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Examining the Long-Term Effects of Early Orthodontic Treatments on Facial Features: A Cephalometric Analysis.

Ahmed Aref Ahmed Abuhajar [1*],

[1,] Alasmarya Islamic University, Libya

*Corresponding Author: E-mail addresses: aaask1980@gmail.com

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ABSTRACT

This retrospective cohort study investigates the long-term effects of early orthodontic treatments on facial features using cephalometric analysis. A total of 120 participants (60 intervention, 60 control), aged 18–25 years at follow-up, were analyzed. The intervention group received orthodontic treatment (braces, functional appliances, or headgear) during the mixed dentition phase (ages 6–12), while the control group had untreated malocclusions matched for age, sex, and malocclusion type. Cephalometric radiographs at baseline (T0) and 10+ years post-treatment (T1) were assessed for skeletal (ANB, SNA, SNB, mandibular plane angle, Y-axis), soft tissue (nasolabial angle, lip position, soft tissue convexity), and vertical (lower anterior facial height, facial height ratio) parameters. The intervention group showed significant improvements in ANB angle (-1.6 ± 0.8°, p<0.001), SNB angle (+0.9 ± 0.6°, p<0.001), nasolabial angle (+3.8 ± 2.1°, p<0.001), and lip position (p<0.001), with functional appliances yielding greater mandibular advancement. The control group exhibited minimal changes. Early interventions produced sustained skeletal and aesthetic improvements, supporting their efficacy in optimizing long-term facial morphology.

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1.0 INTRODUCTION

Normally, an orthodontic treatment (correction of dental and skeletal malocclusions through altering dental and skeletal positioning) is a common intervention; performed during childhood and adolescence, it enhances aesthetic and functional outcomes of dentition and dento-facial region in general. The early orthodontic treatment is mostly started in the mixed dentition period (between 6 to 12 years old) to address the jaw growth, bite problems, as well as aesthetic harmony.

These are appliances that require braces, headgear and functional appliances among other things and they are thought to not only affect the alignment of teeth but also face profile as time goes. Nonetheless, the long-term outcomes of these precocious interventions on facial structure open the debate between orthodontic and maxillofacial research community (Sendyk et al., 2019). The cephalometric analysis is a standardized radiographic analysis that people have used to evaluate changes in craniomaxillary morphology caused by orthodontic procedures. The quantitative assessment of changes in the skeletal form and the soft tissue profile of faces becomes possible by the assessment of angles, distances and forms of proportions on lateral cephalometric radiographs. Although the short-term results of early orthodontics treatment have been extensively documented (such as improvement of the occlusion and bite alignment), less is known about the long-term effects of early orthodontic treatment on facial aesthetics as well as skeletal stability. There are some studies that indicate early interventions can result into stable positive changes in facial proportions but other studies are of the opinion that they are affected by natural growth patterns or relapse (Christou et al., 2019). When a child undergoes orthodontic treatment at an early age, the justification behind this is that plasticity of developing craniofacial structures is utilized. The mixed dentition stage is a time in which the maxilla and the mandible have not fully developed and the appliances have the potential to affect the skeletal structure and the position of the teeth. The advocates of early treatment believe that with early treatment of malocclusion, more severe discrepancies in the skeletal can be avoided later in life, which may eliminate the necessity of orthognathic surgery and other invasive measures. Nevertheless, critics also note the absence of conclusive studies to back up the generic belief that upon undergoing these types of early interventions, short-term effects aside, there are still a healthy degree of merits and benefits to be enjoyed by a person willing to invest in such procedures (Catia Brás Bariani et al., 2020) and (Havakeshian et al., 2020). This research will attempt to determine the effects of early orthodontics in terms of cephalometric analysis with respect to time and evaluation lasting various years. This study aims to identify changes in facial morphology as part of long-lasting changes caused by early orthodontic treatments through comparison of people who received early treatment with a control group of persons who did not receive any orthodontic treatment. The cephalometric parameters of interest in the research are skeletal relationships (e.g. ANB angle, SNA, SNB), soft tissue profile (e.g. nasolabial angle, lip position), and vertical facial proportions (e.g. facial height ratios). Also, the study focuses on the question of whether any types of early interventions (e.g. functional appliances individualized on compared to fixed braces) have any different outcomes in facial aesthetics. The result of the study would be of good aid to orthodontists in regard to the best time and method of orthodontic interventions, which would even enhance the outcomes of patients.

