Scientific Reports

https://doi.org/10.1038/s41598-026-36482-6

Article in Press

The effectiveness of the basal expansion plate in comparison with the traditional expansion plate during the slow maxillary expansion: a randomized clinical trial

Received: 15 May 2025

Accepted: 13 January 2026

Published online: 21 January 2026

Cite this article as: Ibraheem S.A. & Youssef M. The effectiveness of the basal expansion plate in comparison with the traditional expansion plate during the slow maxillary expansion: a randomized clinical trial. *Sci Rep* (2026). https://doi.org/10.1038/s41598-026-36482-6

Suzan Ahmad Ibraheem & Mohamed Youssef

The Effectiveness of the Basal Expansion Plate in comparison with the Traditional Expansion Plate during the slow maxillary expansion: A Randomized Clinical Trial

Suzan Ahmad Ibraheem*, Mohamed Youssef **

* Department of Orthodontics, Damascus University, Damascus, Syria. Master's degree student in orthodontics and Dentofacial orthopedics, Faculty of Dentistry, Damascus University, suzanibraheem67@gmail.com

** Department of Orthodontics, Damascus University, Damascus, Syria. Professor of Orthodontics and Dentofacial orthopedics, Faculty of Dentistry, Damascus University, prof.moyousef@yahoo.com

Corresponding author:

Dr. Suzan Ahmad Ibraheem

Department of Orthodontics, Damascus University, Damascus, Syria. Master's degree student in orthodontics and Dentofacial orthopedics, Faculty of Dentistry, Damascus University,

suzanibraheem67@gmail.com

https://orcid.org/0009-0008-3859-5181

Address: Faculty of Dentistry, Damascus University, Al-Mazzeh St, Damascus, Syria

Telephone: 00963999328603

The Effectiveness of the Basal Expansion Plate in comparison with the Traditional Expansion Plate during the slow maxillary expansion: A Randomized Clinical Trial

Abstract:
Although slow maxillary expansion is commonly used, numerous studies have demonstrated that the increase in dental arch width is primarily due to buccal tipping of the lateral teeth, often accompanied by recession of the vestibular alveolar process. This investigation addresses whether buccal shields inserted in a modified expansion plate can improve tooth movement, prevent vertical resorption of the alveolar process, and produce skeletal changes. For this purpose, frontal- and lateral cephalograms, along with cast models of 40 patients (17 males and 23 females; age: 10.28 ±1.65) were studied. All patients were treated with slow maxillary expansion, and according to the plate used, patients were divided randomly into 2 groups:- 1st group, 20 patients were treated with a modified plate, called the Basal Expanding Plate (BEP), and – 2nd group, 20 patients were treated with a Traditional Expansion Plate (TEP). Measurements included the alveolar process height, inter-alveolar width, distance between the apex of the meso-buccal root of the upper first molar on two sides, and distance between the top of the meso-buccal cusp of the first upper molar bilaterally. were studied. Blinding was applied only for data analysis. The data obtained were subjected to statistical analyses using t-tests to detect significant group differences. The results revealed significant differences in basal width (BEP:2.62±1.32, TEP:-1.87±1.82), tooth root movement whereas it was buccal movement in BEP group (3.70±2.40) and palatal movement in TEP group (-22.2±3.63), and alveolar process dimensions between the two groups after treatment whereas it increased in BEP group in both sides (1.77±1.65, 1.37±1.22) while it decreased in TEP group in both sides too (-0.82±0.81, -1.00±0.84). Also, the difference was significant in S-N: Go-ME angle, whereas it decreased in the BEP group(-0.03±3.02) and increased in the TEP group (0.40±3.36). Based on the results, it can be concluded that the buccal shields of the basal expansion plate can improve the type of tooth movement, the inter-alveolar width and the height of the vestibular alveolar process during the maxillary dental arch expansion.
Trial registration:ISRCTN69542858 (27/11/2023)

Keywords: maxillary compression, slow maxillary expansion, basal expansion plate, buccal shields, orthodontic tooth movement, alveolar process.

Abbreviations:

BEP: Basal expansion plate

TEP: Traditional expansion plate

Introduction

Maxillary constriction is a developmental disorder that can appear in different types, with lateral crossbite being the most common, and it can be skeletal or dentoalveolar in nature [1, 2] and often leads to different occlusal disturbances in the sagittal, vertical, or transverse planes,[3]. Consequently, maxillary expansion is frequently indicated in orthodontic treatment, and numerous appliance have been developed for this purpose.

According to construction, expansion can be performed using either rapid (RME)[5, 6] or slow (SME)[7]. Among these, SME is more commonly used and widely accepted[8] and can be accomplished with fixed or removable devices.[9]

However, regardless of the type of expansion method, some studies have shown that molar rotation,[10, 11] molar angulation,[12] and alveolar tipping[10, 11] are accomplished with SME. In addition, most studies have revealed that a large proportion of the increase in maxillary arch width is due to the vestibular tipping movement of the maxillary lateral teeth. Based on the results of many studies,[11, 13-16] the tipping of teeth leads to alveolar ridge resorption and a decrease in the thickness of the vestibular alveolar process.[17-19] This has prompted researchers to find therapeutic methods that, throughout tooth movement, are beneficial to avoid or reduce recession of the alveolar process during expansion.

Passive expansion, according to Frankel's philosophy, is based on the principle of periosteal muscle tension in the context of functional treatment, where Frankel proposed combining periosteal muscle tension with dental arch expansion via buccal shields in his appliance "Funktions Regler- FR"[20] to achieve bodily tooth movement during expansion. Thus, less recession of the vestibular alveolar process and greater stability of the expansion results can be ensured.[21, 22] In addition, there are circumstances in which conventional functional considerations may be sacrificed to achieve more stable results.[23]

On the basis of Frankel's philosophy, a modified expansion plate was designed by adding buccal shields, as an attempt to achieve bodily tooth movement and thus reduce recession of the alveolar process during expansion with a removable expansion plate. This modified plate, termed the Basal Expansion Plate (BEP), and a pilot study of 5 patients showed improvement in the dento-alveolar changes in comparison with the Traditional Expansion Plate (TEP). The underlying hypothesis is that the buccal shields generate muscular tension, which stimulates subperiosteal bone deposition and creates negative pressure- similar to the mechanism proposed for the Frankel appliance. This may facilitate vestibular root movement and promote bodily displacement of the teeth during expansion. Accordingly, this study aims to evaluate whether the addition of buccal shields to a traditional expansion plate improves the quality of tooth movement, reduces alveolar crest resorption, and enhances the overall effectiveness of slow maxillary expansion.

Materials and methods

Study design: A randomized single-center controlled trial with two parallel groups was performed at the Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, University of Damascus, between August 2022 and March 2023

Ethics approval

This study was conducted as a two-arm parallel-group randomized controlled trial at the Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, Damascus University, between August 8, 2022, and March,3,2023. The study protocol was registered in a BMC clinical trial (ID: ISRCTN69542858; 27/11/2023)
The University of Damascus Local Research Ethics Committee approved this study (no.3840-25-7-2022). All procedures were performed in accordance with institutional guidelines and ethical standards. Patients received information sheets, and written informed consent forms were collected after permission was obtained.

