severity of the sagittal skeletal imbalance. On one hand, growth modification is advised for patients who have not yet experienced their growth spurt. However, when growth declines, the only remaining alternatives for therapy are orthognathic surgery and orthodontic camouflage, and which one is most effective depends on the degree of the anteroposterior disproportion and the presence of dental compensation [5].

The facemask combined with rapid maxillary expansion (RME) is the most popular method for treating developing Class III patients with maxillary retrognathism. RME was said to disarticulate the circummaxillary sutures as well as open the midpalatal suture. It is therefore claimed to make the orthopaedic impact of a facemask easier [6–8]. But a meta-analysis found that using a facemask for therapy, with or without RME, had no appreciable clinical difference [9].

Protraction forces from elastics attached to the facemask are applied to the dental structures, so they have adverse consequences such as mesial movement and extrusion of maxillary molars, proclination of upper incisors, retroclination of mandibular incisors, backward rotation of the mandible, and subsequently increase in the lower facial height. The clinical scenario will determine whether these side effects are desirable or undesired[10].

A favourable clinical outcome may result from maximizing skeletal effects and reducing dental effects, which will lessen the likelihood of relapse[6]. Kokich et al. used ankylosed canine as a type of absolute anchorage for maxillary protraction in 1985 to achieve this goal [11].

Numerous studies with skeletally anchored maxillary protraction were published with the availability of temporary anchorage devices (TADs), including those by Singer et al.[12], Enacar et al.[13], Hong et al.[14] and Kircelli et al.[15]. This was followed by several studies applying facemask to miniplates at the zygomatic buttress [16,17], lateral nasal wall[18,19], and miniscrews in zygomatic buttress [20], or in the palate [21,22]. Consequently, the aim of this randomized clinical trial is to evaluate the dentoskeletal effects of skeletally anchored facemask.

MATERIALS AND METHODS

The study protocol was approved by the Institutional Review Board and the Ethical Research Committee of Al-Azhar University, Cairo, Egypt (Registration code: 557/3132). This prospective study was carried out from December 2020 to October 2022 on a total sample of 14 patients, 9 boys and 5 girls, who were randomly selected from the Department of Orthodontics, Faculty of Dental Medicine (Boys), Al-Azhar University, Cairo, Egypt. The objectives of the study and the treatment plan were explained to the guardians of the patient and informed written consents were signed before commencing the study.

The patients selected for this study had met the following criteria: Skeletal Class III with maxillary deficiency (ANB$^{\circ}$< 0°) (wits appraisal≤ -1mm) with or without mild mandibular prognathism; Angle Class III molar relation or anterior crossbite; vertically normal growth pattern; all the patients were in the prepubertal stage of skeletal maturity according to McNamara [23] with a late mixed or early permanent dentition at the start of treatment.

The following exclusion criteria were applied: previous history of orthodontic treatment; poor oral hygiene or periodontally compromised patient; patients with craniofacial anomalies; previous history of trauma, bruxim or para functions.

The selected sample was randomly divided into two equal groups, according to the type of anchorage. The process of randomization and group allocation was undertaken using online software (http://www.graphpad.com/quickcalcs/index.com) 7 patients in the conventional group and 7 patients in the palatal miniscrew group.

All patients who participated in this study were treated for 6 months with a petite facemask that was attached to an intra-oral appliance. The intra-oral appliance was comprised of acrylic bite blocks covering the maxillary buccal segment, these acrylic bite blocks were connected to each other by two transpalatal arches. Hooks for the attachment of the facemask arose from the acrylic bite blocks bilaterally and ended at the canine region. In the palatal miniscrew group, two miniscrews [22] with a diameter of 1.6 mm and 10 mm length were inserted in the anterior region of that palate distal to the third palatal rugae and at the premolar region, 3 to 6 mm lateral to the midpalatal suture [24].

Custom-made cast metal caps were fabricated in the laboratory to fit the miniscrew head; these caps were used as a transfer coping during impression making to provide accurate replication of the mini screw position and direction during laboratory procedures. The cast metal caps were soldered to the anterior transpalatal arch of the intra-oral appliance to be cemented over the miniscrew to provide skeletal anchorage.

Patients of both groups were instructed to wear facemask for 12 hours per day [25]. The force magnitude was measured using a force gauge and was set at 380 g to 400 g per side [1,26–30]. The force was directed downward at an angle of 30° to the occlusal plane [25].