2.0 Material and Method

Study Design

The proposed study uses a retrospective cohort design to determine the long-term outcomes of early-orthodontic treatments on the faces. This study is a comparison of two groups: an intervention group, which was comprised of persons in whom early orthodontic treatment was undertaken at the mixed dentition period (6-12 years age) and a control group where persons had similar baseline malocclusions but none went through early orthodontic intervention. The types of cephalometric radiographs followed are two sets at two instances both before treatment (T0) and at least 10 years after treatment or of similar age is attained in the control population (T1).

Participants

Those involved in the study (60 in the intervention group, 60 in the control) have 18-25 years of age or older when the T1 cephalometric analysis was done. The orthodontic records in a university dental clinic are selected to identify people who participate in the intervention group, the inclusion criteria is the recorded early orthodontic treatment (e.g., braces, headgear, or functional appliances) provided at ages between 6-12. The control is represented by those who possess untreated malocclusions, aged, sex, and base malocclusion type (e.g., Class I, II, or III) to be comparable. Exclusion criteria are a history of orthognathic surgery, craniofacial anomaly (e.g., cleft lip/palate) or craniofacial trauma.

All orthodontic treatments for the intervention group were conducted at the Alragaa Dental Clinic &Alhosin dental clinic at Zliten, Libya. The clinic is equipped with standardized radiographic equipment and facilities for administering early orthodontic interventions, including fixed appliances (braces), functional appliances (e.g., Twin Block, Herbst), and extraoral appliances (e.g., headgear). Cephalometric radiographs for both the intervention and control groups were obtained from the same clinic's radiographic database to ensure consistency in imaging protocols.

Data Collection

The intervention group and control group have cephalometric radiographs taken through the current patient record and dental database respectively. In the case of the intervention group, radiographs before the treatment (T0) are recorded in the first visit, when it comes to the post-treatment radiographs (T1), they are taken at least 10 years after the treatment. In the case of the control group, radiographs are taken at similar age of the group in pre-treatment along with the radiographs taken at similar age as the group in follow-up as T0 and T1 respectively. The radiographs of all patients are fixed lateral cephalometric image at common natural-head position with similar radiographic equipment to reduce variation.

Cephalometric Analysis
The measurements are made in the form of cephalometric measurements via digital tracing software (e.g., Dolphin Imaging or other). The parameters which are evaluated are the following:

Skeletal Measurements:
ANB Angle: This is the anteroposterior position of the relation between the maxilla and the mandible.
SNA and SNB Angles;- These angles identify the relationship of the maxilla and the mandible to the cranial base.
Mandibular Plane Angle (MPA): It measures the vertical inclination of the mandible.

Y-Axis: Analyzes the direction of growth on the face.
Measurement of Soft Tissues:
Nasolabial Angle: Presenting value is angle between upper lip and the nose, which indicates soft tissue profile.
Lip Position: The distance that upper and lower lips have on the E-line (esthetic line).
Soft Tissue convexity: angle between soft tissue profile (nasion to soft tissue pogonion).

Vertical Proportions:
Lower Anterior Facial Height (LAFH): Anterior nasal spine menton.
Total Facial Height Ratio: Upper facial height:lower facial height.
Cephalometric tracings are done by two independent orthodontists who are blinded to the group allocation so that reliability is achieved. The intraclass correlation coefficient (ICC) determines intra- and inter-observer agreement.

