Učinek ortopedsko-ortodontske obravnave nepravilnosti razreda II, oddelek 1

Treatment effects of dentofacial orthopedics followed by a multibracket appliance for Class II division 1 malocclusion

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Izvleček

Namen: *Namen te študije je bil ovrednotiti učinke dvofaznega ortodontskega zdravljenja nepravilnosti razreda II, podrazred 1, ter tudi jih primerjati z normalno rastjo pri nezdravljenih primerih razreda II (kontrolna skupina).*
Metode: *V študijo je bilo vključenih 27 pacientov (17 fantov in deset deklet). Analiza je temeljila na stranskih telerentgenih, opravljenih pred začetkom zdravljenja (T0), po zdravljenju s funkcionalnim ortodontskim aparatom v pubertetnem obdobju (T1) ter po zaključenem zdravljenju s fiksnim ortodontskim aparatom za dosego optimalne okluzije (T3). Povprečna starost pacientov pred začetkom zdravljenja s funkcionalnim aparatom je bila 11,7 ± 0,7 let (CVMS 2–4). Učinke rasti smo*

Abstract

Purpose: *The aim of this study was to evaluate the effects of a two-phase orthodontic treatment for Class II division 1 malocclusion and to compare the outcomes with the natural growth observed in untreated Class II subjects.*
Methods: *The study group consisted of 27 patients (17 males and 10 females). Lateral cephalograms were evaluated before treatment (T0), after treatment with a functional orthodontic appliance during puberty (T1), and after treatment with a fixed appliance to achieve proper occlusion (T3). The mean age of patients before functional appliance therapy was 11.7 years (±0.7; Cervical Vertebral Maturation Stage (CVMS) 2–4). The effect of growth was assessed by compar-*

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primerjali z nezdravljeno kontrolno skupino pacientov z nepravilnostjo razreda II.

Rezultati: *V primerjavi z nezdravljeno skupino je prva faza zdravljenja s funkcionalnimi aparati povzročila statistično pomembno povečanje efektivne dolžine mandibule, zmanjšanje skeletnega sagitalnega neskladja med maksilo in mandibulo, izboljšanje obraznega profila ter zmanjšanje sagitalne stopnice (SS). To zmanjšanje je bilo posledica protruzije in proklinacije zgornjih sekalcev ter retruzije in retroklinacije spodnjih sekalcev ($p \le 0{,}022$). Čeljustna ortopedija ni imela statistično pomembnega vpliva na vertikalno dimenzijo obraza. Druga faza zdravljenja s fiksnim aparatom je v primerjavi s kontrolno skupino prispevala k zmanjšanju vertikalne dimenzije obraza ter dodatnemu zmanjšanju SS, in to predvsem zaradi protruzije in proklinacije spodnjih sekalcev ($p \le 0{,}046$).*

Zaključek: *Prva faza zdravljenja nepravilnosti razreda RII/1 je imela izrazitejše učinke kot druga faza zdravljenja. Kljub temu sta obe fazi zdravljenja pokazali večji dentoalveolarni kot skeletni učinek.*

ing the results to untreated Class II cases in the control group.

Results: *Compared to untreated individuals, first-phase treatment with functional appliances significantly increased the effective mandibular length, reduced maxillo-mandibular sagittal skeletal discrepancy, improved the facial profile, and decreased overjet through the protrusion and proclination of maxillary incisors and the retrusion and retroclination of mandibular incisors ($p \le 0.022$). Dentofacial orthopedics did not significantly affect the vertical facial dimension. In the second phase, treatment with fixed appliances reduced the vertical facial dimension and reduced overjet, primarily through proclination and protrusion of the mandibular incisors ($p \le 0.046$).*

Conclusions: *The first phase of Class II division 1 treatment produced greater effects than the second phase. In both phases, changes were predominantly dentoalveolar rather than skeletal.*

INTRODUCTION

Class II malocclusion is typically defined by an anteroposterior discrepancy between the dental arches. The condition becomes more pronounced when it is associated with skeletal imbalance resulting from mandibular retrognathia, maxillary prognathia, or a combination of both (1,2). Skeletal Class II malocclusion is a frequently encountered clinical problem in orthodontics. Data from the National Health and Nutrition Examination Survey III indicated a prevalence of Skeletal Class II malocclusion of approximately 23% in children, 15% in adolescents, and 13% in adults (2). In most individuals, this malocclusion is primarily related to mandibular retrognathia (1,3).

The etiology of Class II malocclusion is multifactorial; therefore, treatment planning must consider several factors, including the patient's stage of skeletal development, the optimal timing of intervention, the severity of the malocclusion, and the choice of orthodontic appliance (4). In growing patients presenting with mandibular retrognathia, functional appliances are widely used to correct Class II malocclusion (2,5,6). Functional appliances, whether removable or fixed, are designed to reposition the mandible sagittally and vertically, thereby promoting orthodontic and orthopedic adaptations in the jaws and dentition (7–10). Commonly used removable functional appliances include the Twin Block appliance (7,10–13), the Sander bite-jumping appliance (14–16), and the mandibular advancement appliance used with Invisalign (17). Fixed functional appliances frequently used in clinical practice include the Herbst appliance (18,19), Forsus (20), Jasper Jumper (21–23), and the mandibular anterior repositioning appliance (24).

