

Comparing the efficiency of maxillary protraction using digital cooperation monitoring in ages 4–7 and 8–11: a prospective study

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Objectives: This study compares the effectiveness of face mask therapy applied after rapid maxillary expansion (RME) in 4- to 11-year-old patients with objective co-operation data collected using thermal sensors. The null hypothesis was that there would be no difference in the effectiveness of the maxillary protraction.

Materials and method: Initial and post-treatment lateral cephalometric radiographs were taken of patients with maxillary retrognathia, aged between 4 to 7 years (6.1 ± 1.88 , $n = 13$) and 8 to 11 years (9.4 ± 1 , $n = 12$) of age. An RME was performed for at least 10 days. The face mask protraction force was set to 450 g per side, and the recommended usage was 10 hr per day. TheraMon® microsensors were integrated into the face mask.

Results: The daily usage was significantly higher in the younger age group (8.9 ± 1.8 hr) compared to the older group (7.1 ± 0.9 hr). The SNA angle, A-Nasionperp (mm), ANB angle, Wiits (mm), maxillary depth, ANS-Me (mm), the molar relationship (mm) and overjet (mm) significantly increased in both groups. Co-A (mm), the saddle angle, articular angle and UL-E Line (mm) showed a significant increase only in the older group, while the L1-A/Pg decreased significantly. The SNB angle decreased significantly only in the younger group. There was no statistically significant difference in the delta values between the two groups.

Conclusion: The null hypothesis was partly rejected since no difference was observed in the examined skeletal and soft tissue parameters.

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Introduction

Coupled with vertical and transverse discrepancies, a Class III malocclusion can be associated with a maxillary deficiency, a mandibular excess, or a combination of both. It has been reported that in 60% of the Class III malocclusion cases, maxillary deficiency is a contributing factor.¹ A range of anatomical factors, including the cranial base, the maxilla and the mandible, plus the respective dentoalveolar compartments, might result in a Class III malocclusion.^{2,3}

Orthopaedic correction is performed in growing patients when the skeletal Class III malocclusion is

diagnosed as maxillary retrognathia.⁴ A face mask is the most commonly used extraoral appliance for the correction of mid-face dysplasia.^{5,6} Whether applied in conjunction with a maxillary expansion appliance, a face mask has demonstrated efficacy in the correction of a mild to moderate skeletal Class III malocclusion linked to a retrognathic maxilla.⁷⁻⁹ Continued daily use is recommended for periods ranging from 12 to 24 hr, and the force applied varies between 300 and 600 grams unilaterally.^{10,11} However, effective results in Class III correction have also been reported in patients who exclusively use a face mask.¹²

The timing of treatment is an important factor in the success of the facemask therapy.^{13,14} While a successful outcome can be achieved during the late mixed or early permanent dentition, better results are reported in the primary or early mixed dentition periods.¹⁵ Studies have further shown that changes achieved through treatment during the primary dentition period are more effective on skeletal structures compared to those achieved during the mixed dentition period.^{16,17}

The rate of growth during the postnatal period varies by age and by individual. The general belief is that face mask application should begin between the ages of 8 and 11 years, which corresponds to the period prior to or during the prepubertal growth spurt.^{6,18–25} However, it is believed that correcting a developing skeletal malocclusion during the growth spurt associated with the “transition to the mixed dentition”, generally understood to occur between the ages of 4 and 7 years, may facilitate the development of the surrounding tissues, particularly the mandible, in a more appropriate functional envelope.²⁶ There is limited information regarding the use of a face mask during the growth spurt occurring between the ages of 4 and 7 years. However, in a meta-analysis conducted by Kim et al., it was reported that the skeletal impact of maxillary protraction performed before the age of 10 years was much greater than that achieved at any other time.⁶ Kapust et al. observed significant differences in apical base change and total molar correction only in younger patients aged between 4 and 10 years treated using a face mask and maxillary expansion. Those changes were statistically insignificant in the older group aged between 10 and 14 years.¹⁸ According to a systematic review, over 75% of Class III malocclusion cases treated using RME and face mask therapy were found to be successful at a review five years following the completion of orthopaedic treatment.⁹ Furthermore, a number of studies have suggested that long-term research is still required to determine the success of early orthopaedic treatment of Class III patients related to growth change.^{14,27}

The aim of the present study was to evaluate the effects of face mask treatment applied after rapid maxillary expansion in two different age groups (4–7 and 8–11 years) with a daily usage time of 10 hr and a unilateral applied force of 350–400 g. Since patient compliance significantly affects treatment outcome,

microsensors were integrated into the face masks to objectively record daily usage time. Therefore, it was also aimed to compare the co-operation between the younger and older age groups.

Assuming that both patient groups received the same level of force and were instructed with the same daily usage and information, the null hypothesis stated that the younger group would show greater changes in skeletal and soft tissue parameters and show greater co-operation compared to the older group.

Materials and methods

The study was approved by the Bezmialem Vakif University Clinical Research Ethics Committee with decision number E.91018 and was conducted in the Department of Orthodontics at Bezmialem Vakif University. Written informed consent forms were signed by the patients and their parents.

The study included individuals aged between 4 and 11 years who exhibited a Class III skeletal malocclusion diagnosed as maxillary retrognathia. All of the included patients had a negative or edge-to-edge incisor relationship and an ANB value $<0^\circ$, Class III molar and canine relationships, no history of previous orthodontic treatment, and no systemic disease or syndrome that could contra-indicate orthodontic treatment. Patients who were not within the appropriate age range, those who had a family history of severe mandibular prognathism, and patients who could not co-operate were excluded from the study. A functional Class III malocclusion was detected in some of the patients in the study sample, but the presence of maxillary retrognathia and an edge-to-edge or negative overjet with the mandible in the retruded position was accepted as an inclusion criterion.