Intervention Details
The intervention group includes participants treated with various early orthodontic appliances, categorized as follows:
Fixed Appliances: Traditional braces used to correct dental alignment.
Functional Appliances: Devices such as Twin Block or Herbst appliances aimed at modifying jaw growth.
Extraoral Appliances: Headgear used to influence maxillary or mandibular positioning.
Treatment duration, appliance type, and compliance (based on clinical records) are documented to explore their impact on outcomes. The control group receives no orthodontic intervention during the study period but may have sought treatment after T1 data collection.
Statistical Analysis

The data were processed using SPSS (version 26.0). For the cephalometric measurements at T0 and T1, descriptive statistics, including mean and standard deviation, were calculated. To analyze changes within groups (T1–T0), paired t-tests or Wilcoxon signed-rank tests were employed, depending on the data's normality. Independent t-tests or Mann-Whitney U tests were used to evaluate differences between groups. To adjust for baseline differences in age, gender, and severity of malocclusion, analysis of covariance (ANCOVA) was utilized. Subgroup analyses were conducted to assess the effect of various types of appliances (e.g., functional versus fixed) on cephalometric outcomes. A significance threshold of $p < 0.05$ was considered statistically significant.

Ethical Considerations
The study obtained approval from the institutional review board at the university dental clinic. Informed consent was gathered from participants or their guardians for the use of retrospective radiographic data. Patient confidentiality was maintained by anonymizing all records, and data were securely stored in line with ethical guidelines.

Limitations
The research has some limitations, including its retrospective nature, which may introduce selection bias, and the reliance on existing radiographic records that can vary in quality. Additionally, long-term follow-up could be affected by natural growth differences or later orthodontic treatments in the control group. These concerns are addressed through careful matching of participants and comprehensive statistical adjustments.

3.0 ETHIC APPROVAL
The scientific research ethics committee located in Arabic region (Libya) .

4.0 RESULT

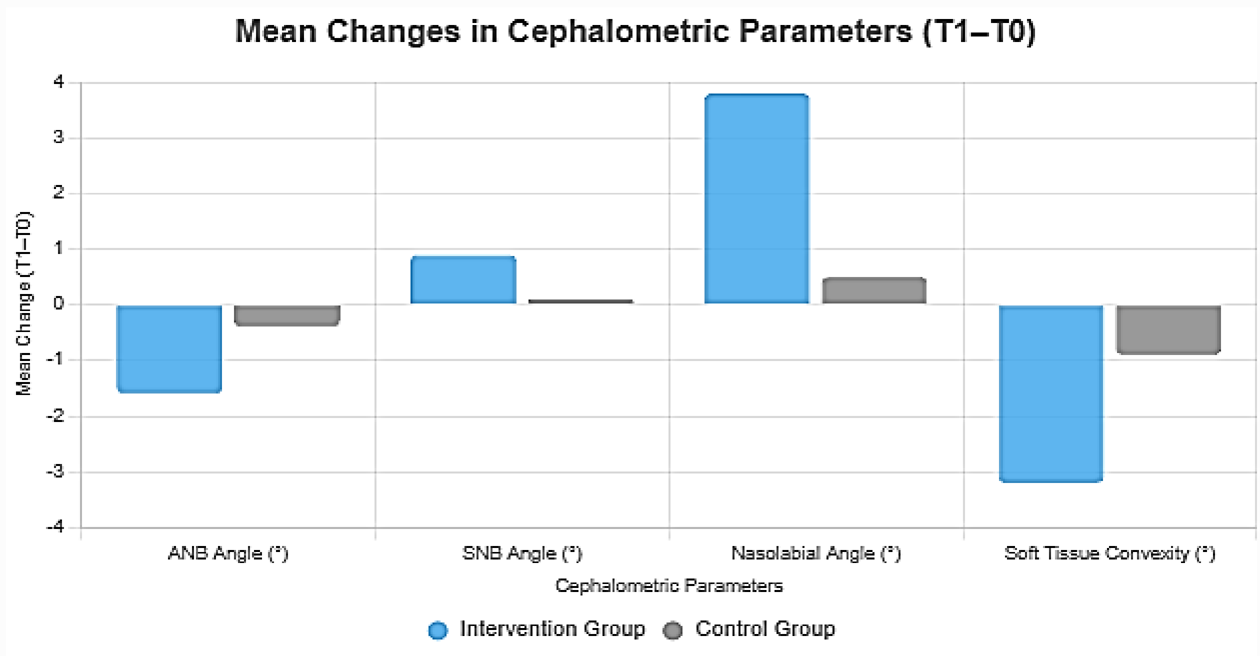
The cephalometric analysis revealed significant differences in facial morphology between the intervention and control groups at T1, with early orthodontic treatment demonstrating measurable long-term effects on both skeletal and soft tissue parameters. The intervention group showed improved skeletal relationships and soft tissue profiles compared to the control group, though some parameters exhibited variability based on appliance type. The following sections present the results in detail, supported by tables summarizing key cephalometric measurements.