The dentoskeletal effects produced by functional appliances may vary depending on the timing of treatment. When therapy is initiated during the pubertal growth spurt, or shortly thereafter, skeletal changes such as increased mandibular length may occur (25,26). Treatment may also contribute to the correction of molar relationships, alignment of incisors, improvement of overjet (OJ) and overbite, and the modification of skeletal relationships (5). However, removable functional appliances are often perceived by patients as uncomfortable and unaesthetic, and the success of treatment largely depends on patient compliance and motivation (27). Nevertheless, some investigators have suggested that the observed treatment effects are predominantly dentoalveolar (8,13) and may be comparable to those achieved through normal growth or conventional edgewise therapy (28,29).

Treatment of Class II malocclusion associated with mandibular retrognathia in growing patients remains challenging. Moreover, some improvements achieved during the first phase of treatment, particularly OJ reduction, may be partially lost during the second phase due to dental decompensation during leveling and alignment, or an unrecognized pterygoid response. Therefore, the aim of this study was to evaluate the impact of treatment with a functional appliance followed by fixed appliance therapy on dentoskeletal characteristics. The primary outcome was dental change, specifically OJ, while secondary outcomes included skeletal changes and changes in the soft tissue facial profile.

The null hypothesis was that treatment mainly produces dentoalveolar changes, but more skeletal changes in the functional appliances phase than the fixed appliance phase. It was anticipated that the increase of mandibular length and the decrease in facial convexity was greater in treated patients than untreated controls.

MATERIALS AND METHODS

Data acquisition

This study protocol was reviewed and approved by the University of Rijeka Ethics Committee (No. 2170-24-01-15-2) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from the parents of all participants prior to inclusion in the study.

Groups

The data were collected from a previously-described one-center study on functional appliances (30).

The patients were considered eligible for the first phase of treatment if they presented a full Class II division 1 malocclusion associated with mandibular retrognathia, an OJ ≥ 5 mm, skeletal maturity corresponding to cervical vertebral maturation stage CVMS 2-4 (26,31), absence of chronic diseases or medical conditions, and Croatian as their native language. The exclusion criteria included vertical facial growth patterns and mental disability.

Twenty-seven patients had complete records available after undergoing treatment with a labial multibracket full fixed straight-wire appliance (McLaughlin, Bennett, and Trevisi (MBT) prescription, 0.022”), without premolar extractions, which was used to finalize and detail the occlusion. Both dental arches were leveled and aligned up to a 0.019” × 0.025” stainless steel archwire, and Class II elastics were applied. The control group consisted of Caucasian individuals selected from the Bolton-Brush, Oregon, Forsyth, and Michigan growth studies (American Association of Orthodontists Craniofacial Growth Legacy Collection). Controls were matched to the treated patients according to skeletal class, sex, and skeletal age.

Lateral cephalograms

Lateral cephalograms (LCs) in the study group were obtained before treatment (T0), at the completion of functional appliance therapy (T1), and immediately before removal of the full fixed appliance (T2). Cephalograms from the untreated control group were collected at the corresponding time intervals.

All LCs were obtained using a standardized cephalometric technique with a cephalostat and a calibration ruler. Only high-quality images without exposure or positioning errors were included in the analysis.

Craniofacial morphological characteristics were analyzed by a single examiner (AF), an orthodontist, using the Audax cephalometric software program (Audax, Ljubljana, Slovenia). The list of cephalometric variables is presented in Table 1.

To assess intra-examiner reliability, measurements of 27 LCs were repeated after a 1-week interval. Reproducibility was evaluated using the intraclass correlation coefficient.

Statistical analysis

The Mann–Whitney U test was used to compare changes in cephalometric variables (T0 – T1 and TI – T2) between the study and control groups. A p-value of 0.05 was considered statistically significant.

RESULTS

Figure 1 indicates the patient progression throughout the clinical trial. Patients whose treatment included tooth extractions were excluded from the study, as extractions may compensate or alter the facial and skeletal profile.

The mean age of patients at the beginning of treatment with a functional appliance was 11.7 years (±0.7 years). The functional appliance phase lasted ~1 year.

Twenty-seven patients treated with a functional appliance subsequently underwent treatment with a full fixed labial multibracket appliance (straight-wire appliance) to finish and detail the occlusion.

The mean (± standard deviation) duration of treatment with the fixed appliance was 27.3 months (±9.01 months). The sex distribution in the treated group consisted of 17 males and 10 females, which was identical to that of the control group. No statistically significant differences were observed between the groups with respect to initial age at treatment or sex distribution ($p > 0.05$).

Treatment effects of functional appliance

Differences in cephalometric measurements before (T0) and after (T1) treatment with a functional appliance are reported in Table 2.

Compared to untreated subjects, the functional appliance group showed a significant increase in the Sella-Nasion-B point (SNB) angle and total mandibular length, as well as a significant decrease

Table 1. Linear and angular measurements and descriptions.