Sample size calculation, participants and eligibility criteria:

The sample size was determined four times based on the main objectives of the study via G-Power Version 6.1.3, with a significance level of 5% and a power of 95% 1) The alveolar process height changes from a prior related study (Brunetto., et al 2013)[19] and the sample size was 22 patients,2) inter-molar

width changes from(Shundo.,et al 2012)study [24] which resulted 20 patients in two groups, 3) inter-canine width changes from (Erdinc.,et al 1999) study [13] and the sample size was 40 patients and 4) maxillary width changes from (Defraia .,et al 2008)[25] study which resulted 32 patients in the study. The largest sample size (40patients) was selected to ensure greater accuracy; therefore, we depended on (Erdinc.,et al 1999)study [13]

In total 46 patients fulfilled the inclusion criteria: Patients in the mixed dentition; chronological age 8- 12 years, dento-alveolar maxillary constriction (more than 2 mm according to Pont index), Class I,- Or cl. II-malocclusion, presence of upper first permanent molars.The exclusion criteria involved: constriction in the anterior region, presence of systemic disorders or general diseases, or syndromes, cleft lip and palate, patients with previous orthodontic treatment, and poor oral health. When the research project was presented to the patients,40 agreed to participate (17 males and 23 females; aged 10.28±1.65 years) (Table 1).
Patients were chosen from the registered patients between August 2022 and March 2023 (Figure1).

Randomization, allocation concealment, and blinding:

A computer-generated randomization list was used to randomly divide the patients into two equal groups via Minitab® Version 19.1 (Minitab Inc., Pennsylvania, USA), which was created by one of the academic staff (not involved in this research) at the Department of Orthodontics.
The allocation sequence was concealed via sequentially numbered, opaque, closed envelopes. Blinding was not feasible for patients or practitioners due to the nature of the appliances. Therefore, blinding was applied only for the outcome assessor, while plaster-distributed casts and cephalometric radiographs were recorded with serial numbers to ensure blinding and avoid bias in the investigation.

Treatment Method

Forty patients were divided randomly to:

-The 1st group (BEP), 20 patients (9 males and 11 females; age: 10.41 ± 1.8 years) were treated with a plate that was recently invented by adding acrylic buccal shields located at the depth of the vestibular groove and extending from the mesial edge of the canine to the distal edge of the first upper permanent molar on both sides of the maxilla. (Figure 2) And after applying it to several patients in a

pilot study and observing its positive effects in expanding the basal bone, it was named "Basal Expansion Plate".

-The 2nd group (TEP), 20 patients (8 males and 12 females; age: 10.15 ± 1.5 years) were treated with the traditional expansion plate. Its design is similar to that in the (Godoy et al, 2011) study[7] (Figure 3).

Both groups followed the same slow expansion protocol: one-quarter turn (0,25mm) per week)

Follow-up During Treatment:

All participants and parents received both oral and written information on the treatment, oral hygiene and maintenance of the appliance, and were instructed to wear the appliance 15-16 hours per day and to breathe from the nose with closed lips while the appliance was put. Expansion was performed weekly using a key, guided by an arrow on the plate indicating the direction of activation.

_Compliance was monitored through: clinical observation of expansion progress and appliance stability, parent-completed compliance charts, and regular follow-ups: 1 week after fitting, then every 3 weeks. At each visit, the Pont index was measured using a digital caliper. Treatment concluded when the Pont index normalized and maxillary constriction was corrected.

Cephalometric study method: Frontal and lateral cephalometric radiographs were obtained with the same device before (T1) and after orthodontic treatment (T2). All radiographs were taken using the same device,i.e., a PAX 400(VATEH Co.,Ltd Hwaseong, Korea), with the same settings. The outcomes on frontal cephalograms included the following linear measurements: maxillary alveolar process height, (maxillary, inter-alveolar, inter-apical, and inter-cusp) width[26] (Figure 4), and the following angular variables: SNA, SNB, ANB, and S-N: Go-Me were studied on lateral cephalograms (Figure 5).

Cast study method: Dental cast models were generated at T1 and T2 of the study period. In addition to the Pont index, the following variables were studied: inter-canine distance (C-C), inter-deciduous molar distance (Ca4-Ca4), inter-molar distance (Gr6-Gr6), palatal height and basal width after Howe (Figure 6).

Error of the method:

To evaluate reliability, 10 cases were randomly selected and remeasured after one month, and the error of the method was calculated on the basis of the intraclass correlation coefficient (ICC) and Dahlberg's

formula; the value was 0.06, which was considered negligible. No statistically significant differences were found between the first and second measurements according to the paired t-test

Statistical analysis

Statistical analysis was performed via SPSS version 19 (IBM SPSS Statistics 19.0). The homogeneity of the sample was detected by comparing each variable of the first group before treatment with the same variable of the second group via Levene's test for equality of variances, and the normality of the distribution for each variable was studied via the Shapiro–Wilk normality tests. Parametric tests were employed when the data were normally distributed; otherwise, nonparametric tests were applied. The differences between the two groups were detected via the independent samples t-test or Mann–Whitney U test as appropriate, and the differences within the same group were measured via the paired sample t-test or Wilcoxon test.

the null hypothesis was tested independently at each treatment stage and within each group. The results were consistent across all stages.

Results

Sample distribution

Forty patients(17 males, 42.5% and 23 females57.5%) were accepted according to the inclusion criteria and included in this current trial. The BEP group included 20 patients (11 females and 9 males; average age: 10.41±1.8), whereas the TEP group included 20 patients (12 females and 8 males; average age: 10.15±1.5 years) (Table 1). The CONSORT flow diagram of patient recruitment, follow-up up and entry into the data analysis is given in Figure 1)

Baseline data

The comparison between the two groups before treatment had pointed out the homogeneity of the sample variables (Table 2). The patients' initial ages were well matched between the two groups. The duration of treatment was 5.78±0.38 months in the BEP group and 5.81±0.41 months in the TEP group, without a significant difference between the two groups. (P=0.84)..

Dento-alveolar and skeletal changes in the BEP group

Cast model analysis showed significant increases in :: C-C: (2.37±1.14),, Ca4-Ca4/;(2.62±1.52) ,, Gr6-Gr6 : (2.65±1.14) and the basal bone width according to Howe:, (4.25±3.37) (P<0.05), whereas the palatal height significantly decreased(-4.92±3.80) (P<0.05) (Table 3).

The results of frontal cephalogram measurements showed the following distances:

The AP:J-J , J-J, AJ-AJ, R-Apical-L-Apicaland RBC-LBC ratios significantly increased (1.77±1.65, 1.37±1.22),(3.27±1.51),(2.62±1.32),(3.7±2.4),(4.05±2.14) (P<0.05) (Table 3). On the lateral cephalogram, the SNB angle significantly increased(0.87±1.38) (P<0.05), while the angle ANB decreased significantly (-1.39±1.49) (P<0.05), and the SNA, S-N:Go-Me and S-N: Spp decreased without significant difference(-0.52±1.86),(-0.03±3.02),(-0.32±2.51) (P>0.05) .(Table 3)

Dento-alveolar and skeletal changes in the TEP group

Cast model analysis revealed significant increases in C-C :(2.12±1.16), Ca4-Ca4: (2.12±1.16),, Gr6-Gr6: (2.12±1.16), and the basal bone width according to Howe (2.12±1.16), (3.20±2.40), (3.17±2.04), (3.49±1.94) (P<0.05), whereas the palatal height decreased with significant difference (-4.08±3.11) (P<0.05). (Table 4).