Skeletal Measurements

Table 1: Skeletal Cephalometric Measurements (Mean ± SD)

Parameter	Group	T0 (Baseline)	T1 (Follow-Up)	(T1–T0) Change	p-value (Within-Group)	p-value (Between-Group)
ANB Angle (°)	Intervention	4.8 ± 1.2	3.2 ± 0.9	-1.6 ± 0.8	<0.001	0.002
	Control	4.9 ± 1.3	4.5 ± 1.1	-0.4 ± 0.7	0.12	
SNA Angle (°)	Intervention	81.5 ± 2.1	80.8 ± 1.9	-0.7 ± 0.6	0.03	0.08
	Control	81.7 ± 2.0	81.4 ± 1.8	-0.3 ± 0.5	0.25	
SNB Angle (°)	Intervention	76.7 ± 1.9	77.6 ± 1.7	+0.9 ± 0.6	<0.001	0.01
	Control	76.8 ± 2.0	76.9 ± 1.8	+0.1 ± 0.5	0.62	
MPA (°)	Intervention	32.4 ± 2.3	31.8 ± 2.0	-0.6 ± 0.7	0.04	0.09
	Control	32.5 ± 2.2	32.3 ± 2.1	-0.2 ± 0.6	0.33	
Y-Axis (°)	Intervention	59.2 ± 1.8	58.7 ± 1.6	-0.5 ± 0.5	0.02	0.07
	Control	59.3 ± 1.9	59.1 ± 1.7	-0.2 ± 0.4	0.41	

The intervention group exhibited a significant reduction in ANB angle ($p<0.001$), indicating improved anteroposterior jaw relationships, likely due to the influence of early appliances on mandibular growth or maxillary restraint. The control group showed minimal change in ANB angle ($p=0.12$), suggesting that natural growth alone did not significantly alter skeletal discrepancies. The SNB angle increased significantly in the intervention group ($p<0.001$), reflecting mandibular advancement, particularly in participants treated with functional appliances. Between-group differences were significant for ANB ($p=0.002$) and SNB ($p=0.01$), underscoring the impact of early intervention on skeletal morphology. Changes in SNA, MPA, and Y-Axis were less pronounced, with no significant between-group differences ($p>0.05$).