Measurement	Definition
SNA (°)	Prognathism of the maxillary alveolar bone, angle formed between the SN plane and point A
SNB (°)	Prognathism of mandibular alveolar bone, angle formed between the SN plane and point B
ANB (°)	Skeletal sagittal class angle, difference between SNA and SNB angle relates jaws to anterior cranial base
Wits (mm)	Skeletal sagittal class appraisal, linear distance between the projecting points A and B perpendicular on the functional occlusal plane (AO and BO). Positive value when AO precedes BO
NAPg (°)	Skeletal facial convexity, angle formed between the N-A line and A-Pg line
AnsPns/ MeGo (°)	Intermaxillary angle, angle between palatal and mandibular plane
SGo/NMe	Face height ratio, the ratio between posterior face height (S-Go) and anterior face height (N-Me)
SNGn (°)	Facial skeltal Y axis, angle between N-S-Gn
Björk polygon (°)	Sum of angles N-S-Ar, S-Ar-Go, Ar-Go-Me
Co-Gn (mm)	Total mandibular length, the linear distance between the condylion and the gnathion points
U1/AnsPns (°)	Maxillary incisor inclination, the angle between the most prominent maxillary incisor (Is-As) and the palatal plane
L1/GoGn (°)	Mandibular incisor inclination, the angle between the most prominent mandibular incisor (Ii-Ai) and the mandible plane
U1/NA (°)	The angle between the long axis of the upper incisors to the NA plane
L1/NB (°)	The angle between the long axis of the lower incisors to the NB plane
OJ (mm)	The horizontal distance from the maxillary incisor tip to the labial surface of the mandibular incisor
Gl-Sn-Pg'	Facial convexity, the angle between soft tissue Gl, Sn, Pg'

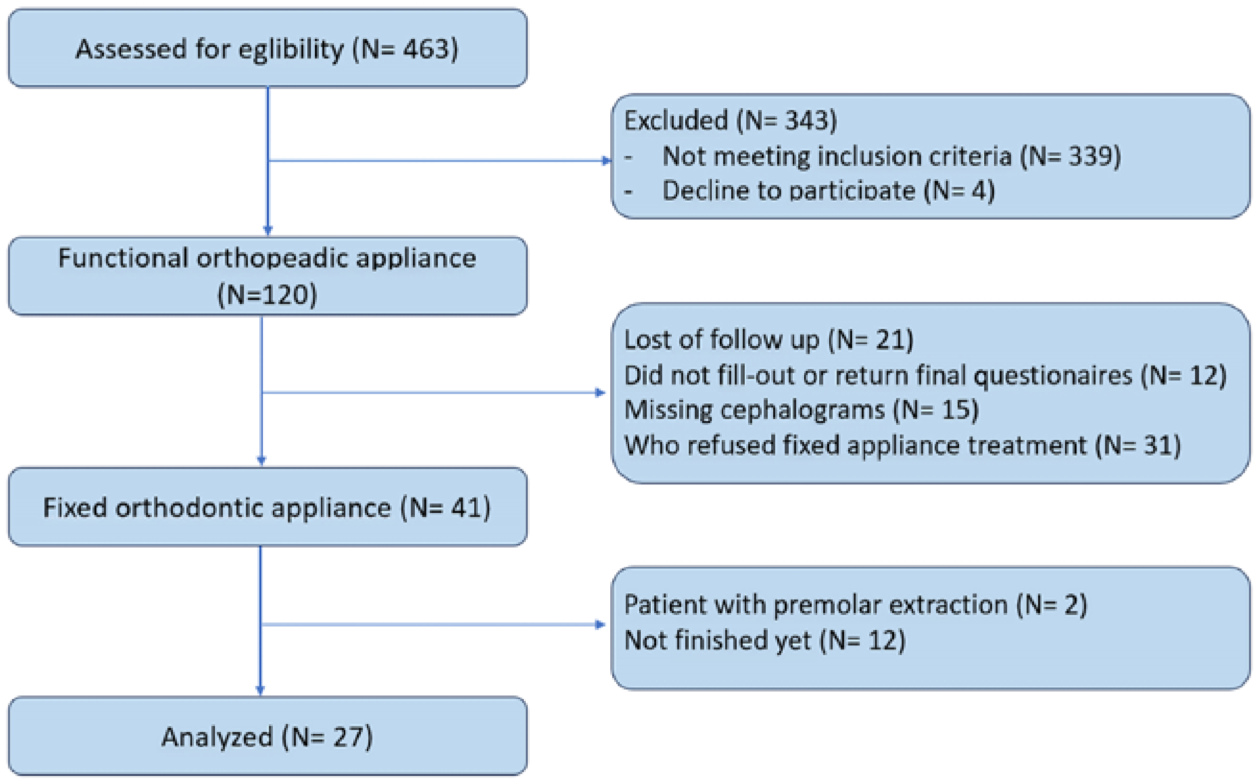

Figure 1. *Diagram of patient progression.*

in the A point-Nasion-B point (ANB) angle and Wits appraisal, while no significant differences were observed in vertical measurements. The inclination and protrusion of the maxillary incisors significantly decreased, whereas the inclination and protrusion of the mandibular incisors increased compared to the untreated group.