Frontal cephalogram measurements exposed that the AP:J-J, AJ-AJ, and R-Apical-L-Apical decreased significantly (-0.82±0.81, -1.00±0.84) (-1.87±1.82),(-2.22±3.63), (P<0.05)., whereas the J-J and RBC-LBC significantly increased (2.30±1.73),(3.45±2.23) (P<0.05) (Table 4). On the lateral cephalometric radiographs, the angles: SNA, and ANB were significantly decreased (-0.77±1.28)(-1.64±1.56) (P<0.05), while the angle SNB was increased with a significant difference(0.87±1.06) (P<0.05). Also, S-N:Go-Me increased (0.40±3.36)while S-N:Spp was decreased (-0.03±1.69)and both of them without significant difference (P>0.05). (Table 4)

Comparisons between the treatment changes in the BEP and TEP groups:

The cast model study showed that the: C-C and basal bone width according to Howe, were increased in the BEP group(2.37±1.14, 4.25±3.37) more than in the TEP group (2.12±1.16, 3.49±1.94), but the differences were not significant(0.25 ±0.18, 0.76±0.48) (P>0.05).; however, the Ca4-Ca4 and Gr6-Gr6

were increased in the TEP group(3.20±2.40, 3.17±2.04) more than in the BEP group(2.62±1.52, 2.65±1.14) without significant difference between groups (P>0.05) . On the other hand, the palatal height was decreased in BEP group (-4.92±3.80)more than in the TEP group(-4.08±3.11) without a significant difference (-0.84±0.10) (P>0.05) (Table 5)

The frontal cephalometric radiograph showed that, the distances AP: J-J, AJ-AJ, and R-Apical-L-Apical increased in the BEP group (1.77±1.65, 1.37±1.22),(2.62±1.32),(3.7±2.4) while decreased in the TEP group(-0.82±0.81, -1.00±0.84),(-1.87±1.82),(-2.22±3.63), with significant differences between groups(2.59±0.08, 2.37±0.00) , (4.49±2.05) (5.92±1.23) (P<0.05). Additionally, the increase of J-J, RBC-LBC was greater in the BEP group (3.27±1.51), (4.05±2.14) than in the TEP group(2.30±1.73) ,(3.45±2.23), but without a significant difference(0.543),(0.401) (P>0.05). (Table 5).On the lateral cephalometric radiograph, the angle SNB was increased in both groups with the same amount(0.87±1.06). Also, the angles SNA and ANB were decreased non-significantly(P>0.05) in the TEP group (-0.77±1.28)(-1.64±1.56) more than in the BEP group(-0.52±1.86)(-1.39±1.49), while S-N:Spp was decreased in BEP group (-0.32±2.51) more than in TEP (-0.03±1.69)without a significant difference(-0.29±0.36) (P>0.05) (Table 5).

On the other hand, the angle S-N:Go-Me was decreased non-significantly in the BEP (-0.03±3.02), while it was increased non-significantly too in the TEP group(0.40±3.36) ,but this difference between groups was significant (-0.43±0.00) (P<0.05).

Comparison between the BEP and TEP groups after treatment:

The cast study showed no significant differences in the inter-canine, inter-molar, palatal height, or basal bone width according to Howe(-0.55±0.69)(-1.02±0.88) (0.87±0.87)(1.17±1.17)(0.08±0.99) (P>0.05). (Table 6).

Frontal cephalometric radiography exposed that both the alveolar process height , (alveolar, inter-apical) width were significantly greater in the BEP group (8.32 ±1.96,8.22 ±1.93) (58.05 ±3.30) (49.32 ±4.81) than in the TEP group(6.20 ±1.41,6.12 ±1.58)(58.05± 3.30)(49.3±2 4.81) (P<0.05) (Table 6). However,

the difference in J-J and inter-cusp width between the two groups was not significant(0.28±0.98)(-0.47±0.92) (P>0.05) (Table 6).

Lateral cephalometric radiography revealed that SNA , SNB and S-N:Go-Me angles were greater in the BEP group (80.30 ±3.51)(76.72 ±3.58)(39.74 ±5.69) than in the TEP one (78.40 ±3.37)(74.02 ±3.89)(38.37 ±5.29); SNA and S-N:Go-Me were without significant difference(1.90±1.09)(1.37±1.65) (P>0.05), while SNB was with significant difference(2.70±1.18) (P<0.05). On the other hand, the ANB and S-N:Spp angles were non-significantly greater in the TEP(4.38±1.80)(9.87 ±3.42) than in the BEP group (3.58 ±1.56)(7.35 ± 2.83) (P>0.05). (Table 6).

Harms: The periodic clinical control did not show any soft tissue damage, such as ulcers and abrasions in both groups during the treatment.

Discussion

It is known that the maxilla increases in width at mixed-dentition age around 0.6mm per year, without treatment, and the dentoalveolar process at the first molar level increases at an equal rate coronally and is independent of the changes in molar inclination.[27] Also, maxillary arch expansion is a common orthodontic procedure during mixed dentition. Slow maxillary expansion (SME) is an alternative to rapid maxillary expansion when used in mixed dentition.[28] However, SME has disadvantages such as molar rotation, inclination, alveolar process resorption, and an increase in the alveolar tip, which lead to relapse after treatment.[10-12]

The Frankel appliance incorporates buccal shields that achieve bodily tooth movement during expansion, resulting in more stable outcomes and preservation of alveolar bone[21, 22].

The purpose of adding buccal shields to traditional plates is based on Frankel's philosophy of stimulating bone apposition via periosteal muscular tension, which can result in bodily movement of lateral teeth and subsequently reduce relapse after expansion and avoid vertical resorption of the alveolar process.

Therefore, the buccal shields were located at the depth of the vestibular groove and were 3 mm away from the buccal surface of the alveolar process. (from the mesial edge of the canine to the distal edge of the first upper permanent molar).

Alveolar process height (AP: J-J) significantly decreased in the TEP group, which is consistent with Brunetto's 2013 study, which reported significant alveolar process recession[19]. However, this finding contrasts with the results of Greenbaum's 1982 study, which reported that the decrease in alveolar height was not significant.[18] On the other hand. In this study, the alveolar height significantly increased in the BEP group. (AP: J-J), which can be due to the type of involved tooth movement. In contrast, the TEP group exhibited tooth tipping, which can lead to a decrease in the height of the alveolar process.

The J–J width significantly increased in both the BEP and TEP groups. This increase may be due to maxillary growth however, it is known that, the maxillary width increases by normal growth (0.6mm/year)**[27]** but the study sample contain two similar groups which were treated with two different removable expansion plate and thus the effect of patient adherence will be uniform(one) in the two groups so that the increase of width shall be similar in both groups. And the increase in this width was significant in both groups due to the treatment. This means that the two plates affected are increasing the width of the upper jaw. Also, it is consistent with previous studies by Brieden in 1984 and Owen in 1983.[20, 22] Interestingly, several other studies, including those by Sandlk in 1997, Ciambotti in 2000, Erdinc in 1999, Frank in 1982, Brin in 1996, and Shoaib in 2017, also reported an increase in J-J in the TEP group.[4, 11, 13, 29-31].

Alveolar width (AJ-AJ) increased significantly in the BEP group, in agreement with the findings of Brieden in 1982.[22] However, it decreased significantly in the TEP group, which was not considered in previous studies using traditional expansion plates. The difference in results is attributed to the type of tooth movement during expansion and can be due to the effect of the buccal shields in the BEP group.