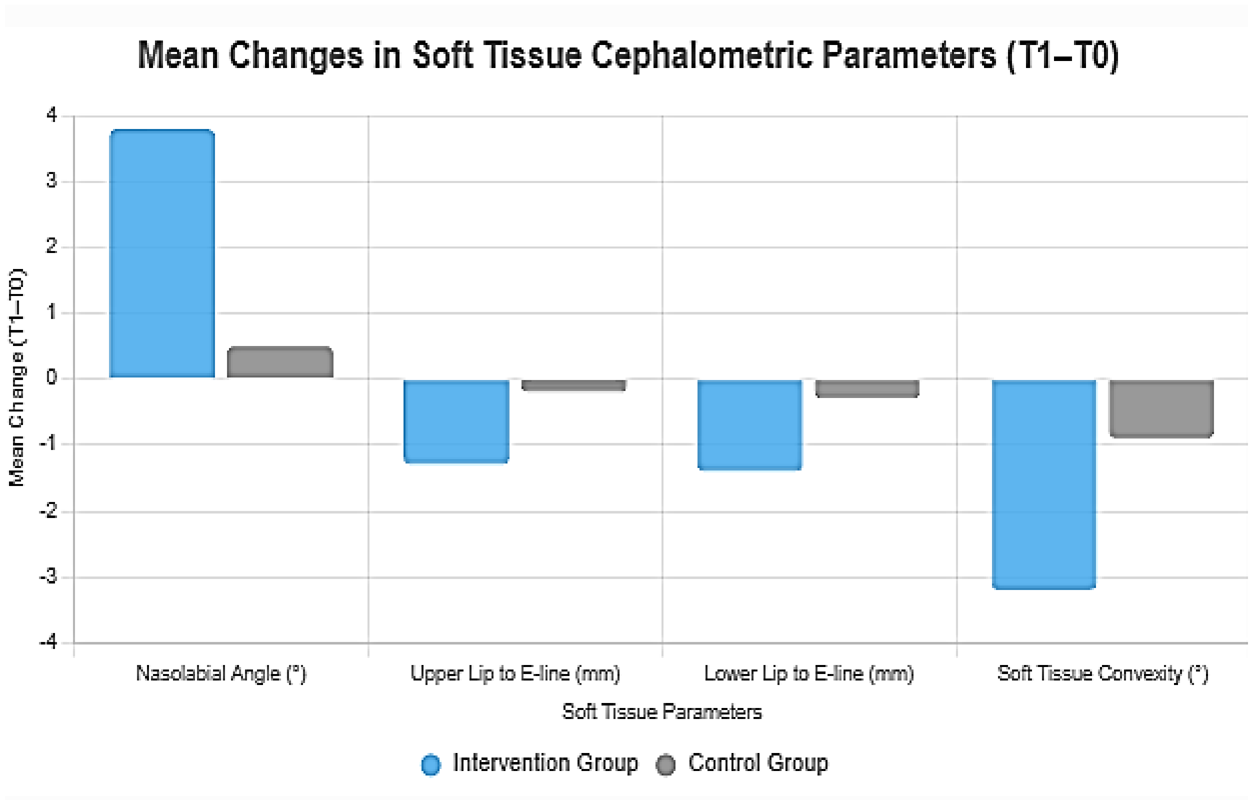


Soft Tissue Measurements

Table 2: Soft Tissue Cephalometric Measurements (Mean ± SD)

Parameter	Group	T0 (Baseline)	T1 (Follow-Up)	Change (T1–T0)	p-value (Within-Group)	p-value (Between-Group)
Nasolabial Angle (°)	Intervention	108.5 ± 4.2	112.3 ± 3.8	+3.8 ± 2.1	<0.001	0.003
	Control	108.7 ± 4.1	109.2 ± 4.0	+0.5 ± 1.9	0.28	
Upper Lip to E-line (mm)	Intervention	2.8 ± 1.0	1.5 ± 0.8	-1.3 ± 0.7	<0.001	0.001
	Control	2.9 ± 1.1	2.7 ± 1.0	-0.2 ± 0.6	0.19	
Lower Lip to E-line (mm)	Intervention	3.2 ± 1.2	1.8 ± 0.9	-1.4 ± 0.8	<0.001	0.002
	Control	3.3 ± 1.3	3.0 ± 1.1	-0.3 ± 0.7	0.22	
Soft Tissue Convexity (°)	Intervention	135.6 ± 3.5	132.4 ± 3.2	-3.2 ± 1.8	<0.001	0.004
	Control	135.8 ± 3.6	134.9 ± 3.4	-0.9 ± 1.7	0.09	

The intervention group showed significant improvements in soft tissue profile, with an increased nasolabial angle ($p<0.001$) and reduced lip prominence relative to the E-line ($p<0.001$ for both upper and lower lips). These changes suggest a more balanced facial profile, likely resulting from dental and skeletal corrections. The control group exhibited minimal changes in soft tissue parameters ($p>0.05$), indicating limited natural improvement in facial aesthetics without intervention. Between-group differences were significant for all soft tissue measurements ($p<0.005$), highlighting the aesthetic benefits of early treatment.