Routine orthodontic records were taken for each patient before and after treatment. Lateral cephalometric radiographs were used to evaluate the changes in the dentoskeletal parameters in both groups. Several dentoskeletal reference points and landmarks were used in study in both groups. (Table1)

TABLE (1) Dentoskeletal landmarks used in the study.

Landmark	Definition
S	The center of Sella turcica.
N	The most anterior point of the nasofrontal suture in the midsagittal plane.
Point A	The deepest point of the curve of the maxilla between the anterior nasal spine and the dental alveolus.
Point B	The deepest point on the bony curvature between the crest of the alveolus and pogonion.
Pg	The most anterior point on the mandibular symphysis.
Gn	It lies at the intersection of the mandibular plane (Go-Me) and the facial plane (Na-Pog).
Go	The midpoint of the angle of the mandible is found by bisecting the angle formed by the mandibular plane and the ramal line, which runs through Ar, and the lower tangent point of the posterior border of the ramus.
Me	The most inferior point on the symphyseal outline
ANS	The tip of the anterior nasal spine
PNS	The tip of the posterior nasal spine.
Co	The most posterior-superior point on the head of the mandibular condyle.
Pg'	The soft tissue pogonion is the most prominent or anterior point on the soft-tissue chin in the midsagittal plane.
Sn	A point located at the junction between the lower border of the nose and the beginning of the upper lip at the midsagittal plane.
Pn	The most prominent or anterior point of the nose.
Ls	A point indicating the mucocutaneous border of the upper lip is usually the most anterior point in the profile view.
Li	The most anterior lower lip points in the profile view.

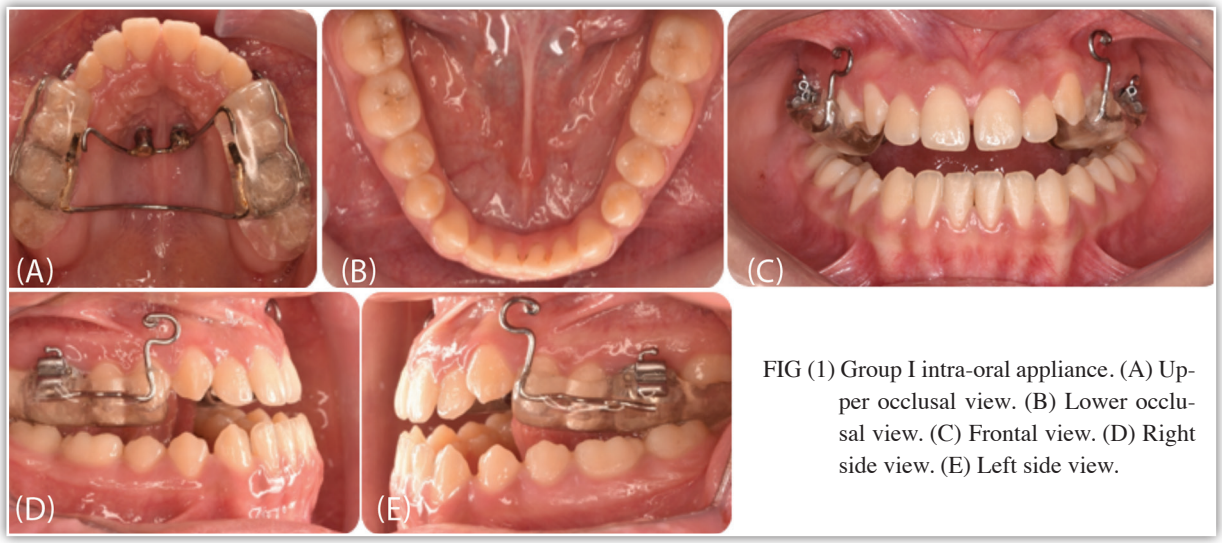

FIG (1) Group I intra-oral appliance. (A) Upper occlusal view. (B) Lower occlusal view. (C) Frontal view. (D) Right side view. (E) Left side view.