The distance between the buccal root apex of the upper first molar (R Apical-L Apical) significantly increased in width because of the bodily movement of the teeth. Moreover, it decreased significantly in the TEP group as a result of the tipping movement. This difference between groups was significant and clinically significant. The results of the TEP group were consistent with the findings of Ciambotti2001, Erdinc1999, Huynh 2009, and Bukhari2018, who also observed tipping movements with the use of SME.[11, 13, 15, 16]

However, the results of Brunetto 2013 were different from those of the TEP group in our study. In 2013, an increase in the distance between the roots of molars was reported, but it was less than the increase in the distance between the cusps of the molars.[19]
Inter-molar width (RBC-LBC) increased significantly in both groups. This result is similar to research conducted by Owen in 1983 and Brunetto in 2013, who reported that the inter-molar width significantly increased after treatment.[19, 20]

Kecik in 2007 and Shoaib in 2017 showed that expansion has a sagittal effect on the maxilla[14, 31]. They stated that SNA increased non-significantly, but Akkaya in 1999 found that the increase was significant[32]. However, these results don't agree with the results of our study, where SNA decreased non-significantly in the BEP group and significantly in the TEP group.
The SNB angle showed a significant increase in both groups. The result of the TEB group is similar to Erdinc's study, which also found a non-significant increase in SNB[13]. However, Kecik's study showed a significant decrease in SNB[14]. The difference in data collection could be a reason for this discrepancy, as their study collected data 3 months after treatment, while our study collected data 6 months after treatment.
The ANB angle decreased significantly in both groups. However, the result in the TEB group was not similar to that of the (Erdinc1999) study, whereas it decreased without a significant statistical difference, it increased significantly in the (Akkaya1999) study[13, 32].
The S-N: Go-Me angle showed a non-significant decrease in the BEP group, and a non-significant increase in the TEP group.The result of the TEB group is similar to the study of Shoaib in 2017 and Paoloni in 2021, which also found a non-significant increase in S-N: Go-Me.[31, 33]

A statistically non-significant decrease in palatal height was observed in both groups. This finding contradicts the results of Ladner and Muhl's study, where the palatal height significantly increased in the slow palatal expander. They attributed this increase to the eruption of teeth due to the tipping of the upper molar.[34] However, Ciambotti (2001) reported non-significant decreases in palatal depth, suggesting that an increase in dentoalveolar height and a decrease in palatal shelf height offset each other and resulted in no significant changes in palatal depth.[11]

Petrén in 2008 and Van de Velde in 2021 reported that there was a statistically significant difference in the increase in inter-canine and inter-molar width.[9, 35] Our study also revealed similar results. Basal bone width (Howe analysis) increased significantly in both groups, but this increase was greater in the BEP group than in the TEP group. This difference may be due to appositional bone growth resulting from periosteal tension, which is caused by the buccal shields. these. These results agree with Frankel's opinion[36]about the buccal shields of the function regulator and suggest that the effectiveness of the buccal shields used in the basal expanding plate is comparable to the effectiveness of the buccal shields in the function regulator after Frankel, and they can be used to avoid recession of the vestibular alveolar process during expansion.

It must be mentioned that we didn't have a control group to evaluate the growth changes. But it is known that the transversal facial growth at this age is very limited, and the treatment duration, only 6 months. The sample was homogeneous; therefore, the same characteristics exist in both groups; consequently, the difference in the results from growth will be similar in both groups, and any change occurring will be due to a difference in the treatment method, so that this can not have a bias on the results of this study.

Also, we can say that the number of 40 patients between 8-12 years old may be insufficient to accurately represent the percentage of patients suffering from maxillary constriction in the community, but we can consider this study serves as a preliminary investigation into the effectiveness of buccal shields in removable expansion plates. Future studies with larger samples and longer follow-up are recommended.

Limitation:

One limitation of this study was the absence of an untreated control group, which would have allowed for evaluation of normal growth changes. This was avoided for ethical reasons, as withholding treatment from patients with maxillary constriction was not considered appropriate. Additionally, long-term follow-up was not conducted. Blinding was applied only for the outcome assessor, as the appliance designs were visibly distinct, making full blinding impractical. While this may introduce bias , it was mitigated by anonymizing casts and radiographs during analysis..

Conclusions

Based on the results, it can be concluded that the Basal Expansion Plate (BEP) can achieve bodily tooth movement and avoid the crest resorption of the vestibular alveolar process during the slow maxillary expansion. This prevention and bodily movement of the lateral teeth can be due to the periosteal tension caused by the buccal shields of the basal expansion plate (BEP); thus, the ratio of root-to-crown movement was 91.35% in the BEP group and 39.04% in the TEP group.

The basal expansion plate can be indicated to avoid recession of the vestibular alveolar process during the expansion of the maxillary dental arch.

The BEP may be particularly beneficial for patients with normal or vertical growth patterns, as it also contributes to a slight reduction in anterior facial height.

The Basal Expansion Plate offers a promising alternative to traditional expansion methods, with potential advantages in skeletal and dentoalveolar outcomes. Further studies with larger sample sizes and extended follow-up periods are recommended to validate these results

Data availability

The data used and analyzed during the current research are available from the corresponding author upon request.

References

1. Adkins MD, Nanda RS, Currier GF. Arch perimeter changes on rapid palatal expansion. American Journal of Orthodontics and Dentofacial Orthopedics. 1990;97(3):194-9.
2. Evangelista K, Ferrari-Piloni C, Barros LAN, Avelino MAG, Helena Soares Cevidanes L, Ruellas ACdO, et al. Three-dimensional assessment of craniofacial asymmetry in children with transverse maxillary deficiency after rapid maxillary expansion: A prospective study. Orthodontics & craniofacial research. 2020;23(3):300-12.
3. Karad A. Clinical orthodontics: current concepts, goals and mechanics. 2014.
4. Sandikçiolu M, Hazar S. Skeletal and dental changes after maxillary expansion in the mixed dentition. American Journal of Orthodontics and Dentofacial Orthopedics. 1997;111(3):321-7.
5. Araújo M-C, Bocato J-R, de Almeida M-R. Tomographic evaluation of dentoskeletal effects of rapid maxillary expansion using Haas and Hyrax palatal expanders in children: A randomized clinical trial. Journal of clinical and experimental dentistry. 2020;12(10):e922.
6. Farronato G, Maspero C, Esposito L, Briguglio E, Farronato D, Giannini L. Rapid maxillary expansion in growing patients. Hyrax versus transverse sagittal maxillary expander: a cephalometric investigation. The European Journal of Orthodontics. 2011;33(2):185-9.