Treatment with a functional appliance improved the facial profile with a reduction in facial convexity due to an increase in the Nasion-A point-Pogonion (NAPg’) and Glabella-Subnasale-Pogonion (Gl-Sn-Pg’) angles.

Treatment effects with fixed orthodontic appliance

Differences in cephalometric measurements after (T2) treatment with the fixed orthodontic appliance and at the end of treatment with the functional appliance (T1) are reported in Table 3. An increase in the Wits measurements and a decrease in the vertical dimension (Björk) was observed following treatment with a fixed orthodontic appliance. The reduction in OJ observed in the treated group compared to the untreated group was also observed with an increase in mandibular incisor inclination and protrusion. A greater protrusion of the maxillary incisors was also observed in the treated group compared to the control group.

DISCUSSION

The present study demonstrated that a greater treatment effect in Class II division 1 malocclusion was achieved during the first phase with a functional appliance than during the second phase with a fixed multibracket appliance combined with Class II elastics. The majority of the treatment effect observed in both phases was dentoalveolar, and therefore, the null hypothesis was partially accepted.

Effects of functional appliance therapy

Treatment with a functional appliance during active growth resulted in statistically and clinically significant skeletal changes compared to untreated

Table 2. Treatment effects with functional appliances (T1–T0) compared to the control group.

Variable	Treated group median (interquartile range)	Control group median (interquartile range)	p
SNA (°)	0.2 (-0.1-0.7)	-0.4 (-1-0.9)	0.130
SNB (°)	1.4 (0.6-2.0)	0.2 (-0.4-1.0)	≤ 0.001
ANB (°)	-0.8 (-1.8-(-0.5))	-0.5 (-0.8-0.4)	0.003
Wits (mm)	-2.0 (-3.0-(-2.0))	-0.1 (-1.0-1.2)	≤ 0.001
NSGn (°)	-1 (-1-3)	0 (-0.7-0.7)	0.411
NAPg (°)	-2.4 (-4.7-(-1.2))	-0.9 (-2.5-1.3)	0.003
AnsPns/MeGo (°)	-0.5 (-1.4-0.7)	-0.7 (-2.3-1.6)	0.782
SGo/NMe (%)	0.9 (-1.4-2.6)	0.0 (0.0-0.0)	0.622
Björk's sum (°)	-1.0 (-2.2-0.8)	0.2 (-1.2-1.0)	0.183
Co-Gn (mm)	7.0 (5.0-9.0)	2.8 (1.0-3.6)	≤ 0.001
U1/AnsPns (°)	-4.7 (-7.5-(-2.0))	0.0 (-2.3-2.0)	≤ 0.001
L1/GoMe (°)	2.6 (0.7-5.0)	0.5 (-1.0-1.7)	0.005
U1/NA (mm)	-1.5 (-2.6-(-0.8))	0.2 (-0.5-1.0)	≤ 0.001
L1/NB (mm)	1.8 (0.0-2.6)	0.2 (-0.1-0.4)	0.022
OJ (mm)	-3.9 (-5-(-2.5)	0 (-1-0.7)	≤ 0.001
Gl-Sn-Pg' (°)	2.2 (1.3-3.9)	(-1.4-3.0)	0.022

Table 3. Treatment effects with fixed orthodontic appliance (T2-T1) compared to the control group

Variable	Treated group median (interquartile range)	Control group median (interquartile range)	p
SNA (°)	0.0 (-0.1-0.9)	0.3 (-0.7-1.4)	0.169
SNB (°)	0.4 (-0.2-1.5)	1.6 (0.1-3.1)	0.067
ANB (°)	-1.0 (-1.8-0.0)	-1.3 (-2.3-(-0.5))	0.382
Wits (mm)	0.3 (-1.0-1.5)	-1.2 (-2.6-0.0)	0.021
NSGn (°)	-0.3 (-1.5-0.8)	-0.5 (-1.9-0.2)	0.411
NAPg (°)	-0.7 (-3.5-0.7)	-2.2 (-4.9-(-0.4))	0.117
AnsPns/MeGo (°)	-1.3 (-3.1-0.6)	1.6 (-3.1-3.3)	0.085
SGo/NMe (%)	0.0 (0.0-0.1)	0.0 (0.0-0.0)	≤ 0.001
Björk's sum (°)	-3.0 (-5.1-(-0.6))	1.0 (-2.8-0.8)	0.037
Co-Gn (mm)	4.1 (2.4-5.3)	2.8 (0.4-6.4)	0.452
U1/Ans-Pns (°)	2.7 (-2.2-5.5)	4.9 (1.2-7.7)	0.087
L1/GoMe (°)	2.9 (-2.1-6.0)	-2.7 (-4.0-3.0)	0.046
U1/NA (mm)	2.7 (0.2-4.3)	-2.3 (-4.8-(-0.7))	< 0.001
L1/NB (mm)	1.4 (0.4-2.6)	-0.2 (-1.6-0.2)	< 0.001
OJ (mm)	-1.9 (-3.0-(-1.0))	-0.8 (-1.9-(-0.2))	0.027
Gl-Sn-Pg' (°)	0.2 (-3.0-2.4)	-1.0 (-2.9-0.4)	0.359