FIG (2) Right and left extra-oral photos with facemask. (C) Right profile view. (D) Left profile view

Statistical Analysis

Data were collected, coded and analyzed with the Statistical Package for Social Science (SPSS) software for Windows (SPSS Version 23, Inc., Chicago, Illinois, USA). The distribution of quantitative data was tested by Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. Data were statistically described as mean, standard deviation, 95% confidence interval (95% CI), standard error of mean, and mean differences i.e. T2-T1 changes. The data were then checked for pre-treatment equivalence between the two studied groups with independent sample t-test. Paired t-test was used to compare the changes within each group before (T1) and after facemask therapy (T2). Additionally, independent sample t-test was used to compare the two studied groups according to the amount of change (T2-T1) in the analyzed variables. The significance level was set at $p \leq 0.05$.

TABLE (2) Definitions of dentoskeletal measurements used in the study

Measurement	Definition
SNA (°)	The angle between 3 landmarks S, N, and A points, determining the anteroposterior position of the maxilla relative to the cranial base.
SNB (°)	The angle between 3 landmarks S, N, and B point, determine the anteroposterior position of the mandible relative to the cranial base.
ANB (°)	The angle between 3 landmarks, A point, N and B point, determining the anteroposterior relation between the maxilla and the mandible relative to the cranium
A-NV (mm)	The linear distance measured between point A and Nv line, measuring the anteroposterior position of the maxilla relative to the Nasion vertical line.
B-NV(mm)	The linear distance measured between point B and the Nv line, determining the anteroposterior position of the mandible relative to the Nasion vertical line.
Co-A (mm)	The average of the bilateral linear distance between Co and A points, measuring the effective mid-facial length.
Co-Gn (mm)	The linear distance between points Co and Gn, measuring the effective mandibular length.
MP-FHP (°)	The angle between FHP and the MP.
U1-FHP (°)	The angle formed between the FHP and the long axis of the most protruded upper incisor.
L1-FHP (°)	The angle formed between the FHP and the long axis of the most protruded lower incisor.
L1-MP (°)	The angle formed between the MP and the long axis of the most protruded lower incisor.
U1-L1 (°)	The angle formed between UI and LI long axes.

RESULTS

During the course of the study, 1 patient from each group (2 females) were excluded because of repeated missing appointments. However, the remaining 14 patients (9 males and 5 females) had completed the study.

Kolmogorov-Smirnov and Shapiro-Wilk tests show that the data was normally distributed. Accordingly, parametric tests were used for statistical evaluation. Systematic error was assessed with paired t-test, and random error was assessed with the coefficient of reliability between the first measurement (data of the total sample) and the 2nd measurements. No statistically significant differences were found between 1st and 2nd measurements (p>0.05).

1. Comparison of lateral cephalometric dentoskeletal measurements before (T1) and after (T2) facemask within each group:

Tables (3&4) show a comparison of lateral cephalometric skeletal measurements before (T1) and after (T2) facemask therapy in both groups using paired t-test. In both groups, the anteroposterior maxillary position improved, as revealed by the increase in SNA, Max Depth, A/Na V, and Co-A; however, a statistically significant difference was found in SNA only in group I (P≤ 0.05) and in SNA, Max Depth, and A/Na V in group II (P ≤ 0.01).

On the other hand, the anteroposterior measurements of the mandibular sagittal position decreased, denoting mandibular backward positioning. However, the statistically significant differences occurred in both groups were in Pg/ Na v and facial angle in addition to SNPg in Group II only (P≤ 0.05). Also, there was a significant increase in the Y-axis and FMA in both groups after treatment (P≤ 0.05).

Comparison of the dental measurements at T1 and T2 within both groups using paired t-test showed that the upper incisors' inclination (U1-FHP) changes were statistically non-significant(P≤0.05) while the lower incisors' inclination (L1-MP) was significantly decreased in both groups (P≤0.01).

2. Comparison of changes in dentoskeletal (T2-T1) measurements between SAFM group and control group using independent sample t-test.

Table (5) shows a comparison of changes (T2-T1) in dentoskeletal measurements between Group I and control Group II using independent sample t-test. The results show non-significant differences between both groups regarding all studied parameters except SNA, Max Depth, and A/Na V, which revealed a significant difference (P≤0.05).