It was aimed to compare two groups formed by younger and older children between the ages of 4 and 11 years. According to a power analysis and taking into account the significant change in the SNA angle with a 95% confidence level, a type I error of 0.05 and 80% power, determined that at least 11 people were needed in each group.²⁸ The first group of children consisted of those above 4 years and under 7 years and 6 months of age, while the second group included those over that age, and up to 11 years and 6 months. Twenty-five people in all, accounting for potential losses, were included in the study.



Figure 1. Pre-treatment intra- and extra-oral records of a 5-year-old patient.

Routine orthodontic records, panoramic radiographs, and lateral cephalometric radiographs were collected (Figure 1). The absence of dental or bony anomalies was verified using the panoramic x-rays. A cephalometric analysis formed with parameters from different authors was performed using the Nemoceph® software (Copyright© NEMOTEC, Madrid, Spain) by one examiner (KY) (Table I). The skeletal, dental, and soft tissue parameters were determined on the lateral cephalometric films taken before treatment (T0) and after using a face mask (T1).

To determine the method error, 10 randomly selected cephalograms were retraced by the same author (KY)

after an interval of 3 weeks. Intra-operator correlation coefficients were found to lie between 0.91 and 0.95.

An acrylic cap type expansion appliance was prepared using the Leone A2620 expansion screw (Leone Orthodontic Products, Sesto Fiorentino, Florence, Italy) for each group. Hooks were added distal to the lateral incisors. After occlusal adjustments, the RME appliance was bonded using a glass ionomer cement (Multi-cure Glass ionomer/3M™-Unitek™-Monrovia, USA). The RME appliance was applied to the deciduous teeth of 5 patients (3 males and 2 females) between the ages of 4 and 7, as their permanent molars had not yet erupted. The families were instructed to activate the screw two quarter turns a

Table 1. The skeletal, dental, and soft tissue parameters

Sagittal parameters	Norms
SNA (°)	82° ± 2
Maxillary High (°)	53 ± 3
Maxillary Depth (°)	90 ± 3
A-Nasionperp (mm)	0 ± 3
Co-A (mm)	81
SNB (°)	80° ± 2
Pg-Nasionperp (mm)	-4 ± 5
Co-Gn (mm)	99-102
Maxillomandibular relationship parameters	
ANB (°)	2° ± 2
Wits (mm)	-1 ± 3
Vertical parameters	
S-N (mm)	73.2 ± 3
ANS-Me (mm)	57-58
FH-Palatal Plane (°)	4 ± 3
SN-GoGn (°)	32° ± 7
FMA (°)	25° ± 5
Y Axis (°)	59° ± 6
Saddle Angle (°)	122 ± 5
Articular Angle (°)	143 ± 6
Gonial Angle (°)	130 ± 7
N-Me (mm)	114.4 ± 5
S-Go (mm)	74.4 ± 4
Dental parameters	
U1/SN (°)	102° ± 5
U1/PP (°)	110° ± 5
U1-A/Vert (mm)	4 mm ± 3
U1/Occlusal Plane (°)	57.8 ± 3
L1-A/Pg (mm)	2.7 mm ± 1
IMPA (°)	90° ± 5
Interincisor Angle (°)	130° ± 6
Holdaway Ratio	1/1 ± 0.5
Molar Relation (mm)	-3 ± 3
Overjet (mm)	2.5 ± 2.5
Overbite (mm)	2.5 ± 2.5
Soft tissue Parameters	
Nasolabial Angle (°)	104° ± 8
UL-E Line (mm)	-4 ± 2
LL-E Line (mm)	-2 ± 2

day (2 x ¼ turn = 0.5 mm), every morning and every evening for the first 10 days. In patients who did not need expansion, activation was still performed for 10 days to ensure suture mobilisation. In cases in which further expansion was required, RME activation was continued until the necessary amount of expansion was achieved (Figure 2). Mid-palatal sutural opening was not monitored radiologically, but midline diastema formation or widening was observed in all children. An expansion of 10.8 ± 2.4 days was carried out on average for the 4–7 age group and 10.8 ± 1.8 days on average for the 8–11 age group.

After the RME phase, a face mask (HUBIT, Seoul, Korea) was applied with traction elastics orientated at an inclination of 30° from the face mask to the occlusal plane (Figure 3a). The elastic force exerted was measured with the help of an extraoral force gauge (CORREX, Bern, Switzerland) and adjusted to provide 450 grams of force on each side. All of the patients were instructed to wear the face mask for 10 hours a day.

In order to measure the duration of appliance use, microsenors (TheraMon® (MC Technology GmbH, Hargelsberg, Austria)) activated by body temperature were incorporated into the face mask's forehead pad (Figure 3b). The measurement frequency of the sensors was set to record every 15 minutes, the device type was set to "headgear", and the measured temperature range was between 28°C to 37°C. Each patient's identity was defined in the user account at <https://cloud.thera-mon.com/>, and the activated microsensor was matched with the patient's identity (Figure 4). Patients were followed by monthly checks, and the digital data recording compliance was stored in the TheraMon® (MC Technology GmbH, Hargelsberg-Austria) cloud.

Maxillary protraction was terminated with the achievement of a half-cusp to full-cusp Class II relationship of the canines and molars (Figure 5). At the end of the treatment, retention was provided by wearing a Bionator III at night. In some cases, a Y-plate appliance was inserted due to the need for upper incisor proclination, and in others, a Hawley appliance was placed as a space maintainer due to the early loss of primary teeth.