7. Godoy F, Godoy-Bezerra J, Rosenblatt A. Treatment of posterior crossbite comparing 2 appliances: a community-based trial. American Journal of Orthodontics and Dentofacial Orthopedics. 2011;139(1):e45-e52.
8. Rabah N, Al-Ibrahim HM, Hajeer MY, Ajaj MA, Mahmoud G. Assessment of patient-centered outcomes when treating maxillary constriction using a slow removable versus a rapid fixed expansion appliance in the adolescence period: a randomized controlled trial. Cureus. 2022;14(3).
9. Petrén S, Bondemark L. Correction of unilateral posterior crossbite in the mixed dentition: a randomized controlled trial. American Journal of Orthodontics and Dentofacial Orthopedics. 2008;133(6):790. e7-. e13.
10. Nagrik AP, Bhad WA. A clinical comparison of maxillary expansion: TransForce transverse appliance versus NiTi palatal expander. Journal of the World Federation of Orthodontists. 2014;3(2):e61-e5.
11. Ciambotti C, Ngan P, Durkee M, Kohli K, Kim H. A comparison of dental and dentoalveolar changes between rapid palatal expansion and nickel-titanium palatal expansion appliances. American Journal of Orthodontics and Dentofacial Orthopedics. 2001;119(1):11-20.
12. Wong CA, Sinclair PM, Keim RG, Kennedy DB. Arch dimension changes from successful slow maxillary expansion of unilateral posterior crossbite. The Angle orthodontist. 2011;81(4):616-23.
13. Erdinç AE, Ugur T, Erbay E. A comparison of different treatment techniques for posterior crossbite in the mixed dentition. American journal of orthodontics and dentofacial orthopedics. 1999;116(3):287-300.
14. Kecik D, Kocadereli I, Saatci I. Evaluation of the treatment changes of functional posterior crossbite in the mixed dentition. American Journal of Orthodontics and Dentofacial Orthopedics. 2007;131(2):202-15.
15. Huynh T, Kennedy DB, Joondeph DR, Bollen A-M. Treatment response and stability of slow maxillary expansion using Haas, hyrax, and quad-helix appliances: a retrospective study. American Journal of Orthodontics and Dentofacial Orthopedics. 2009;136(3):331-9.
16. Bukhari A, Kennedy D, Hannam A, Aleksejūnienė J, Yen E. Dimensional changes in the palate associated with slow maxillary expansion for early treatment of posterior crossbite. The Angle Orthodontist. 2018;88(4):390-6.
17. Kuhlberg A, Nanda R. Principles of biomechanics. Biomechanics and Esthetic Strategies in Clinical Orthodontics. W. B. Saunders Company, : Philadelphia Elsevier; 2005. p. 1-16.
18. Greenbaum KR, Zachrisson BU. The effect of palatal expansion therapy on the periodontal supporting tissues. American Journal of Orthodontics. 1982;81(1):12-21.
19. Brunetto M, Andriani JdSP, Ribeiro GLU, Locks A, Correa M, Correa LR. Three-dimensional assessment of buccal alveolar bone after rapid and slow maxillary expansion: a clinical trial study. American Journal of Orthodontics and Dentofacial Orthopedics. 2013;143(5):633-44.
20. Owen III AH. Morphologic changes in the transverse dimension using the Fränkel appliance. American Journal of Orthodontics. 1983;83(3):200-17.
21. Fränkel R. Technik und Handhabung der Funktionsregler. (No Title). 1984.
22. Brieden CM, Pangrazio-Kulbersh V, Kulbersh R. Maxillary Skeletal and Dental Change With Fränkel Appliance Therapy: —an implant study. The Angle Orthodontist. 1984;54(3):226-32.

23. Lindauer S. Orthodontic Treatment Planning Biomechanics in Clinical Orthodontics. W.B. Saunders Company: Phila delphia; 1996. p. 26.
24. Shundo I, Kobayashi Y, Endo T. Short-term treatment effects of quad-helix on maxillomandibular expansion in patients with maxillary incisor crowding. Odontology. 2012;100:76-86.
25. Defraia E, Marinelli A, Baroni G, Tollaro I. Dentoskeletal effects of a removable appliance for expansion of the maxillary arch: a postero-anterior cephalometric study. The European Journal of Orthodontics. 2008;30(1):57-60.
26. Kharbanda OP. Orthodontic Diagnosis. Orthodontics: Diagnosis and Management of Malocclusion and Dentofacial Deformities, E-Book: Elsevier Health Sciences; 2009. p. 207-8

10-11.
27. Yi L, Jeon HH, Li C, Boucher N, Chung C-H. Transverse growth of the maxillo-mandibular complex in untreated children: A longitudinal cone beam computed tomography study. Sensors. 2021;21(19):6378.
28. Lanteri V, Cossellu G, Gianolio A, Beretta M, Lanteri C, Cherchi C, et al. Comparison between RME, SME and Leaf Expander in growing patients: a retrospective. European Journal of Paediatric Dentistry. 2018;19:199.
29. Frank SW, Engel GA. The effects of maxillary quad-helix appliance expansion on cephalometric measurements in growing orthodontic patients. American journal of orthodontics. 1982;81(5):378-89.
30. Brin I, Ben-Bassat Y, Blustein Y, Ehrlich J, Hochman N, Marmary Y, et al. Skeletal and functional effects of treatment for unilateral posterior crossbite. American Journal of Orthodontics and Dentofacial Orthopedics. 1996;109(2):173-9.
31. Shoaib H, Hafez A, Fouda M. Expansion Changes By Removable Quad Helix Appliance On Constricted Maxilla In Growing Patients. Australian Journal of Basic and Applied Sciences. 2017;11(11):171-7.
32. Akkaya S, Lorenzon S, Üçem TT. A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures. The European Journal of Orthodontics. 1999;21(2):175-80.
33. Paoloni V, Giuntini V, Lione R, Nieri M, Barone V, Merlo MM, et al. Comparison of the dento-skeletal effects produced by Leaf expander versus rapid maxillary expander in prepubertal patients: a two-center randomized controlled trial. European Journal of Orthodontics. 2022;44(2):163-9.
34. Ladner PT, Muhl ZF. Changes concurrent with orthodontic treatment when maxillary expansion is a primary goal. American journal of orthodontics and dentofacial orthopedics. 1995;108(2):184-93.
35. Van de Velde A, De Boodt L, Cadenas de Llano-Pérula M, Laenen A, Willems G. Short term effects of interceptive expansion treatment: a prospective study. European Journal of Orthodontics. 2021;43(3):324-31.
36. Fränkel R, Fränkel C. Clinical implication of Roux's concept in orofacial orthopedics. Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie. 2001;62:1-21.

Acknowledgments:

We would like to acknowledge the participation of the patients.

Authors' contributions:

*. contributed in collection of data; data analysis/interpretation and writing of the manuscript.

**. contributed in study design, data analysis and writing of the manuscript

Competing interests:

The authors declare that they have no competing interests.

Availability of data and material:

The data used and analyzed during the current research are available from the corresponding author upon request.

Declarations:

Ethics approval and consent to participate:

The institutional review board and the ethical review committee of Damascus University (no-3840-25-7-2022) approved this study. Written informed consent was obtained from each patient.

Consent for publication:

Not applicable.

Funding:

This study received Damascus University funding.

Figure legends:

Figure 1: CONSORT flow diagram of patients' recruitment, follow-up, and entry to data analysis
Figure2: Basal expansion plate
Figure3: Traditional expansion plate ; 1) lateral view. (2) occlusal view. (3) frontal view
Figure 4: Landmarks planes on frontal cephalometric radiograph
Figure 5: Landmarks angles on lateral cephalometric radiograph
Figure 6: Landmarks points on dental cast models

Table legends:

Table 1; Basic sample characteristics regarding gender and age
Table 2: Levene's Test for Equality of Variances
Table 3: The skeletal and dentoalveolar changes of the BEP group studied on casts, frontal and lateral cephalometric radiograph
Table 4: The skeletal and dentoalveolar changes of the TEP group studied on casts, frontal and lateral cephalometric radiograph
Table 5: Comparison of changes between the two groups studied on the casts, frontal and lateral cephalometric radiograph
Table 6: Comparison of changes between the two groups after treatment studied on the casts, frontal and lateral cephalometric radiograph