TABLE (3) Comparison of dentoskeletal measurements before and after facemask therapy in the Group I (N=7) using paired t-test:

Measurement	T1		T2		Mean diff.	SE	95% CI.		t-value	p-value	Sig.
	Mean	SD	Mean	SD			UL	LL			
SNA	79.91	3.22	81.39	3.35	1.47	0.43	2.52	0.42	3.43	.014	**S**
Max Depth	88.59	2.65	89.09	4.16	0.50	0.75	2.33	-1.33	0.67	.529	NS
A/Na V	-1.36	2.38	-0.66	3.98	0.70	0.77	2.57	-1.17	0.92	.395	NS
Co-a	74.56	3.07	76.29	4.27	1.73	0.73	3.52	-0.06	2.37	.056	NS
SNB	81.77	4.57	80.00	3.39	-1.77	0.74	0.04	-3.58	-2.39	.054	NS
PgNaV	0.01	3.96	-4.31	5.25	-4.33	1.40	-0.90	-7.76	-3.09	.021	**S**
Facial angle	90.04	2.39	87.57	2.79	-2.47	0.76	-0.62	-4.32	-3.27	.017	**S**
SNPg	81.46	5.02	79.80	3.77	-1.66	0.75	0.17	-3.48	-2.22	.068	NS
Co-gn	101.87	3.07	101.26	6.54	-0.61	1.56	3.21	-4.44	-0.39	.708	NS
ANB	-1.93	3.05	1.46	3.02	3.39	0.84	5.45	1.32	4.02	.007	**HS**
AO-BO	-5.64	3.04	-1.00	1.73	4.64	1.20	7.58	1.71	3.87	.008	**HS**
Angle of convexity	-3.49	8.38	3.24	7.73	6.73	1.76	11.03	2.43	3.83	.009	**HS**
Y-axis	56.34	2.29	59.60	3.00	3.26	0.76	5.11	1.40	4.29	.005	**HS**
Facial axis	94.09	5.11	90.64	4.64	-3.44	1.12	-0.70	-6.18	-3.08	.022	**S**
FMA	25.79	2.06	28.63	3.02	2.84	0.83	4.88	0.80	3.41	.014	**S**
Pal-Mandibular	25.84	4.34	29.97	3.99	4.13	1.18	7.01	1.25	3.51	.013	**S**
SN-Mandibular	34.30	4.77	36.40	4.39	2.10	0.77	3.99	0.21	2.72	.035	**S**
SN-Palatal	8.46	3.36	6.71	2.53	-1.74	0.50	-0.53	-2.96	-3.51	.013	**S**
Cranial Base angle	132.29	5.93	131.47	4.54	-0.81	0.85	1.26	-2.89	-0.96	.374	NS
Gonial angle	128.59	5.88	127.24	8.67	-1.34	1.65	2.69	-5.38	-0.82	.446	NS
S-Go / N-Me P / A	61.90	4.30	60.97	3.30	-0.93	0.92	1.33	-3.19	-1.01	.353	NS
ANS-Me / N-Me L / A	54.21	1.98	55.66	1.01	1.44	0.54	2.76	0.13	2.68	.036	**S**
Ll- Mand	87.91	3.94	81.71	3.67	-6.20	1.40	-2.77	-9.63	-4.42	.004	**HS**
L1- Frank	66.80	5.57	69.37	4.98	2.57	1.93	7.30	-2.16	1.33	.231	NS
L1 - N-B angle	24.13	4.69	18.26	4.35	-5.87	1.20	-2.94	-8.81	-4.89	.003	**HS**
L1 - A-Pg mm	6.36	1.49	4.71	3.15	-1.64	1.28	1.48	-4.77	-1.28	.246	NS
UI- SN	106.23	7.34	108.37	7.20	2.14	1.52	5.87	-1.58	1.40	.209	NS
U1-Frank	114.76	4.47	116.19	5.99	1.43	1.84	5.93	-3.07	.77	.467	NS
UI-Palatal	113.69	8.16	114.99	6.63	1.30	1.93	6.03	-3.43	.67	.526	NS
UI-NA angle	26.17	6.24	26.89	6.86	0.71	1.55	4.51	-3.08	.46	.661	NS
UI-A Pog mm.	2.19	2.15	5.27	2.09	3.09	0.29	3.79	2.38	10.70	.000	**HS**

SE= Standard error, P= Probability level, NS= Non-significant p >0.05, S= statistically significant at p ≤ 0.05, HS= highly significant at p ≤ 0.01, SD= standard deviation, CI= Confidence interval, UL=upper limit, LL= lower limit.