Statistical analysis was conducted using the Statistical Package for the Social Sciences version 24.0 (IBM SPSS Statistics 24; IBM Corp., Chicago, IL, USA) software. Parameters that were evaluated



Figure 2. Acrylic Cap Splint Rapid Maxillary Expansion Appliance.

and showed a normal distribution were presented as a mean $\pm$ standard deviation (SD), while parameters that did not show a normal distribution were presented as median, minimum, and maximum values. The distribution of the data was examined using the Shapiro–Wilk test. For parameters that did not show a normal distribution, group comparisons were conducted using the Mann–Whitney U test, and for parameters that showed a normal distribution, paired t tests within the groups and independent t tests between the groups were used for comparison. The distribution of gender was analysed using the chi-square test.

Results

The study started with 25 participants and ended with 11 in each group after three children who missed appointments on a regular basis were eliminated. All 22 patients followed the instructions and were treated successfully. Figure 6 displays the treatment flow chart.

Gender and treatment duration did not show any statistically significant difference between the 4–7 years and 8–11 years age groups (Table II). Daily usage time was recorded as 8.9 ± 1.8 hr for the 4–7 years group and 7.1 ± 0.9 hr for the 8–11 years group,

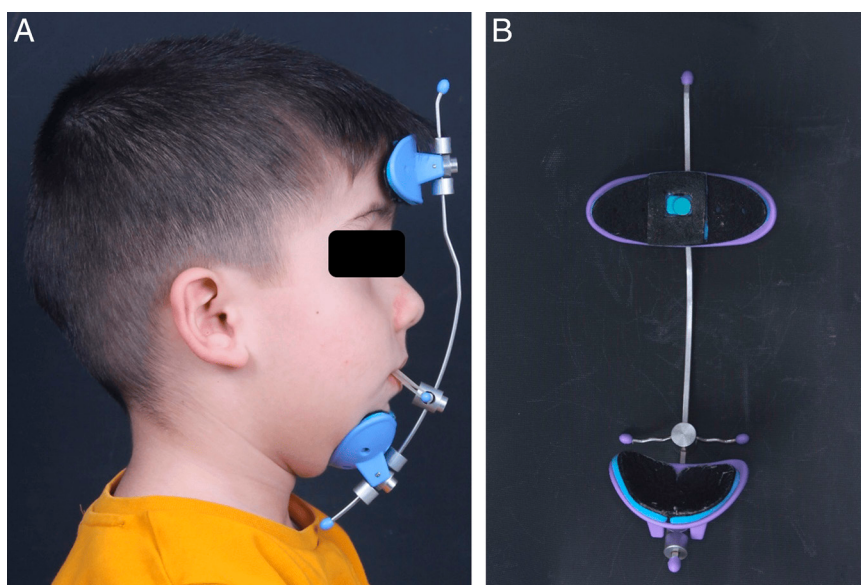


Figure 3. Application of the face mask (A) and the microsensor incorporation into the forehead pad (B).

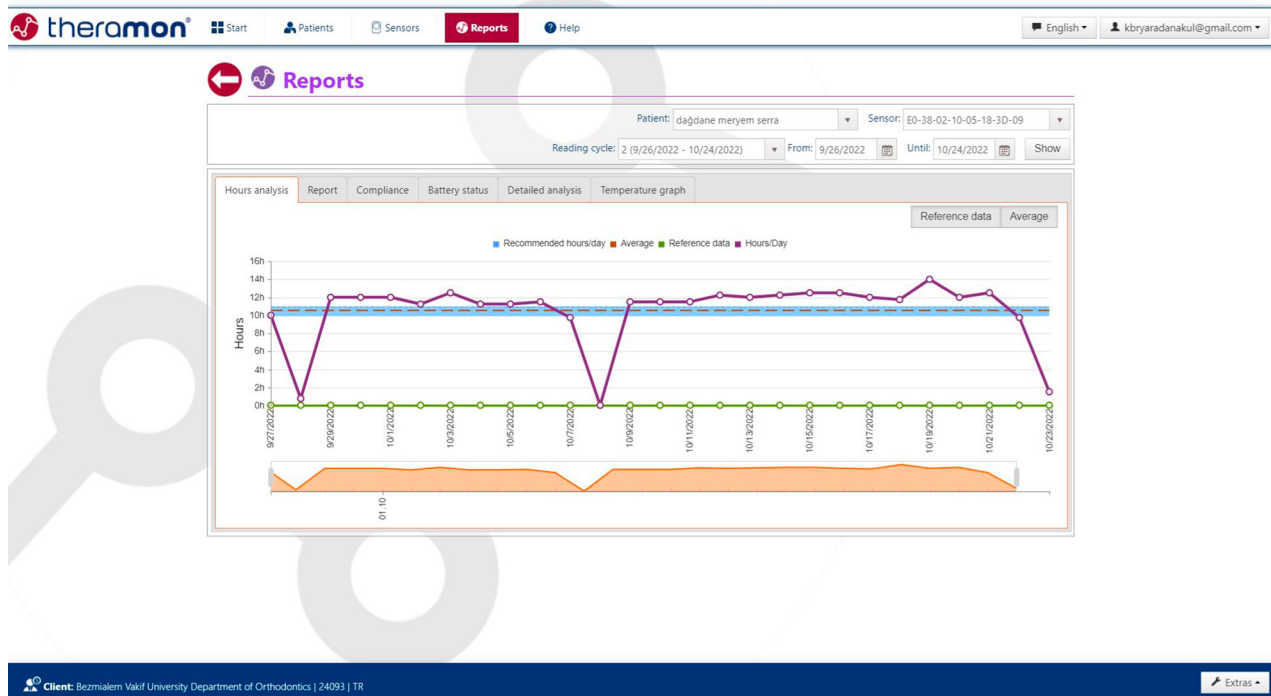


Figure 4. A patient's digital monitoring chart displaying the duration of appliance wear over a month.

and the between groups comparison revealed that co-operation was statistically greater in the younger group compared to the older (Table II).