controls. In particular, a significant increase in the SNB angle and total mandibular length (Co–Gn) was observed, accompanied by a reduction in the ANB angle and Wits appraisal. Those findings support the concept that functional appliances can stimulate mandibular growth or redirect mandibular development when applied during an appropriate phase of skeletal maturation. Consistent with previous studies reporting enhanced mandibular advancement during the pubertal growth spurt (25,26), these changes may represent a temporary acceleration of mandibular growth; however, it cannot be excluded that growth subsequently slows.
The median increase in mandibular length in the treated group exceeded that observed in the matched control group (7.0 mm vs 2.8 mm), suggesting that the observed changes cannot be attributed solely to normal growth. A study by McNamara (32) demonstrated a greater mandibular response to functional orthopedic appliances in pubertal patients (8.7 ± 2.8 mm) compared to prepubertal patients (5.9 ± 2.3 mm), while untreated pubertal and prepubertal control groups showed increases of 4.8 ± 1.9 mm and 3.7 ± 1.1 mm, respectively. Those findings support the view that functional appliances used in growing patients may exert a true orthopedic effect rather than only dentoalveolar camouflage, regardless of appliance type. However, the issue remains controversial in the literature (9,14,31,32).
Cozza et al. (9) and Santamaria-Villegas et al. (33) found that the largest monthly increase in mandibular length occurred following use of the Sander bite-jumping appliance (0.34 mm per month) and the Herbst appliance (0.28 mm per month), followed by the Twin Block (0.23 mm per month), Bionator (0.17 mm per month), and Harvold Activator (0.12 mm per month). By contrast, the Frankel appliance produced the smallest increase, at 0.09 mm per month.
The absence of significant vertical changes further indicates that sagittal correction was achieved without unfavorable vertical growth patterns, which is clinically advantageous in Class II patients. The findings are comparable to those reported by Saikoski (34), Mills (35), and Soheilifar (36). The presence of acrylic bite ramps in functional appliances likely produces a bite-plane effect on posterior teeth, thereby improving vertical control.
In addition to skeletal effects, significant dentoalveolar changes were observed during the functional appliance phase. OJ decreased significantly as a result of mandibular advancement and dental compensation, including retroclination and retrusion of the maxillary incisors, and proclination and protrusion of the mandibular incisors.
Such dental changes align with previous findings (23,32,37) and are indicative of the functional appliances' mode of action and the loss of anchorage in the mandibular dentition (5). The retroclination of maxillary incisors observed in the study group may be explained by contact with lip musculature and the labial bow during functional appliance therapy. Toth and McNamara (37) also reported palatal tipping of the maxillary incisors caused by lip pressure during Twin Block treatment. Proclination of mandibular incisors may result from mesial forces acting on the mandibular incisors due to the forward positioning of the mandible, which is consistent with other studies (37). However, the magnitude of skeletal correction suggests that dental compensation alone does not explain the observed improvements.
The control group showed a slight decrease in OJ over time, which was not statistically significant and has also been reported in previous studies (23,28).

Effects of fixed orthodontic appliance therapy

The second phase of treatment with a fixed multibracket appliance and Class II elastics was primarily characterized by dentoalveolar changes. Although OJ continued to decline during this stage, the extent of skeletal change remained minimal and was not significantly different from that seen in the untreated control group.
The increase in Wits appraisal and the minimal change in SNB suggest a partial relapse or normalization of sagittal skeletal relationships during this phase, possibly related to growth patterns or dental decompensation associated with leveling and alignment mechanics.
Maxillary incisors showed a tendency toward protrusion during leveling and aligning using a fixed appliance. At the same time, lower incisor proclination and protrusion increased significantly due to use of Class II elastics. Class II elastics produce dental compensation rather than skeletal correction,

particularly after the peak growth period. These observations also support previous findings that skeletal gains achieved during functional appliance therapy may be partially masked during subsequent fixed appliance treatment if dental decompensation is not carefully controlled.

Vertical skeletal changes during the fixed appliance phase were minimal, although a significant decrease in Björk's sum suggested a tendency toward forward mandibular rotation. However, the changes were small and of uncertain clinical relevance. Importantly, no further enhancement in soft tissue facial convexity was detected during this phase, suggesting that the majority of the esthetic improvements occurred during the period of functional appliance therapy.

Soft tissue profile changes

Class II division 1 malocclusion affects facial profiles and aesthetics, often leading to concerns about appearance. The characteristic convex profile caused by mandibular retrusion creates an imbalance in facial proportions. Such aesthetic concerns can impact self-perception and social confidence, particularly in adolescents and young adults.

In our study, soft tissue analysis showed that functional appliance therapy significantly reduced facial convexity (Gl-Sn-Pg'), improving the facial profile. These findings are clinically relevant, as facial esthetics are often a primary concern for patients and parents seeking early treatment.