TABLE (4) Comparison of dentoskeletal measurements before and after facemask therapy in Group II (N=7) using paired t-test:

Measurement	T1		T2		Mean diff.	SE	95% CI.		t-value	p-value	Sig.
	Mean	SD	Mean	SD			UL	LL			
SNA	79.21	3.91	82.24	3.97	3.03	0.43	4.08	1.98	7.039	.000	**HS**
Max Depth	86.74	2.47	89.44	3.07	2.70	0.40	3.67	1.73	6.832	.000	**HS**
A/Na V	-3.10	2.28	-.514	2.78	2.59	0.33	3.39	1.78	7.892	.000	**HS**
Co-a	76.83	4.38	79.01	5.61	2.19	1.03	4.71	-0.33	2.122	.078	NS
SNB	83.67	3.96	82.01	3.46	-1.66	0.69	0.03	-3.35	-2.399	.053	NS
PgNaV	3.10	3.98	-.286	4.99	-3.39	1.16	-0.54	-6.23	-2.909	.027	**S**
Facial angle	91.76	2.30	89.76	2.86	-2.00	0.68	-0.34	-3.66	-2.957	.025	**S**
SNPg	84.04	3.38	82.51	2.94	-1.53	0.62	-0.01	-3.05	-2.465	.049	**S**
Co-gn	107.80	6.66	107.83	7.66	0.03	1.15	2.84	-2.78	.025	.981	NS
ANB	-4.44	0.87	0.24	2.56	4.69	0.75	6.52	2.85	6.258	.001	**HS**
AO-BO	-8.27	3.64	-1.771	4.02	6.50	0.50	7.73	5.27	12.975	.000	**HS**
Angle of convexity	-10.79	3.04	-.729	6.65	10.06	1.47	13.66	6.46	6.839	.000	**HS**
Y-axis	57.80	4.63	60.40	4.62	2.60	0.55	3.94	1.26	4.739	.003	**HS**
Facial axis	94.40	2.73	91.87	3.43	-2.53	0.65	-0.93	-4.12	-3.878	.008	**HS**
FMA	25.19	1.48	27.26	2.15	2.07	0.52	3.33	0.81	4.012	.007	**HS**
Pal-Mandibular	22.90	4.09	25.04	3.86	2.14	1.21	5.11	-0.82	1.768	.128	NS
SN-Mandibular	32.77	2.37	34.54	3.32	1.77	0.74	3.59	-0.04	2.390	.054	NS
SN-Palatal	9.91	3.63	8.57	3.35	-1.34	0.57	0.05	-2.74	-2.360	.056	NS
Cranial Base angle	131.61	5.01	131.57	4.59	-0.04	0.53	1.26	-1.34	-.081	.938	NS
Gonial angle	127.06	5.76	125.46	7.16	-1.60	1.17	1.27	-4.47	-1.364	.222	NS
S-Go / N-Me P / A	63.70	1.45	62.30	2.04	-1.40	0.79	0.54	-3.34	-1.769	.127	NS
ANS-Me / N-Me L / A	53.37	2.56	55.13	2.53	1.76	0.34	2.60	0.91	5.094	.002	**HS**
Ll- Mand	84.83	6.18	76.54	8.01	-8.29	1.38	-4.91	-11.66	-6.001	.001	**HS**
L1- Frank	70.14	6.34	76.03	8.06	5.89	1.64	9.90	1.87	3.587	.012	**S**
L1 - N-B angle	21.39	4.73	13.20	6.90	-8.19	1.43	-4.68	-11.69	-5.710	.001	**HS**
L1 - A-Pg mm	7.29	1.45	3.07	3.79	-4.21	1.40	-0.79	-7.64	-3.013	.024	**S**
UI- SN	112.19	3.46	111.06	5.79	-1.13	1.56	2.69	-4.94	-.724	.496	NS
U1-Frank	118.63	1.69	118.11	5.55	-0.51	1.75	3.78	-4.81	-.293	.779	NS
UI-Palatal	120.40	2.57	119.34	5.03	-1.06	1.52	2.65	-4.76	-.698	.512	NS
UI-NA angle	31.31	1.64	28.83	5.72	-2.49	1.66	1.58	-6.55	-1.496	.185	NS
UI-A Pog mm.	2.37	0.92	4.87	1.82	2.50	0.45	3.59	1.41	5.610	.001	**HS**

SE= Standard error, P= Probability level, NS= Non significant p >0.05, S= statistically significant at p ≤ 0.05, HS= highly significant at p ≤ 0.01, SD= standard deviation, CI= Confidence interval, UL=upper limit, LL= lower limit.