In both groups, a statistically significant increase was recorded in the sagittal skeletal parameters, including the SNA angle, A-Nasion perp. (mm), ANB angle, Wits (mm), and maxillary depth (Table III, Table IV). The parameter Co-A (mm) showed a statistically significant increase only in the 8–11 years group (Table III). The SNB angle significantly decreased from T0 to T1 only in the 4–7 years group (Table IV). The vertical skeletal parameters, such as ANS-Me (mm) showed a statistically significant increase in both groups from T0 to T1 (Tables III, Table IV). The saddle and the articular angles showed a statistically significant increase from T0 to T1 only in the 8–11-year-old group (Table III). The N-Me (mm) and SN-GoGn values increased significantly from T0 to T1 only in the 4–7 years group (Table IV).

No other significant difference was observed in the soft tissue parameters, except for an increase in the UL-E Line (mm) parameter detected in the 8–11 age group (Table III, Table IV).

Statistically significant increases were observed in the parameters of molar relation (mm) and overjet (mm) in both groups (Table III, Table IV). The dental parameter L1-A/Pg showed a statistically significant decrease in the 8–11 years group (Table III). Owing to the emergence of the permanent incisors during therapy or the absence of the incisors at the start of treatment, incisor parameters were not evaluated for a few children in the 4–7 age group.

There was no statistically significant difference in the intergroup comparison of the molar relationship (mm), overjet (mm), overbite (mm) parameters, as well as the nasolabial angle, UL-E Line (mm), and LL-E Line (mm) soft tissue parameters (Table V).

Discussion

The null hypothesis was partly rejected as the younger group did not show greater effects in the skeletal and soft tissue parameters but was more co-operative compared to the older group.

Orthopaedic appliances are used in the early treatment of cases in which the skeletal Class III malocclusion is related to maxillary retrognathia.^{7,8} Although there is no consensus regarding the timing