This improvement was maintained during the fixed appliance phase, although no further significant soft tissue changes were observed. The results emphasize the importance of early mandibular advancement in achieving favorable facial esthetics and highlight the clinical relevance of correcting skeletal discrepancies before final orthodontic detailing. Similar finding has also been reported in study by Singh and Clark (38).

Clinical implications

The findings of this study highlight the importance of treatment timing in Class II malocclusion with mandibular retrognathia. A two-phase treatment approach appears effective in achieving both skeletal correction and optimal dental occlusion in growing patients with Class II division 1 malocclusion. Functional appliances should preferably be used during the peak pubertal growth phase to achieve maximum mandibular advancement, while fixed appliances are mainly intended to complete occlusal correction and dental alignment.

Clinicians should be aware that some skeletal correction achieved during the first phase may be partially offset during the second phase due to dentoalveolar compensation. Therefore, careful treatment planning and biomechanical control are essential. Monitoring of lower incisor proclination is particularly important, as both treatment phases contributed to its increase, which may have implications for long-term periodontal health.

Additionally, this treatment approach may shorten overall treatment duration compared to conventional two-phase treatment in which removable functional appliances are used before puberty (approximately 2.3 years vs 3.4 years) (4,39,40). Furthermore, Giuntini et al. (4) reported shorter treatment durations with fixed appliances compared to combined treatment using fixed appliances and fixed functional appliances (1.2 years vs 2.3 years, respectively).

Limitations

Several limitations of this study should be acknowledged. First, the sample size was relatively small and derived from a single center, which may limit the generalizability of the findings. Second, the use of historical controls may introduce potential bias, despite matching for skeletal age and sex. Third, the study evaluated short-term treatment effects; therefore, long-term stability (e.g., 5 years) of skeletal and dental changes requires further investigation. Fourth, compliance with functional appliance wear was assumed but not objectively measured, which may have influenced the magnitude of the observed skeletal effects. Finally, LCs provide a two-dimensional assessment of three-dimensional structures, which may underestimate skeletal changes. Future studies incorporating three-dimensional imaging and long-term follow-up would provide additional insight into the stability of treatment outcomes. Notably, however, comparisons of one-phase vs two-phase treatment using new diagnostic tools and long-term stability has substantial clinical potential.

CONCLUSIONS

Treatment of Class II division 1 malocclusion using a functional appliance followed by fixed appliance therapy results in significant mandibular advancement, reduction in OJ, and improvement of facial profile. Skeletal changes occur primarily during the functional appliance phase, while fixed appliances contribute primarily to dental alignment and occlusal finishing. This two-phase treatment approach represents an effective strategy for managing growing patients with mandibular retrognathia, while balancing skeletal correction and esthetic outcomes.

REFERENCES

1. McNamara JA Jr. Components of class II malocclusion in children 8-10 years of age. Angle Orthod. 1981; 51(3): 177-202.
2. Proffit WR, Fields HW Jr, Moray LJ. Prevalence of Malocclusion and Orthodontic Treatment Need in the United States: Estimates from the NHANES III Survey. Int J Adult Orthod Orthognath Surg. 1998; 13(2): 97-106. PMID: 9743642.
3. Buckhardt DR, McNamara JA, Jr, Baccetti T. Maxillary molar distalization or mandibular enhancement: a cephalometric comparison of comprehensive orthodontic treatment including the pendulum and the Herbst appliances. Am J Orthod Dentofacial Orthop. 2003; 123(2): 108-16. doi.org/10.1067/mod.2003.7
4. Giuntini V, McNamara JA, Franchi L, Treatment of Class II malocclusion in the growing patient: Early or late? Sem Orthod, 2023; 29(3): 183-8. doi: 10.1053/j.sodo.2023.04.008
5. Baccetti T, Franchi L. Maximizing esthetic and functional changes in Class II treatment by appropriate treatment timing. In: McNamara JA, Jr, Kelly KA eds. Frontiers of Dental and Facial Esthetics. Ann Arbor: Craniofacial Growth Series, Center for Human Growth and Development, The University of Michigan; 2001; 38:237-51.
6. McNamara JA Jr, Brudon WL. Orthodontics and Dentofacial Orthopedics. Ann Arbor: Needham Press; 2001.
7. Spalj S, Mroz Tranesen K, Birkeland K, Katic V, Pavlic A, Vandevska-Radunovic V. Comparison of activator-headgear and Twin Block treatment approaches in class II division 1 malocclusion. BioMed Res Int. 2017; 4861924. doi: 10.1155/2017/4861924. Epub 2017 Jan 22. PMID: 28203569; PMCID: PMC5292161
8. Koretsi V, Zymperdikas VF, Papageorgiou SN, Papadopoulos MA. Treatment effects of removable functional appliances in patients with Class II malocclusion: a systematic review and meta-analysis. Eur J Orthod 2015; 37(4): 418-34. doi: 10.1093/ejo/cju071. Epub 2014 Nov 13. PMID: 25398303.
9. Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara JA Jr. Mandibular changes produced by functional appliances in Class II malocclusion: a systematic review. Am J Orthod Dentofacial Orthop. 2006 May; 129(5): 599.e1-12; doi: 10.1016/j.ajodo.2005.11.010. PMID: 16679196
10. Ristić V, Stefanović N, Stamenković Z, Živković-Sandić M, Stojić V, Glišić B. Effects of three types of functional appliances in class II malocclusions treatment - sagittal and vertical changes. Srp Arh Celok Lek. 2018; 146: 149-56.
11. Lombardo EC, Lione R, Franchi L, Gaffuri F, Maspero C, Cozza P, Pavoni C. Dentoskeletal effects of clear aligner vs twin block-a short-term study of functional appliances. J Orofac Orthop. 2024: Sep; 85(5): 317-26. doi: 10.1007/s00056-022-00443-1. Epub 2023 Jan 18. PMID: 36651930; PMCID: PMC11358164
12. Jena AK, Duggal R, Parkash H. Skeletal and dentoalveolar effects of Twin-block and bi-