TABLE (5) Comparison of changes (T2-T1) in dentoskeletal measurements between Group I and Group II using independent sample t-test.

Measurement	Group I (n = 7)		Group II (n = 7)		p-value	Sig.
	Mean	SE	Mean	SE		
SNA	1.47	0.43	3.03	0.43	.025	**S**
Max Depth	0.50	0.75	2.70	0.40	.023	**S**
A/Na V	0.70	0.77	2.59	0.33	.043	**S**
Co-a	1.73	0.73	-0.61	1.56	.724	NS
SNB	-1.77	0.74	-1.66	0.69	.912	NS
PgNaV	-4.33	1.40	-3.39	1.16	.614	NS
Facial angle	-2.47	0.76	-2.00	0.68	.651	NS
SNPg	-1.66	0.75	-1.53	0.62	.897	NS
Co-gn	-0.61	1.56	0.03	1.15	.746	NS
ANB	3.39	0.84	4.69	0.75	.271	NS
AO-BO	4.64	1.20	6.50	0.50	.178	NS
Angle of convexity	6.73	1.76	10.06	1.47	.172	NS
Y-axis	3.26	0.76	2.60	0.55	.496	NS
Facial axis	-3.44	1.12	-2.53	0.65	.494	NS
FMA	2.84	0.83	2.07	0.52	.446	NS
Pal-Mandibular	4.13	1.18	2.14	1.21	.263	NS
SN-Mandibular	2.10	0.77	1.77	0.74	.764	NS
SN-Palatal	-1.74	0.50	-1.34	0.57	.606	NS
Cranial Base angle	-0.81	0.85	-0.04	0.53	.456	NS
Gonial angle	-1.34	1.65	-1.60	1.17	.901	NS
S-Go / N-Me P / A	-0.93	0.92	-1.40	0.79	.705	NS
ANS-Me / N-Me L / A	1.44	0.54	1.76	0.34	.632	NS
Ll- Mand	-6.20	1.40	-8.29	1.38	.310	NS
L1- Frank	2.57	1.93	5.89	1.64	.216	NS
L1 - N-B angle	-5.87	1.20	-8.19	1.43	.239	NS
L1 - A-Pg mm	-1.64	1.28	-4.21	1.40	.200	NS
UI- SN	2.14	1.52	-1.13	1.56	.159	NS
U1-Frank	1.43	1.84	-0.51	1.75	.460	NS
UI-Palatal	1.30	1.93	-1.06	1.52	.356	NS
UI-NA angle	0.71	1.55	-2.49	1.66	.184	NS
UI-A Pog mm.	3.09	0.29	2.50	0.45	.291	NS

SE= Standard error, mm=millimeters, P= Probability level, NS= Non significance p >0.05, N= Number, Sig=Significant.

DISCUSSION

One of the most challenging malocclusions to correct in orthodontics is skeletal Class III. The difficulty of this issue is exacerbated by the continued growth of the craniofacial structure after therapy, particularly when the mandible is identified as the primary offending jaw [31,32]. The stability of the results of patients who have received treatment is grately jeopardized by the rate and pattern of growth that occurs following the orthopedic phase. As a result, it is suggested that annual checkups be made to look for any early indications of relapse and that patients' parents be thoroughly informed of any potential post-protraction effects [26,33]. Various patterns and combinations of maxillary and mandibular positions can be the result of Class III malocclusion. These patterns include mandibular prognathism with maxillary normal position, maxillary retrognathism with normal mandibular position, normal maxilla and mandible, a combination of maxillary retrognathism and mandibular prognathism, and finally a bimaxillary prognathism or retrognathism. These skeletal patterns vary depending on the racial and ethnic groups[4,34]. Maxillary retrognathism shows a prevailing frequency as the main contributor to Class III malocclusion [4].

In this study, all participating patients used a protraction facemask as the first stage for skeletal Class III patients with maxillary retrognathism. The present inclusion criteria were based on previous studies [20,22]. In the present investigation, a petite facemask was used as it is more appealing to the patients because of its small size and hence it is more likely to be tolerated. The assessment of skeletal age was performed via the evaluation of cervical vertebral maturation method, according to Baccetti et al [23].