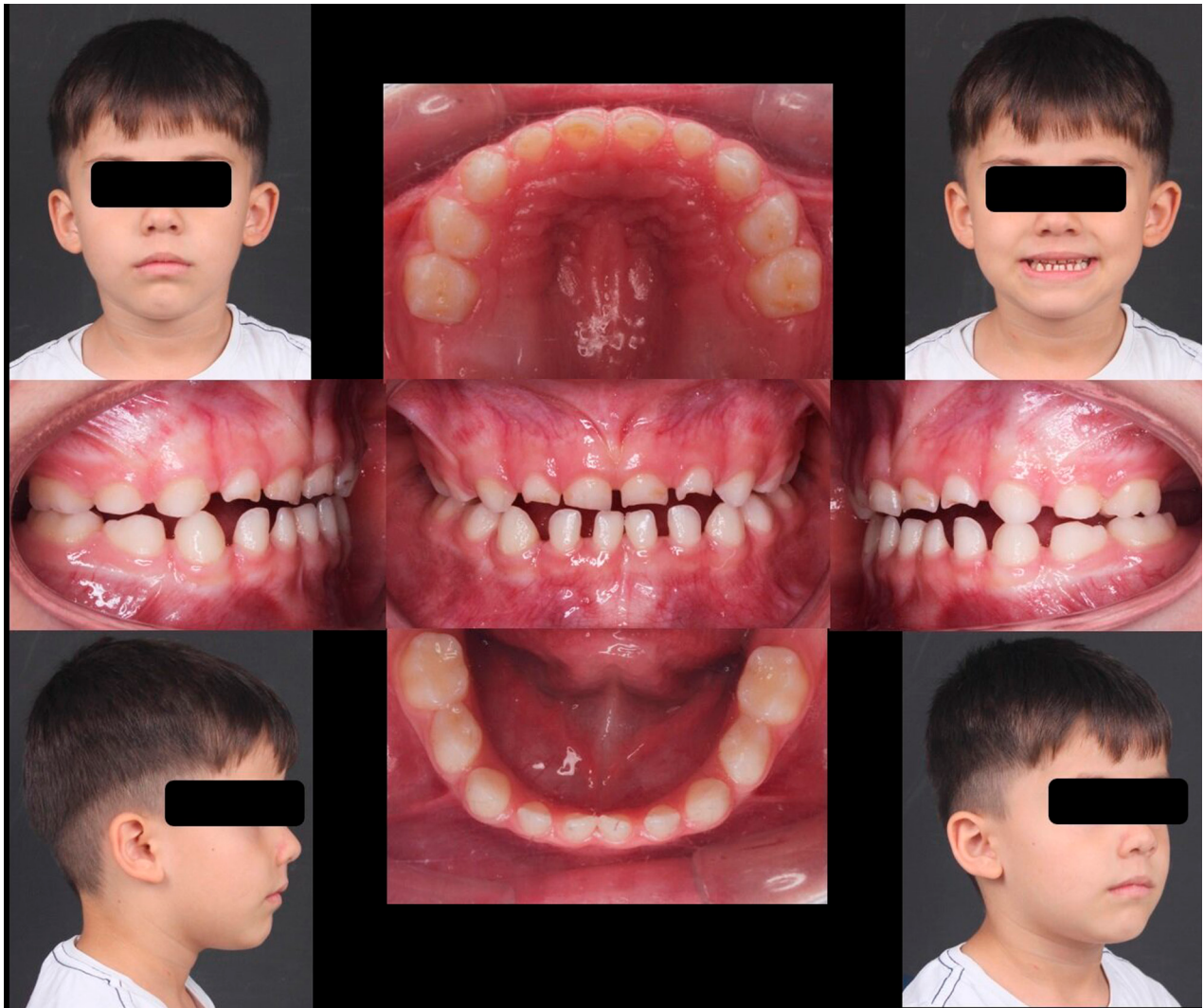


Figure 5. Intra- and extra-oral records of the same patient after face mask therapy, prior to the removal of the rapid maxillary expansion appliance.

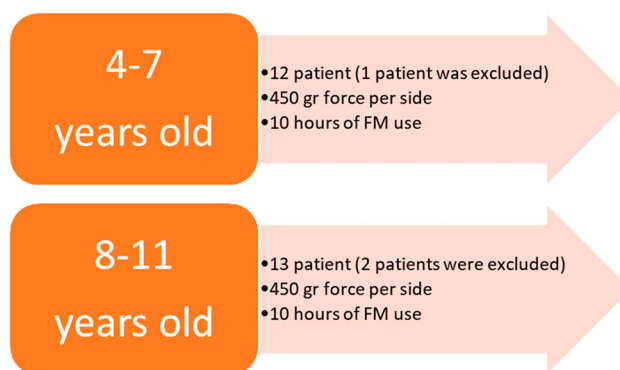


Figure 6. The flow chart.

Table II. Intergroup comparison of the demographic data between the 4–7 and 8–11 year old groups

	4–7 Years old	8–11 Years old	
	<i>n</i> = 11	<i>n</i> = 11	<i>p</i> -value
Male	5 (%45.5)	4 (%36.4)	0.66 ¹
Female	6 (%54.5)	7 (%63.6)	
Treatment starting age (years)			
Median (min-max)	6.3 (4.9–7.6)	9.1 (7.9–11.4)	
Treatment duration (months)			
Mean+SD	6.6 + 1.3	7.6 + 1.2	0.09 ²
Med (min-max)	6.3 (5.2–9.3)	7.8 (5.4–9.1)	
Daily usage time (hours)			
Mean+SD	8.9 + 1.8	7.1 + 0.9	<0.01 ^{3*}

¹Chi squared, ²Mann–Whitney *U*, ³Independent *t* test, (*p*<0.05*), 95% confidence level.

of orthopaedic treatment, many studies have reported that a face mask applied together with maxillary expansion in the early period maximises maxillary anterior advancement.^{18,29} Many authors have suggested that treatment may start in the early mixed dentition, after the eruption of the upper permanent first molars and incisors, around the age of 6–8 years,^{13,30} even though early treatment approaches are still debatable due to the unpredictable nature of mandibular growth.^{31,32} Because maxillary and mandibular growth differ proportionately during the pubertal growth spurt, a second phase of treatment may be necessary after the early correction of the skeletal discrepancy.³³ Even though long-term stability is unknown, early preventive orthodontic treatment is recommended for a functional, aesthetic, and for psychological reasons.³⁴

Early treatment aims to reduce the complexity of subsequent treatment, the severity of the malocclusion, and the severity of surgery if orthognathic surgery is further needed.^{35,36} Cozzani³⁷ stated that protraction applied at the age of four years, in line with the direction of maxillary growth, yielded a more stable outcome. Children with a Class III malocclusion in the early or late mixed dentition who received RME and face mask treatment were compared to children who did not receive treatment by Baccetti et al.²⁹ Treatment resulted in greater advancement of the maxillary structures and more upward and forward development of the condyles in the early mixed dentition group.²⁹ However, it has

been suggested that there is no correlation between the timing of treatment and the efficacy of maxillary protraction.^{38,39}

The best age to begin treatment of a Class III malocclusion, noticeable during childhood, has not been agreed upon, and there are few studies that have used face masks before the age of eight years.^{14,40} Based on the premise that a Class III malocclusion begins during the growth spurt that happens during the transition through the mixed dentition, the present study compared the effectiveness of traditional face mask therapy applied to 8–11 year old patients to treatment of 4–7 year old patients which is a group that has previously received little attention.⁴¹ In the present study, the 4–7 age group's average treatment start age was 6.3 (4.9–7.6) years, while the 8–11 age group's average treatment start age was statistically significantly higher at 9.1 (7.9–11.4) years. The SNA angle, ANB angle, A-Nasion perp. (mm), Wits (mm), maxillary depth, overjet, and molar relationship parameters demonstrated significant positive changes in both groups, which is consistent with past findings. No statistically significant difference was observed in any of the examined parameters when the amount of change between groups was compared.