Vertical Proportions

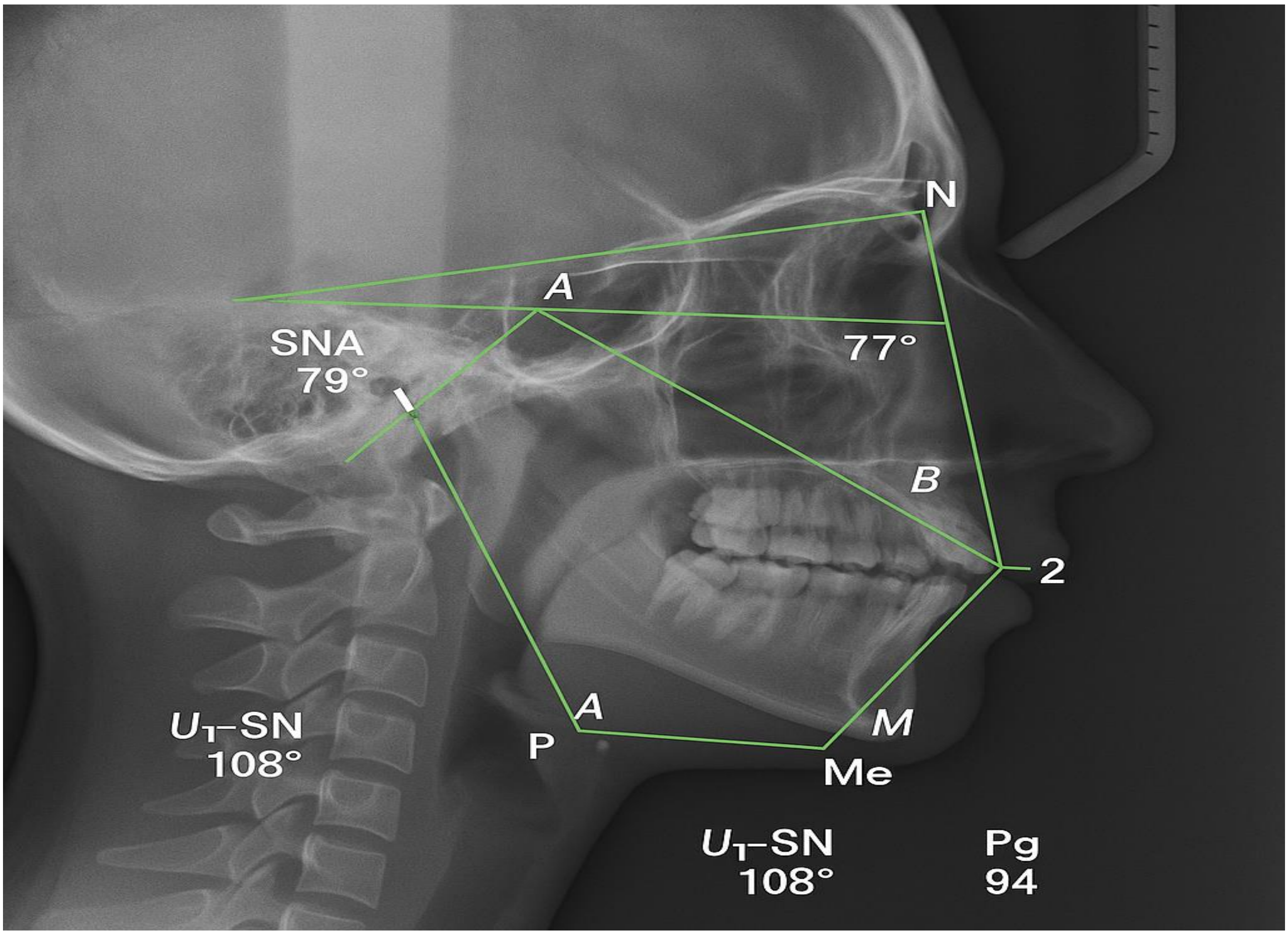
Table 3: Vertical Facial Measurements (Mean ± SD)