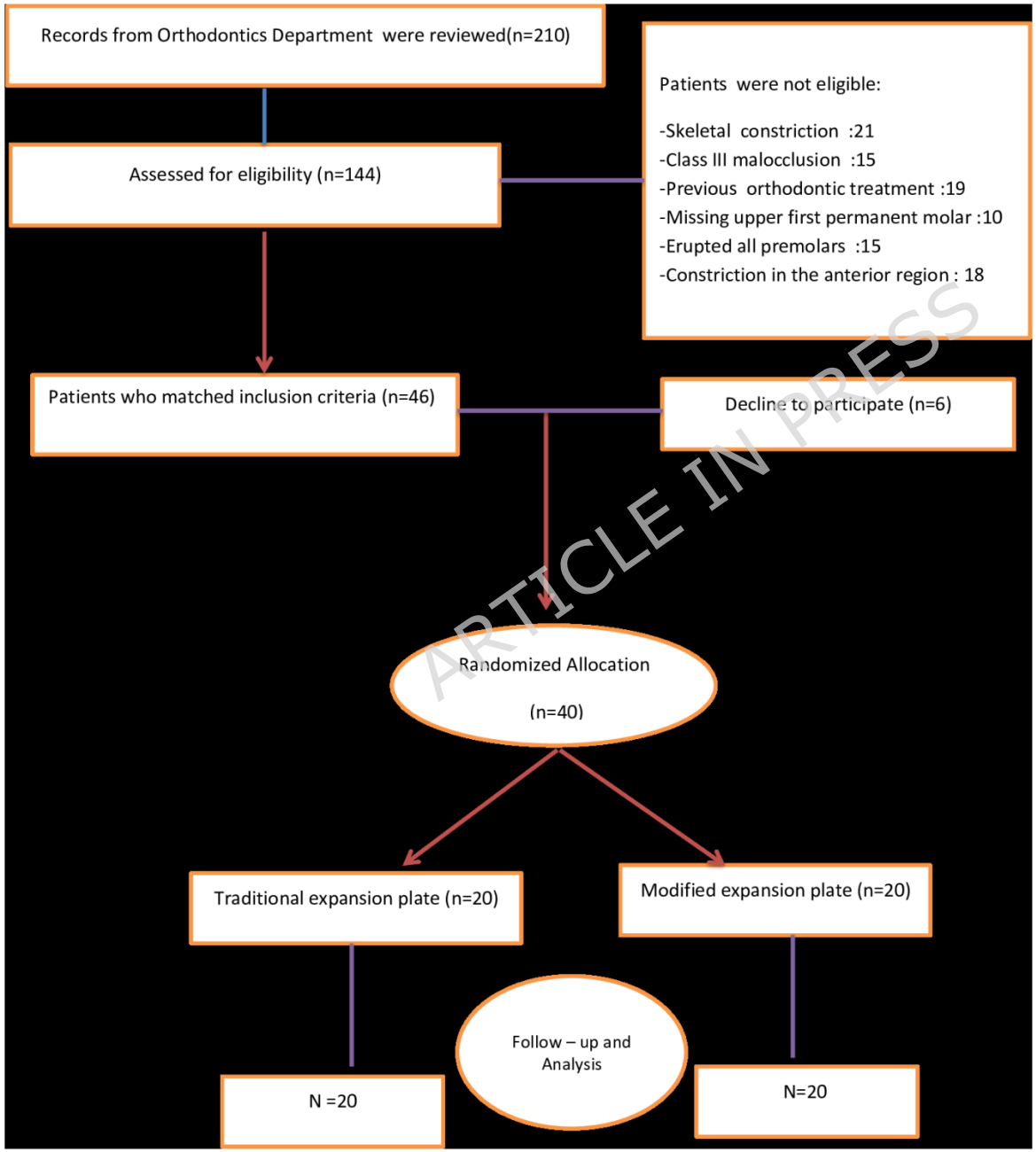

Figure1: CONSORT flow diagram of patients' recruitment, follow-up, and entry to data analysis

Figure2: Basal expansion plate

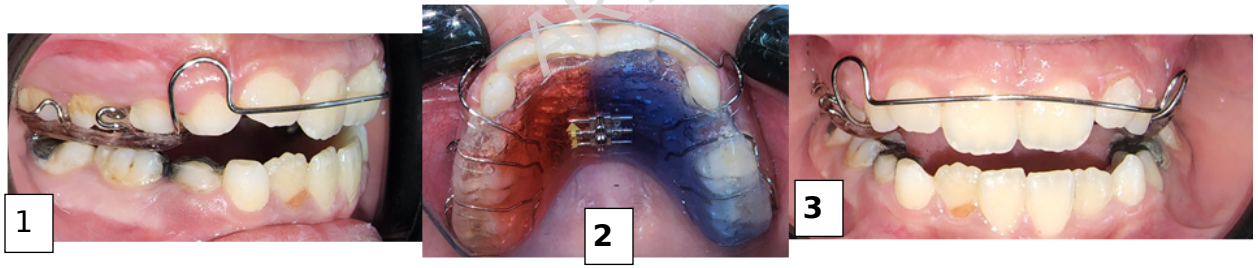

Figure3: Traditional expansion plate ; 1) lateral view. (2) occlusal view. (3) frontal view

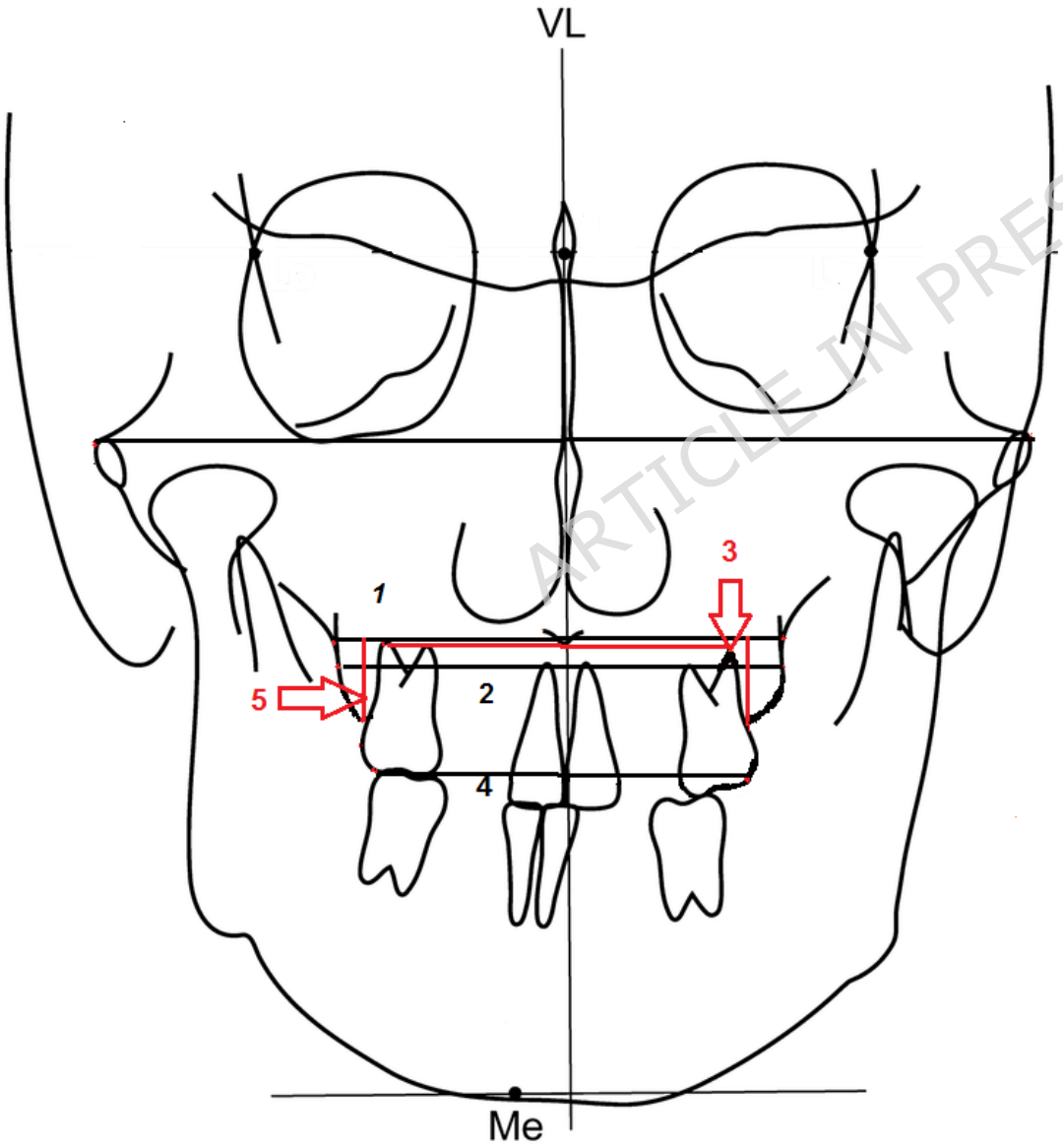

Figure 4: Landmarks planes on frontal cephalometric radiograph: 1-J-J: Maxillary width,2-AJ-AJ: Alveolar width,3-RApical-LApical:Inter-apical width,4-RBC-LBC:Inter-cusp width,5-AP:J-J: process height