In the present study, the intra-oral appliance consisted of an acrylic cap splint encompassing as many posterior teeth as feasible to reinforce the anchorage and to help protraction by disarticulation and removal of interferences during occlusion. To ensure the rigidity of the device, two 1.1 mm stainless steel wires joined the acrylic cap splints to one another. The acrylic cap splints were then finished up with two hooks one on either side that ended at the canine region for elastic attachment. The miniscrews were inserted in the anterior region of the palate lateral to the mid-palatal suture and at the premolar region. This site was chosen as it offers the maximum thickness of bone, does not contain vital structures and so offers a greater success rate for the miniscrews [24]. The protraction phase was not preceded by rapid palatal expansion based on the study by zhang et al.[9] which concluded that both facemask and facemask with rapid palatal expansion are effective treatment techniques for Class III correction. The inclusion of a Class III control group would have been advantageous to differentiate between changes resulting from growth and those of the treatment. However, it was not ethical to keep a Class III patients without treatment. So, the current study did not include a passive control group.

The current study started with 16 patients but unfortunately, 2 patients, one from each group, dropped out due to non-compliance and repeated missing appointments.

Skeletal and dental effects of facemask therapy with and without skeletal anchorage:

In the current study, lateral cephalometric images were obtained at T1 and T2, to assess the dentoskeletal changes following facemask therapy in both groups, with and without skeletal anchorage.

A. Maxillary skeletal changes:

Facemask therapy is supposed to result in maxillary forward movement, the results of the current study revealed a significant maxillary advancement in group I, which is concurrent with the previous studies of Seiryu et al.[22], Ge et al.[20] and, Aglarci et al.[35]. On the other hand, group II exhibited a highly signicifcant maxillary advancement, this is in accordance with the results of De Souza et al [36], Seiryu et al. [22], Ge et al. [20], Maino et al [37], Bozkaya

et al. [16], Sar et al [38], Al-Mozany et al [39] and Lee et al. [40]. The rate of maxillary protraction in skeletally anchored FM group in the current study is 0.43 mm per month which is similar to the rate reported by Kircelli and Pektas [15] 0.44 mm per month and Sar et al.[41] 0.45 mm per month. Moreover, the rate in the current study is higher than that reported by Aglarci et al. [35] 0.29 mm per month, Cevidanes et al.[42] 0.31 mm per month and Nguyen et al. [43] 0.31 mm per month. Comparison of treatment changes between both groups showed a more favorable maxillary skeletal effects in group II regarding the anteroposterior position which is in accordance with those of Seiryu et al.[22], Aglarci et al. [35] and Sar et al. [41] who found that the amount of maxillary skeletal advancement was doubled when a skeletal anchorage is used. This is most probably due to the direct application of force on the maxillary skeletal base without being consumed in the periodontal ligaments or tooth movement.

B. Mandibular skeletal changes:

Concerning the mandibular skeletal changes, the current study revealed non-significant mandibular retrusion in group I, this was similar to the findings of Ge et al.[20], Ngan et al.[10] and Vaughn et al.[44]. Also, group II showed a non-significant mandibular retrusion after facemask therapy, this is in accordance with the results of Nienkemper et al. [45], Maino et al. [37], Ge et al.[20], and Sar et al [38]. The mandibular retrusion that resulted after treatment is caused by the forces on the chin from the facemask chin pad. The intergroup comparison revealed a non-significant difference between the two groups regarding the mandibular skeletal changes after treatment. These results concur with the results of Ge et al.[20] and Seiryu et al.[22]. Because there is no difference in the technique used in the two groups with regard to the mandible, and the effect on the mandible is correlated with the amount of protraction force applied rather than the anchorage strength, the non-significant differences in mandibular sagittal changes between the two groups were expected.

C. Maxillomandibular changes:

The aim of orthopedic treatment of skeletal Class III malocclusion is to align the skeletal bases and achieve good relation between the maxilla and the mandible in order to facilitate the orthodontic treatment. The current study results regarding the maxillomandibular relation after facemask therapy revealed enhancement and improvement of the maxillomandibular relationship mostly due to maxillary advancement and partially due to mandibular retrusion. Both treatment groups exhibited highly significant correction of the maxillomandibular relation after treatment. This is similar to the findings of Ge et al. [20] and Lee et al. [46]. However, when the treatment changes of the two groups were compared, the difference between the two groups was non-significant. This finding concurs with the results of Ge et al. [20], Lee et al. [47], Jamilian et al.[48], and Seiryu et al.[22].