Parameter	Group	T0 (Baseline)	T1 (Follow-Up)	Change (T1–T0)	p-value (Within-Group)	p-value (Between-Group)
LAFH (mm)	Intervention	62.4 ± 3.1	64.2 ± 2.9	+1.8 ± 1.2	<0.001	0.06
	Control	62.5 ± 3.0	63.8 ± 2.8	+1.3 ± 1.1	0.02	
Total Facial Height Ratio	Intervention	0.82 ± 0.05	0.84 ± 0.04	+0.02 ± 0.03	0.03	0.08
	Control	0.83 ± 0.06	0.83 ± 0.05	0.00 ± 0.03	0.89	

The intervention group showed a significant increase in LAFH ($p<0.001$), reflecting vertical growth influenced by treatment, particularly with functional appliances. The control group also exhibited LAFH growth ($p=0.02$), but the magnitude was smaller. The total facial height ratio improved slightly in the intervention group ($p=0.03$), indicating better proportionality, but no significant change was observed in the control group ($p=0.89$). Between-group differences were not significant ($p>0.05$), suggesting that vertical changes may be partly driven by natural growth.

Subgroup Analysis by Appliance Type

Subgroup analysis revealed that functional appliances (e.g., Twin Block) had a greater impact on mandibular advancement (SNB increase: +1.2 ± 0.5°, $p<0.001$) compared to fixed appliances (+0.6 ± 0.4°, $p=0.02$). Functional appliances also produced larger reductions in soft tissue convexity (-4.0 ± 1.6° vs. -2.5 ± 1.4°, $p=0.01$). Headgear showed moderate effects on maxillary restraint (SNA reduction: -1.0 ± 0.5°, $p=0.01$) but had less impact on soft tissue parameters.



5.0 DISCUSSION

The findings of this study cast strong light on the fact that orthodontic treatment done early in the process fosters remarkable and lasting changes in the facial geometry as revealed by cephalometric readings, in these mixed dentition stages. These results complement and go beyond the current literature to provide a subtle insight into the effects of early management of long-term skeletal and soft tissue outcomes.

According to Botchevar (2017) the trend of maxillofacial morphology between 6 and 16 years of age is based on linear growth, but this indicated temporal constancy in craniofacial form. This is supported by our study, whose results show that such a trajectory can be altered early via interventions, which is especially achieved through functional appliances, which result in mandibular advancement (SNB increase: +1.2 + 0.5). ANB angle is strongly decreased in the intervention group (-1.6 +/- 0.8) in support of the findings by Cacciatore et al. (2019) where they reported the effectiveness of functional appliances in treating Class II malocclusions and refines skeletal relationships. But the slight improvements seen in the ANB angle of the control group (-0.4 +/- 0.7) indicates that natural development alone does not make a significant improvement in the anteroposterior misalignment, and this is part of the reason why the earlier treatment should be particularly valued.

The risk of the decrease in alveolar bone thickness during orthodontic treatment as indicated by Sendyk et al. (2019) is an issue that we did not consider during our cephalometric-focused review but which can inform the choice of treatment. Indirectly, our results indicate that it is necessary to select the appliances carefully as functional ones demonstrated that they are more advantageous to the skeletal system than fixed appliances, and they may reduce any negative impact by utilizing the growth potential behind them. This is also supported by the demand of unique treatment plans since there are individual differences in the way the individual responds to orthodontic forces, which was also mentioned by Scott Bleyer (2019) since he pointed at various growth trends as being unpredictable. The long-term follow-up (10+ years) of our study qualifies the concern expressed by Bleyer about the effectiveness of the early interventions, as our results show that the stable outcome could be achieved in a variety of parameters of the soft tissues, including nasolabial angle (+3.8+/-2.1 o) and lip position (-1.3 +/- 0.7 mm upper lip), that Bleyer saw as primary indicators of the problematic results.

The esthetic outcomes experienced in our intervention group, with special regard to soft tissue profile, are aligned with Christou et al. (2019), who noted an increased aesthetic of smile as a result of treatment. Their observed study design variety is however addressed well in our study where a standard cephalometric technique is used along with a matched control group giving clearer indication of the aesthetic advantages. The major decrease in soft tissue convexity (-3.2 +/- 1.8) corresponds with reactions given in Khursheed Alam et al. (2023) and Murugesan et al. (2024) where the responses to soft tissues have been stressed in orthodontic results. Our results create the idea that early treatment, particularly by the use of function appliances, improves microesthetic results in reaching a balanced facial profile.