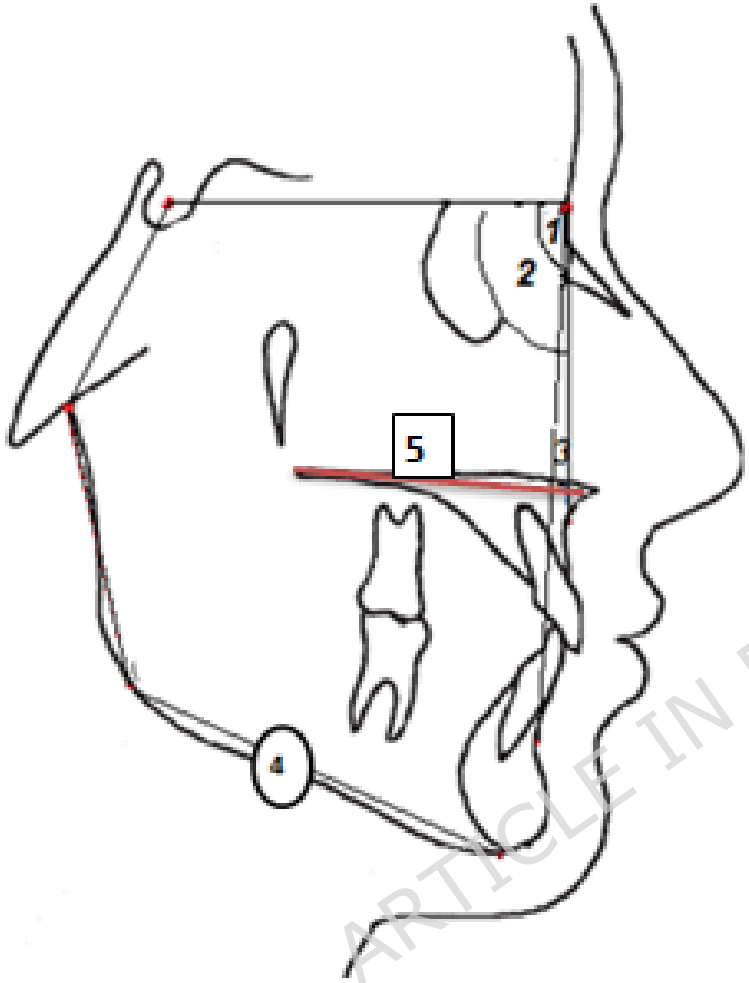

Figure 5: Landmarks angles on lateral cephalometric radiograph:1-SNB: Sagittal mandibular jaw position, 2-SNA: Sagittal maxillary jaw position,3-ANB: The angle between upper and lower jaw in sagittal plane,4-S-N:Go-Me:Vertical mandibular jaw position,5- S-N: Spp: Vertical maxillary jaw position

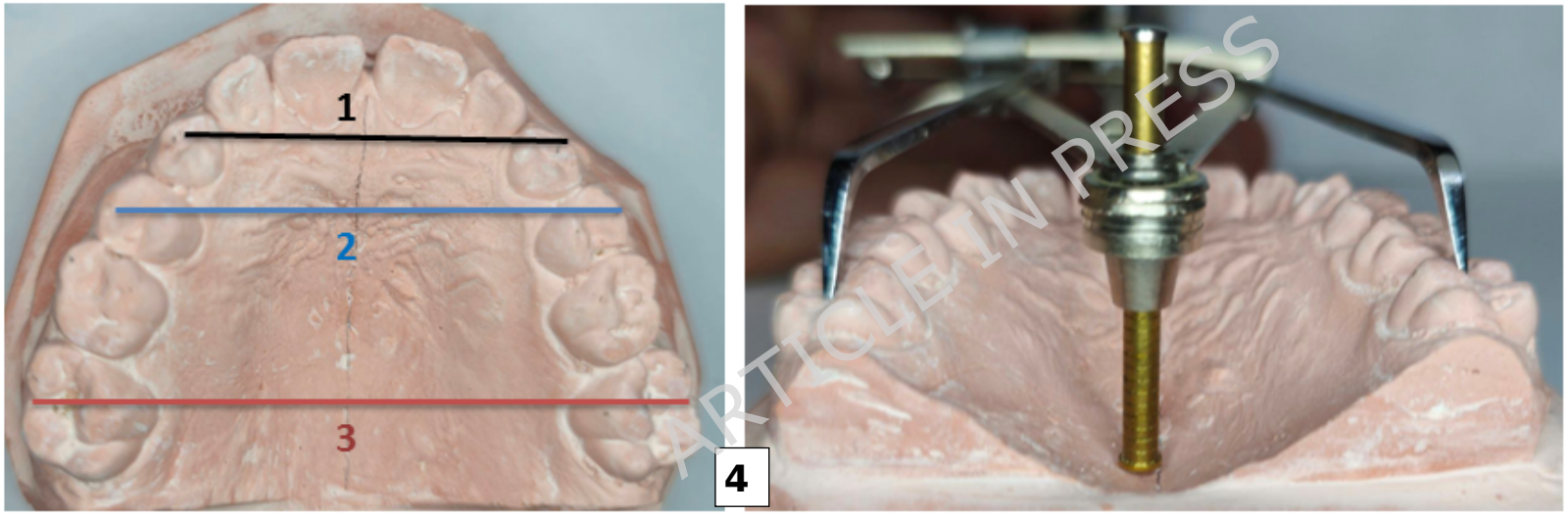

Figure 6: Landmarks points on dental cast models :1-C-C:Inter-canine width,2- Ca4-Ca4**:**Inter-premolar width,3-Gr6-Gr6:Inter-molar width,4**-**Palatal heigh**t**

Variable/Group		BEP (n=20)	TEB (n=20)	Study sample		P value	Significance
				Number	Ratio%		
Gender	male	9	8	17	42.50	0.321[a]	NS
	female	11	12	23	57.50		
Age (in years): mean ± SD	10.41 ±1.8		10.15 ±1.5	10.28 ±1.65		0.265[b]	NS
BEP: basal expansion plate, TEP: traditional expansion plate a Chi-Square; b Independent-samples t test; NS: non- significant at P>0.05.							