D. Vertical skeletal changes:

Regarding the vertical dimension, both groups revealed a highly significant increase in the vertical dimension after the facemask therapy. This resulted from the pressure on the chin from the facemask that caused a clockwise mandibular rotation and hence increased the vertical dimension. The results of the current study regarding the vertical dimension are similar to those of Ge et al.[20] and Lee et al.[40]. These results contradict those of De Clerck et al.[49] who found a non-significant difference in the vertical dimension after treatment and those of Elnagar et al.[17] who found a significant closure of the mandibular plane angle. This contradiction is attributed to the different treatment techniques as they used miniplates with Class III elastics which provides better control of the vertical dimension.

The intergroup comparison revealed a non-significant difference regarding the amount of change in the vertical dimension between the two groups. This is in accordance with the results of Ge et al [20] and Seiryu et al [22].

Regarding the palatal plane, a counterclockwise rotation occurred in both groups. However, this counterclockwise rotation was significant in group I similar to Sar et al [41], and non-significant in group II. This non-significant anterior rotation of the palatal plane in group II is similar to the results of Sar et al. [41] and Eid et al.[50]. Comparing the changes in the palatal plane in both groups revealed a non-significant difference resembling the findings of Ge et al.[20] and Seiryu et al.[22].

E. Changes in the upper incisors

In the current study, the upper incisor inclination increased in group I after treatment. However, this proclination was non-significant. This is similar to the findings of Seiryu et al [22] and Ge et al [20]. On the contrary, the upper incisors were retroclined after treatment in group II. However, this retroclination was non-significant and similar to the findings of Seiryu et al [22] and Maino et al[37]. This retroclination of the maxillary incisors may be due to the increased amount of maxillary advancement and improvement in the maxillomandibular relation and hence the need for dentoalveolar compensation is reduced. Comparison of the upper incisor changes between the two groups showed a non-significant difference although they were proclined in group I and retroclined in group II. This non-significant difference is similar to what was found by Seiryu et al. [22] and Ge et al.[20].

In group I, there was a highly significant advancement of the maxillary incisors after treatment. Similarly, group II showed a highly significant advancement in the maxillary incisor position in relation to A-pogonion. Although, the maxillary incisors in group II were retroclined; this significant advancement of the maxillary incisors may be due to the marked advancement of the maxilla in group II. The difference between the treatment effects in Group I and Group II regarding the maxillary incisor position was non-significant.

F. Changes in the lower incisors

In group I, there was a highly significant retroclination of the mandibular incisors in relation to the mandibular plane after the facemask therapy. Also, they were significantly backward positioned. This is in accordance with Ge et al. [20]. In group II, the lower incisors showed similar highly significant retroclined and also were significantly backward positioned, which is similar to the results of Ge et al. [20]. On the other hand, these results are contradictory with authors[17,42] used mini plates in maxilla and mandible with Class III elastics as the lower incisor inclination increased. This is due to the elimination of the pressure from the facemask chin pad that may impinge on the lower incisors.

The intergroup comparison revealed a non-significant difference in the degree of lower incisor inclination after treatment. This is concurrent with what was found by Ge et al.[20].

CONCLUSION

1. The use of the protraction facemask in conjunction with palatal miniscrews in the present sample of skeletal Class III malocclusion provided an improved anteroposterior maxillary advancement.
2. The protraction facemask with or without palatal miniscrews produced comparable increased vertical dimension subsequent to the selected observation period of the study.
3. The use of palatal miniscrews with protraction facemask not only prevented the unwanted maxillary incisor proclination but also resulted in their retroclination.
4. The mandibular effects of protraction facemask with or without palatal miniscrews were equivalent as these effects are related to the force magnitude rather than the anchorage value.
5. Regarding the mandibular incisors, both approaches of maxillary protraction revealed equivalent retroclination.

6. The use of skeletal anchorage could be utilized in cases where the deciduous teeth are missing, or their roots are progressively resorbed.

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