The treatment duration may vary depending on the patient's age. Yüksel et al. examined the effect of age on Class III treatment duration while using face masks in two different age groups of patients and determined that treatment targets were reached in an average of 7 months in both the early and

Table III. Intragroup comparison of the changes in dental, soft tissue, and skeletal parameters in children aged 8 to 11

	T0		T1			
n=11	Mean	SD	Mean	SD	p-value	Norms
SNA (°)	78	3.68	80.7	4.22	<0.001***	82° ± 2
SNB (°)	78.1	3.45	77.8	3.78	0.53	80° ± 2
ANB (°)	-0.1	2	2.8	1.4	<0.001***	2° ± 2
A-Nasionperp (mm)	-2	1.79	0.45	2.17	<0.01**	0 ± 3
Pg-Nasionperp (mm)	-3.66	3.24	-3.7	4.2	0.97	-4 ± 5
Wits (mm)	-4.72	2.8	-1.97	2.45	<0.01**	-1 ± 3
Y Axis (°)	59	2.48	59.5	2.16	0.44	59° ± 6
SN-GoGn (°)	35.18	2.78	36.36	3.47	0.09	32° ± 7
FMA (°)	28	2.79	28.9	2.5	0.15	25° ± 5
N-Me (mm)	102.5	3.6	103.8	4.25	0.15	114.4 ± 5
S-Go (mm)	66.69	3.11	66.72	4.54	0.97	74.4 ± 4
ANS-Me (mm)	57.11	2.93	59.29	2.8	<0.001***	57-58
Co-A (mm)	74.5	3.5	76.47	3.91	<0.01**	81
Co-Gn (mm)	98.69	4.9	99.57	6	0.4	99-102
S-N (mm)	62.35	3	62.37	2.7	0.96	73.2 ± 3
Maxillary Depth (°)	87.27	2	90.45	2.2	<0.01**	90 ± 3
Maxillary Height (°)	59.9	2.8	59.36	2.54	0.31	53 ± 3
FH-Palatal Plane (°)	-0.09	2.7	-1.36	3.5	0.16	4 ± 3
Saddle Angle(°)	125.72	6.97	122.77	6.69	<0.05*	122 ± 5
Articular Angle (°)	138.18	6.88	142.9	7.64	<0.01**	143 ± 6
Gonial Angle (°)	130.8	7.97	130.8	8.93	1	130 ± 7
Nasolabial Angle (°)	110.45	12.6	112.5	13	0.32	104° ± 8
UL-E Line (mm)	-2	1.3	-0.9	1.42	<0.001***	-4 ± 2
LL-E Line (mm)	0.59	2.66	0.68	2.27	0.79	-2 ± 2
U1/SN (°)	99.45	4	99.72	5.2	0.84	102° ± 5
U1/PP (°)	105.9	6	107.9	6.3	0.45	110° ± 5
U1-A/Vert (mm)	2.1	0.75	2.1	1.74	1	4 mm ± 3
U1/Occlusal Plane (°)	60.27	3.77	58.5	5.33	0.37	57.8 ± 3
L1-A/Pg (mm)	2.59	1.99	0.6	1.51	<0.01**	2.7 mm ± 1
IMPA	87.27	6.55	84.36	7.85	0.08	90° ± 5
Interincisor Angle (°)	137	8.49	138.3	10	0.51	130° ± 6
Holdaway Ratio	-1.76	5.45	-4.86	13.5	0.39	1/1 ± 0.5
Molar Relation (mm)	-2.79	1.84	0.6	1.5	<0.001***	-3 ± 3
Overjet (mm)	-0.13	2.3	3.6	2.4	<0.001***	2.5 ± 2.5
Overbite (mm)	-0.03	1.9	-0.8	2.9	0.81	2.5 ± 2.5

Independent t Test (p<0.05*) (p<0.01**) (p<0.001***) 95% confidence level.

Table IV. Intragroup comparison of the changes in dental, soft tissue, and skeletal parameters in children aged 4 to 7

n=11	T0		T1		p-value	Norms
	Mean	SD	Mean	SD		
SNA (°)	79.72	4	82.72	4.1	<0.01**	82° ± 2
SNB (°)	79.6	3.93	78.6	3.88	<0.05*	80° ± 2
ANB (°)	0.27	2.24	4	1.37	<0.001***	2° ± 2
A-Nasionperp (mm)	-0.69	4.2	2.1	3.5	<0.01**	0 ± 3
Pg-Nasionperp (mm)	-2.6	6.7	-2.87	5.2	0.82	-4 ± 5
Wits (mm)	-5.4	3	-2.2	2.97	<0.001***	-1 ± 3
Y Axis (°)	57.9	4.6	58	2.6	0.77	59° ± 6
SN-GoGn (°)	34.2	4	36.8	5	<0.05*	32° ± 7
FMA (°)	27.9	4.39	29	3.1	0.23	25° ± 5
N-Me (mm)	94.5	3	97.3	3	<0.001***	114.4 ± 5
S-Go (mm)	62	4.4	61.6	3.8	0.59	74.4 ± 4
ANS-Me (mm)	53.9	3.4	56.8	2.1	<0.001***	57-58
Co-A (mm)	70.32	2.78	72	3.3	0.05	81
Co-Gn (mm)	92	3.6	92.7	3.3	0.31	99-102
S-N (mm)	59.48	2.4	59.8	1.99	0.47	73.2 ± 3
Maxillary Depth (°)	89.27	4.26	92.36	3.44	<0.01**	90 ± 3
Maxillary Height (°)	56.27	3.9	57.36	2.5	0.34	53 ± 3
FH-Palatal Plane (°)	-1.54	4.32	-3	2.97	0.34	4 ± 3
Saddle Angle(°)	120	3.4	120.6	4.6	0.61	122 ± 5
Articular Angle (°)	140.45	6.36	144.27	9	0.15	143 ± 6
Gonial Angle (°)	131.9	4.41	132.9	5.87	0.49	130 ± 7
Nasolabial Angle (°)	119.18	10	118.54	7.47	0.78	104° ± 8
UL-E Line (mm)	-0.4	1.79	0.06	1.96	0.3	-4 ± 2
LL-E Line (mm)	2	1.62	0.82	2.46	0.05	-2 ± 2
Molar Relation (mm)	-3.54	2.68	-0.71	2	<0.001***	-3 ± 3
Overjet (mm)	-1.46	2.12	2.15	1.32	<0.001***	2.5 ± 2.5
Overbite (mm)	0.33	3.5	-0.47	2.4	0.38	2.5 ± 2.5