onator appliances in the treatment of Class II malocclusion: a comparative study. Am J Orthod Dentofacial Orthop. 2006; 130 (5): 594-602. doi: 10.1016/j.ajodo.2005.02.025. PMID: 17110256.
13. Jena AK, Duggal R. Treatment effects of twin-block and mandibular protraction appliance-IV in the correction of Class II malocclusion. Angle Orthod. 2010; 80 (3): 485-91. doi: 10.2319/062709-359.1. PMID: 20050741; PMCID: PMC8985713
14. Faccioni P, De Santis D, Sinigaglia S, Zarantonello M, Zotti F, Pancera P, Iurlaro A, Finotti M, Marchiori M, Bazzanella S, Alberti C, Zangani A, Capocasale G, Donadello D, Faccioni F, Nocini PF. Effects of the sander bite jumping appliance in patients with class ii malocclusion before growth peak. J Biol Regul Homeost Agents. 2020; 34(6) :1-7. PMID: 33541060.
15. Martina R, Cioffi I, Galeotti A, Tagliaferri R, Cimino R, Michelotti A, Valletta R, Farella M, Paduano S. Efficacy of the Sander bite-jumping appliance in growing patients with mandibular retrusion: a randomized controlled trial. Orthod Craniofac Res. 2013; 16(2): 116-26. doi: 10.1111/ocr.12013. Epub 2013 Jan 7. PMID: 23323608.
16. Sander F, Synodinos FN, Iglezos E, Sander M, Iglezou E, Sander C. The functional orthodontic-orthopedic VDP appliance (Vorschubdoppelplatte, Bite jumping appliance, Sander II). Literature review and typical clinical case presentation. Hell Orthod Rev. 2007; 10: 11-27.
17. Kicirelli BH, Tek FB, Cetinkoya-Tokmak E, Cobanoglu G. Comparative effects of mandibular advancement with Invisalign Enhanced Precision Wings and Twin Block appliance on dentofacial structures. Orthod Craniofac Res. 2025. doi.org/10.1111/ocr.70058
18. Pancherz H, Fackel U. The skeletofacial growth pattern pre- and post-dentofacial orthopaedics. A long-term study of class II malocclusions treated with the Herbst appliance. Eur J Orthod. 1990; 12(2): 209-18. doi: 10.1093/ejo/12.2.209. PMID: 2351206
19. Pancherz H. The effects, limitations, and long-term dentofacial adaptations to treatment with the Herbst appliance. Semin Orthod. 1997; 3(4): 232-43. doi: 10.1016/s1073-8746(97)80056-4. PMID: 9573885
20. Jones G, Buschang PH, Kim KB, Oliver DR. Class II non-extraction patients treated with the Forsus Fatigue Resistant Device versus intermaxillary elastics. Angle Orthod 2008; 78(2): 332-8. doi: 10.2319/030607-115.1. PMID: 18251605
21. Karacay S, Akin E, Olmez H, Gurton A.U, Sagdic D. Forsus Nitinol Flat Spring and Jasper Jumper corrections of Class II division 1 malocclusions. Angle Orthod. 2006; 76(4): 666-72. doi: 10.1043/0003-3219(2006)076 [0666:FNFSAJ]2.0.CO;2. PMID: 16808575
22. Kucukkeles N, Ilhan I, Orgun A. Treatment efficiency in skeletal Class II patients treated with the Jasper Jumper. Angle Orthod. 2007; 77(3): 449-56. doi: 10.2319/0003-3219(2007)077[0449:TEISCI]2.0.CO;2. PMID: 17465652.
23. de Oliveira JN Jr, Rodrigues de Almeida R, Rodrigues de Almeida M. Dentoskeletal changes induced by the Jasper Jumper and cervical headgear appliances followed by fixed orthodontic treatment. Am J Orthod Dentofacial Orthop. 2007; 132(1): 54-62. doi: 10.1016/j.ajodo.2005.07.028. PMID: 17628251.
24. Pangrazio MNK, Pangrazio-Kulbersh V, Berger JL, Bayirli B, Movahhedian A. Treatment effects of the mandibular anterior repositioning appliance in patients with Class II skeletal malocclusions. Angle Orthod. 2012; 82(6): 971-977. doi: 10.2319/120511-748.1. Epub 2012 Mar 21. PMID: 22432591; PMCID: PMC8813139.
25. Perinetti G, Primožič J, Furlani G, Franchi L, Contardo L. Treatment effects of fixed functional appliances alone or in combination with multibracket appliances: a systematic review and meta-analysis. Angle Orthod. 2015; 85(3): 480-92. doi: 10.2319/102813-790.1. Epub 2014 Sep 4. PMID: 25188504; PMCID: PMC8612434.
26. Baccetti T, Franchi L, McNamara JA Jr. The Cervical Vertebral Maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Or-