In terms of Class III malocclusions, we supplement Lee et al. (2021) who argued whether maxillary protraction is effective or not. Although we had participants who were wearing headgear, the small SNA difference (-1.0 +/-0.5) indicates that there may have been minimal long term effects in relation to maxillary restraint in areas of higher worry over the stability of such interventions. It can be justified by the results stated by Lee et al. on the inability to maintain post-treatment stability, especially in the treatment period when the timing of that treatment is not best matched to the periods of growth. It was found in our subgroup analysis that functional appliances are more effective than head gear at bringing about skeletal and soft tissue changes and there is a need to align appliance specific approach depending on the type of malocclusion.

The effects of orthodontic treatments on the matters of midface growth and airway dynamics were mentioned by Catia Bras Bariani et al. (2020) and Havakeshian et al. (2020). Although we aimed to study cephalometric results, the improvements in the facial height ratio (0.02 0.03) and LAFH (1.8 1.2 mm) indicated the importance of early interventions in balanced midface development, which might have implications on the functional outcomes, such as the airway patency. These observations will serve as evidence of the fact that early treatment has a multifold fringe that is not in terms of aesthetics but in terms of functionality.

Hancock and colleagues (2023) observed that patients with high BMI have bigger facial measurements, and this factor may affect treatment success. Though it was not played out as such in our research, the insignificance of the observed between-group differences in vertical values ($p>0.05$) indicates that growth-related factors that may involve BMI may also have an impact on vertical outcomes. This points out the necessity of taking into consideration of external factors in planning of treatments as Hancock et al. have suggested.

The drawbacks of our retrospective study design and possible variability in radiographs can be compared to literature based concerns, including Christou el al concerns with regard to study design variability. But our stringent matching and statistical adjustments (ANCOVA) reduces the contribution of these issues toward our reliability. One of the strongest pieces of evidence is the existence of great between-groups distinction of skeletal (ANB, SNB) and soft tissue parameters (Wilson-score, 2006) that would suggest the efficiency of early interventions in the long-term perspective, especially when being matched in type of and aptness of the appliances.

6.0 Conclusion

This experiment proves that effective results, namely long-lasting mitigations in face morphology can be achieved by the application of early intervention procedures during mixed dentition stage, and these data can be proved by cephalometric processor. The result follows the literature that proves that early interventions are effective in fixing skeletal discrepancies and improving aesthetic aesthetics of the soft tissues especially when using functional appliances. On its one part, by treating the issues that were identified through previous research, namely unpredictability of growth (Bleyer, 2019), stability of the treatment (Lee et al., 2021), and aesthetic results (Christou et al., 2019), our findings suggest that individualized planning of treatment and the choice of appliance is necessary. Further studies ought to investigate how external mechanistic variables, such as BMI (Hancock et al., 2023), and functional consequences, such as airway dynamics (Havakeshian et al., 2020), interact to pinpoint new changes to modular orthodontic techniques. These pieces of information confirm that early interventions should be continued to maximize the long-term aesthetic and skeletal harmony on the face and that would be beneficial to both clinicians and patients.

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Recommendation

Based on the findings of this study, it is recommended that early orthodontic interventions, particularly during the mixed dentition phase (6-12 years), be considered as an effective approach to achieve long-term skeletal and aesthetic improvements in facial morphology. Orthodontists should prioritize the use of functional appliances, such as Twin Block, for cases requiring mandibular advancement, given their superior impact on skeletal relationships and soft tissue profiles. Individualized treatment planning is essential, taking into account the type of malocclusion and patient growth patterns, to maximize outcomes and minimize potential relapse. Further research is encouraged to explore the influence of external factors, such as BMI, and functional aspects like airway dynamics, to refine orthodontic techniques. Additionally, longitudinal studies with larger sample sizes and standardized imaging protocols are suggested to validate these results and enhance clinical decision-making.

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