Independent t Test (p<0.05*) (p<0.01**) (p<0.001***), 95% confidence level.

late period groups.¹⁹ In the present study, treatment was continued until the canines reached a Class II relationship as an overcorrection in order to account for any relapse related to possible pubertal mandibular growth and anterior rotation of the mandible after the expansion appliance was removed. The average duration of treatment was recorded as 6.6 months in the 4–7 age group and 7.6 months in the 8–11 age group and between the two groups, there was no statistically significant difference in

the length of treatment considering the groups were initially similar.

Although face mask therapy has been shown to produce positive dentoskeletal changes, there are certain drawbacks to using the appliance. The children's reluctance to wear the appliance because of aesthetic concerns, non-compliance with the use of the elastics, and potential irritation and injury, particularly in the chin area where the extraoral appliance might create pressure, are documented.⁴²

Table V. Comparison of the 4–7 and 8–11 age groups' changes in skeletal, soft tissue, and dental parameters

Groups	4–7 Years old		8–11 Years old		<i>p-value</i>
	Mean	SD	Mean	SD	
Δ SNA (°)	3	2	2.7	1.1	0.7
Δ SNB (°)	-0.9	1	-0.3	1.8	0.4
Δ ANB (°)	2.7	3.4	3	1.4	0.8
Δ A-Nasionperp (mm)	2.7	2.7	2.5	1.6	0.8
Δ Pg-Nasionperp (mm)	-0.2	3.3	-0.3	4.1	0.94
Δ Wits (mm)	3.2	1.7	2.4	2.9	0.4
Δ Y Axis(°)	0.2	3.1	0.3	2.2	0.9
Δ SN-GoGn (°)	2.5	2.9	1.1	2	0.22
Δ FMA (°)	1.1	3.1	0.9	1.9	0.8
Δ N-Me (mm)	2.7	1.6	1.4	2.8	0.2
Δ S-Go (mm)	-0.4	2.3	0.1	3.4	0.66
Δ ANS-Me (mm)	2.9	1.6	2	1.3	0.19
Δ Co-A (mm)	2.3	1.9	1.9	1.7	0.65
Δ Co-Gn (mm)	0.7	1.9	0.8	3.4	0.89
Δ S-N (mm)	0.3	1.5	0.1	1.5	0.72
Δ Maxillary Depth (°)	3	2.7	3	2	1
Δ Maxillary Height (°)	1	3.6	-0.5	1.6	0.19
Δ FH-Palatal Plane (°)	-1.5	5	-1.2	2.7	0.89
Δ Saddle Angle (°)	1	4	-2.4	4.1	0.06
Δ Articular Angle (°)	1.4	7.8	4.7	4.3	0.24
Δ Gonial Angle (°)	0.8	4.6	0	4.4	0.67
Δ Nazolabial Angle (°)	-0.6	7.6	2	6.72	0.38
Δ UL-E Line (mm)	0.8	1.9	1.1	0.5	0.58
Δ LL-E Line (mm)	-0.4	2.1	0.7	1.1	0.52
Δ Molar Relation (mm)	2.89	1.6	3.4	2	0.49
Δ Overjet (mm)	3.3	2.4	3.6	2.3	0.75
Δ Overbite (mm)	-0.8	2.9	-0.03	1.9	0.46

While some authors advocate using orthopaedic appliances full-time, Witt et al. were the first to suggest a shorter wear routine of 14 hr a day to avoid those problems.⁴³

Research using the TheraMon co-operation monitoring system revealed that despite achieving successful results, 92% of the patients wore their appliances for no more than 9 to 10 hr a day, and that co-operation was never as high as the orthodontist prescribed.^{44,45} It has been suggested that the daily

use period for functional orthopaedic appliances may be less than 14–15 hr, raising doubts about the daily recommended usage time.^{44,45} Schäfer et al. found that only 7% of patients adhered to the recommended level of daily use.⁴⁶ According to Schott and Ludwig, 25% of patients wore their appliances for significantly fewer than seven hours per day.⁴⁵

Few studies have been conducted which have compared compliance across various age groups. Arreghini et al. reported that younger patients

(ages 6–8 years) were statistically significantly more compliant than older patients (ages 12–15 years).⁴⁷ Similarly, Weiss and Eiser found that pre-adolescents were more co-operative than adolescents.⁴⁸ In the present study, daily usage times were measured using an objective data collection method and compared between the groups as the co-operation of the patients directly affects the treatment results of removable and extraoral appliances.⁴⁸ Consistent with the literature, the younger group (4–7 age group) showed higher co-operation compared to the older group (8–11 age group).