thod. 2005; 11(3): 119-29. doi.org/10.1053/j.sodo.2005.04.005

27. Stefanovic NL, Uhac M, Brumini M, Zigante M, Perkovic V, Spalj S. Predictors of patient compliance during Class II division 1 malocclusion functional orthodontic treatment. Angle Orthod. 2021; 91(4): 502-8. doi: 10.2319/090820-780.1. PMID: 33587107; PMCID: PMC8259759.
28. Pangrazio-Kulbersh V, Berger JL, Chermak DS, Kaczynski R, Simon ES, Haerian A. Treatment effects of the mandibular anterior repositioning appliance on patients with Class II malocclusion. Am J Orthod Dentofacial Orthop. 2003; 123(4): 286-95. doi: 10.2319/090820-780.1. PMID: 33587107; PMCID: PMC8259759.
29. Ceekmore T. D, Radney L. J. Frankel appliance therapy: orthopedic or orthodontic. Am J Orthod. 1983; 83(2): 89-108. doi: 10.1016/s0002-9416(83)90294-4. PMID: 6572043.
30. Cukaj Ademi H, Zigante M, Premaraj Thyagaseely S, Tudor V, Palomo JM, Spalj S. Mandibular advancement in dentofacial orthopaedics: Effects on pharyngeal airway, dentoskeletal characteristics and quality of life: A randomised controlled trial. Orthod Craniofac Res. 2025; Feb;29(1): 122-33. doi: 10.1111/ocr.70056. Epub 2025 Nov 10. PMID: 41211711; PMCID: PMC12779193.
31. McNamara JA Jr, Franchi L. The cervical vertebral maturation method: A user's guide. Angle Orthod, 2018; 88(2): 133-43. doi: 10.2319/111517-787.1. Epub 2018 Jan 16. PMID: 29337631; PMCID: PMC8312535.
32. McNamara JA, Bookstein FL, Shaughnessy TG. Skeletal and dental changes following functional regulator therapy on Class II patients. Am J Orthod. 1985: 88 (2): 91-110. doi: 10.1016/0002-9416(85)90233-7. PMID: 3861103.
33. Santamaría-Villegas A, Manrique-Hernandez R, Alvarez-Varela E, Restrepo-Serna C. Effect of removable functional appliances on mandibular length in patients with class II with retrognathism: systematic review and meta-analysis. BMC Oral Health. 2017; 17(1): 52. doi: 10.1186/s12903-017-0339-8. PMID: 28148248; PMCID: PMC5289049.
34. Saikoski LZ, Cançado RH, Valarelli FP, de Freitas KM. Dentoskeletal effects of Class II malocclusion treatment with the Twin Block appliance in a Brazilian sample: a prospective study. Dental Press J Orthod. 2014; 19(1): 36–45. doi: 10.1590/2176-9451.19.1.036-045.oar. PMID: 24713558; PMCID: PMC4299421.
35. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a cephalometric study. Am J Orthod Dentofacial Orthop. 1998; 114(1): 15-24. doi: 10.1016/s0889-5406(98)70232-x. PMID: 9674675.
36. Soheilifar S, Alafchi B, Molabashi V, Banisafar Z. Is there any difference in the outcome of growth modification treatment between Class II division 1 and 2 malocclusions? Avicenna J Dent Res. 2019; 11: 48-52.
37. Toth LR, McNamara JA Jr. Treatment effects produced by the twin-block appliance and the FR-2 appliance of Fränkel compared with an untreated Class II sample. Am J Orthod Dentofacial Orthop. 1999; 116(6): 597-609. doi: 10.1016/s0889-5406(99)70193-9. PMID: 10587592.
38. Singh GD, Clark WJ. Localization of mandibular changes in patients with class II division 1 malocclusions treated with twin-block appliances: finite element scaling analysis. Am J Orthod Dentofacial Orthop. 2001; 119(4): 419-25. doi: 10.1067/mod.2001.113265. PMID: 11298315.
39. Tulloch JFC, Proffit WR, Phillips C. Outcomes in a 2-phase randomized clinical trial of early Class II treatment. Am J Orthod Dentofacial Orthop. 2004; 125(6): 657-67. doi: 10.1016/j.ajodo.2004.02.008. PMID: 15179390.
40. Tulloch JFC, Phillips C, Koch G, et al. The effect of early intervention on skeletal pattern in Class II malocclusion: a randomized clinical trial Am J Orthod Dentofacial Orthop. 1997; 111(4): 391-400. doi: 10.1016/s0889-5406(97)80021-2. PMID: 9109584.