The 4 to 7 age group recorded an average daily usage time of 8 ± 1.8 hr, while the 8–11 age group recorded an average daily usage time of 7.1 ± 0.9 hr. This is consistent with the literature which indicates that the prescribed usage time of 8–15 hr per day never exceeds 7–9 h.^{45,46} TheraMon (MC Technology GmbH, Hargelsberg, Austria) microensors are user-friendly, have a proven track record of reliability, and are most commonly used in studies which determine objective usage.⁴⁹ As a result, the TheraMon system was chosen to collect objective usage data, and in accordance with previous research, a measurement frequency of every 15 minutes was set.⁵⁰

It has been noted that a maxillary transverse deficiency is typically associated with a Class III malocclusion.⁵¹ Short- and long-term research has led to the belief that maxillary expansion results in favourable alterations in the sagittal plane when applied in combination with orthopaedic devices.^{52,53} In the present study, an acrylic cap-type expansion appliance was designed, and expansion was performed for a minimum of 10 days, with the expectation that rapid maxillary expansion would assist sagittal correction. Expansion was continued in some patients when needed, but no expansion was performed for more than 16 days in any patient. An expansion of 10.8 ± 2.4 days was carried out on average for the 4 to 7 year age group and 10.8 ± 1.8 days on average for the 8 to 11 year age group. It is believed that the amount of maxillary protraction would not be affected by the expansion amount because treatment time was similar between the groups, and may not be considered as a limitation of the study.

The literature reveals method differences regarding the level of force application, usage duration, and force direction during face mask treatments.^{17,29} According to Kajiyama et al.,¹⁷ modified maxillary

protraction headgear should be worn for 10 to 12 hr a day at a 30° angle to the occlusal plane, and to apply 400 grams of force per side. Following rapid maxillary expansion, Baccetti et al.²⁹ advised patients to wear a face mask for 14 hr every day while applying 400 grams of force parallel to the occlusal plane. While using the face mask and contacting extraoral anchorage areas, particularly at the chin, using excessive forces may result in injuries and loss of compliance.⁴² In the present study, an average of 450 g of force was applied per side in an effort to eliminate these drawbacks.

Treating a Class III skeletal malocclusion in growing individuals is critical to avoiding future orthognathic surgery therefore sparing patients from an invasive and costly procedure, while promoting positive psychosocial development.^{35,36} Welcome changes in function and facial aesthetics were attained with the sagittal forward movement of the maxilla using the treatment protocol prescribed in the present study. The younger and older treatment groups did not differ in treatment effectiveness; however, the younger group exhibited greater compliance.

Although more co-operation was observed in the younger age group, statistically significant intra-group changes were observed in the Co-A, saddle angle, articular angle and UL-E Line parameters in the older group. The increase in Co-A, saddle angle, and articular angle can be explained by noting that the older patients were closer to the prepubertal growth spurt period. However, the younger age group was closer by age to the growth spurt that is expected when switching to the mixed dentition.²⁶ The difference in the amount of growth between these two growth spurt periods may be valid in explaining the difference. Similarly, Battagel et al. reported that the maximum change in facial features of growing Class III individuals occurred between the ages of 9.5 and 12 years.³ That there was a statistically significant difference in the UL-E Line (mm) parameter in the 8 to 11 age group can be attributed to the central incisors in this age group were present in all patients, and provided lip support which made the changes noticeable. However, this parameter appeared stable in the younger group and related to the expected exfoliation of the incisors.

The developmental age of the children and their level of cognition and emotion play a prominent role in their behaviour during treatment. Improved

behaviour can be expected after the age of 3 years.^{54–56} Self-concept is defined as the perception of a person's ability to master or deal effectively with the environment.⁵⁷ Self-concept is affected by the reactions of others, and while parents and teachers play an active role in the development of a young child's self-concept, peers play an important role during pre-adolescence.⁵⁸ It is believed that young children who attend scheduled appointments with their parents would be more influenced by parental and doctor guidance and therefore have a higher level of compliance. According to the assumption that children in the more mature age group would be more affected by their peers, the presence of individuals who also wore extraoral devices would possibly produce positive and heightened co-operation. However, given the uncommon nature of extraoral appliance wear, it could be argued that peer influence may be ineffective.⁵⁹ This could explain the lower level of co-operation in the older age group.

It is considered that early correction will have a positive effect on the development of the functional envelope, and growth will occur more favourably even though there is no difference in the effectiveness of treatment. In this respect, comparing patients by long-term follow-up will contribute to clinical knowledge. Furthermore, it was observed that even trustworthy patients reported using the appliances for longer periods of time in comparison with the objective data. The possibility of data mishap resulting from the sensor's loss of contact with the skin during undesired movements during sleep must be considered when interpreting this data. Despite the discrepancy between the self-report of compliance and the objective data, it is considered that the clear visual signals produced by the microsenors facilitate communication between the clinician, the patient, and their parents. This may help raise awareness among many parents who hold false beliefs about their children's compliance. Additionally, it is important to appreciate that objective monitoring could offer protection against medical malpractice lawsuits that stem from treatment failures brought on by non-compliant patients.

Conclusions

In a consideration of the data obtained, positive improvements were achieved in the parameters determining the sagittal position of the maxilla in

both groups, leading to an improved intermaxillary relationship. The null hypothesis, that there would be a significant difference between groups in skeletal and soft tissue parameters, was largely rejected, but was partly confirmed since a significant difference in co-operation between the younger and older groups was found. The amount of daily appliance wear in the early age treatment group (ages 4–7 years) was higher compared to the older age group (ages 8–11 years).

Conflicts of interest

The authors declare that there is no conflict of interest.

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Data availability

The data supporting this article will be shared on reasonable request to the corresponding author.

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Authors' contributions

KY: Data curation; Funding acquisition; Investigation; Methodology; Writing - original draft; Writing - review & editing. BY: Conceptualization; Data curation; Funding acquisition; Investigation; Methodology; Project administration; Supervision; Writing - original draft; Writing - review & editing.

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