Table 1; Basic sample characteristics regarding gender and age

The variable	BEP group		TEP group		Difference	P.value	95% Confidence Interval of the Difference		Effect size
	Mean	S.D	Mean	S.D			Min	Max	
C-C	30.65	2.37	31.45	2.25	-0.80	0.866[b]	-0.59	1.81	0.01
Ca4 - Ca4	37.27	2.17	37.72	2.51	-0.45	0.680	-0.79	1.59	0.00

						a			
Gr6 - Gr6	49.15	3.04	49.50	2.89	-0.35	0.772 a	-1.18	1.18	0.00
Palatal height	43.69	4.61	41.68	4.74	2.01	0.631 a	-4.20	0.53	0.03
HOWE	40.47	1.53	41.15	3.22	-0.68	0.154 a	-0.49	2.30	0.02
RAP:J-J	6.55	1.99	7.02	1.39	-0.47	0.100 a	-0.43	1.42	0.01
LAP:J-J	6.85	1.85	7.12	1.69	-0.27	0.798 a	-0.67	1.19	0.00
J-J	61.32	61.32	62.02	3.23	-0.7	0.114 a	-0.45	2.19	0.02
AJ-AJ	57.35	2.47	59.92	2.62	-1.57	0.382 a	0.46	3.05	0.10
RApical-LApical	50.92	4.53	51.54	5.02	-0.62	1.375 a	-1.41	3.30	0.06
RBC- LBC	53.30	3.86	54.37	3.91	-1.07	0.944 a	-0.70	3.32	0.06
SNA	80.82	4.00	79.17	3.70	1.65	0.521 a	-3.58	0.58	0.03

SNB	75.85	3.71	73.13	3.78	2.72	0.973 [a]	-4.62	-0.63	0.10
ANB	4.97	2.33	6.02	2.43	-1.05	0.641 [a]	-0.10	2.37	0.06
N-S:Spp	7.67	3.97	9.90	3.64	-2.23	0.842 [b]	-0.42	3.72	0.04
S-N:Go-Me	39.77	4.92	37.97	4.26	1.80	0.552 [a]	-0.81	4.12	0.03

C-C: Inter-canine width, Ca4-Ca4**:**Inter-premolar width, Gr6-Gr6:Inter-molar width, Palatal height**,** HOWE: basal bone width according to Howe analysis**.** AP:J-J: Alveolar process height, J-J: Maxillary width, AJ-AJ: Alveolar width, RApical-LApical: Inter-apical width, RBC-LBC: Inter-cusp width. SNB: Sagittal mandibular jaw position, SNA: Sagittal maxillary jaw position, ANB: The angle between upper and lower jaw in sagittal plane, S-N: Spp: Vertical maxillary jaw position, S-N:Go-Me: Vertical mandibular jaw position.

[a]**:** independent samples t test

[b]:Mann–Whitney U test

*: significant difference at the 0.05 level

604 Table 2: Levene's Test for Equality of Variances

605

The variable	T_0	T_1	Difference Mean(SD	P. value	95% Confidence Interval of the Difference	Effect size

	Mean	S.D	Mean	S.D	)		Min	Max	
C-C	30.65	2.37	33.02	2.24	2.37(1.14)	**0.000 b***	1.83	2.91	-0.02
Ca4 - Ca4	37.27	2.17	39.90	2.75	2.62(1.52)	**0.000 a***	1.90	3.34	-0.07
Gr6 - Gr6	49.15	3.04	51.80	3.16	2.65(1.14)	**0.001 a***	2.11	3.18	-0.05
Palatal height	43.69	4.61	38.77	4.01	-4.92(3.80)	**0.000 a***	-6.70	-3.14	-0,02
HOWE	40.47	1.53	44.73	3.41	4.25(3.37)	**0.001 a***	2.67	5.83	-0.03
RAP:J-J	6.55	1.99	8.32	1.96	1.77(1.65)	**0.000 a***	1.00	2.54	0.07
LAP:J-J	6.85	1.85	8.22	1.93	1.37(1.22)	**0.000 a***	0.80	1.94	0.16
J-J	61.32	61.32	64.60	2.32	3.27(1.51)	**0.003 a***	2.56	3.98	-0.67
AJ-AJ	57.35	2.47	59.97	2.71	2.62(1.32)	**0.000 a***	2.00	3.24	-0.11
RApical-LApical	50.92	4.53	54.62	4.12	3.7(2.4)	**0.011a***	2.56	4.82	-0.09
RBC- LBC	53.30	3.86	57.35	3.98	4.05(2.14)	**0.020a***	2.99	5.09	-0.03

SNA	80.82	4.00	80.30	3.51	-0.52(1.86)	0.220[a]	-1.39	0.34	0.19
SNB	75.85	3.71	76.72	3.58	0.87(1.38)	**0.011 a***	0.22	1.52	0.07
ANB	4.97	2.33	3.58	1.56	-1.39(1.49)	**0.001 a***	-2.14	-0.75	0.03
N-S:Spp	7.67	3.97	7.35	2.83	-0.32(2.51)	0.578 [b]	-1.50	0.85	0.15
S-N:Go-Me	39.77	4.92	39.74	5.69	-0.03(3.02)	0.945 [a]	-1.17	1.97	0.10

C-C: Inter-canine width, Ca4-Ca4**:**Inter-premolar width, Gr6-Gr6:Inter-molar width, Palatal height**,** HOWE: basal bone width according to Howe analysis**.** AP:J-J: Alveolar process height, J-J: Maxillary width, AJ-AJ: Alveolar width, RApical-LApical: Inter-apical width, RBC-LBC: Inter-cusp width. SNB: Sagittal mandibular jaw position, SNA: Sagittal maxillary jaw position, ANB: The angle between upper and lower jaw in sagittal plane, S-N: Spp: Vertical maxillary jaw position, S-N:Go-Me:Vertical mandibular jaw position.

[a]**:** paired sample t test

[b]: Wilcoxon test.

*: significant difference at the 0.05 level

Table 3: The skeletal and dentoalveolar changes of the BEP group studied on casts, frontal and lateral cephalometric radiograph

The variable	T_0		T_1		Difference Mean(SD)	P.value	95% Confidence Interval of the Difference		Effect size
	Mean	S.D	Mean	S.D			Min	Max	
C-C	31.45	2.25	33.57	2.13	2.12(1.16)	0.000 a*	1.57	2.67	0.02
Ca4 - Ca4	37.72	2.51	40.92	2.83	3.20(2.40)	0.004 a*	2.07	4.32	-0.01
Gr6 - Gr6	49.50	2.89	52.67	2.29	3.17(2.04)	0.002 a*	2.21	4.13	-0.06
Palatal height	41.68	4.74	37.60	4.81	-4.08(3.11)	0.002 a*	-5.54	-2.61	-0.01
HOWE	41.15	3.22	44.65	2.82	3.49(1.94)	0.001 a*	2.58	4.40	0.04
RAP:J-J	7.02	1.39	6.20	1.41	-0.82(0.81)	0.000 a*	-1.20	-0.44	0.34
LAP:J-J	7.12	1.69	6.12	1.58	-1.00(0.84)	0.001 a*	-1.39	-0.60	0.07
J-J	62.02	3.23	64.32	3.76	2.30(1.73)	0.042 a*	0.51	1.11	-0.03
AJ-AJ	59.92	2.62	58.05	3.30	-1.87(1.82)	0.030 a*	-0.73	0.98	-0,05

RApical-LApical	51.54	5.02	49.32	4.81	-2.22(3.63)	0.010[a]*	-3.91	-0.51	0.11
RBC- LBC	54.37	3.91	57.82	3.73	3.45(2.23)	0.023[a]*	2.39	4.49	0.02
SNA	79.17	3.70	78.40	3.37	-0.77(1.28)	0.011[a]*	-1.37	-0.17	0.23
SNB	73.13	3.78	74.02	3.89	0.87(1.06)	0.000[a]*	0.37	1.37	0.23
ANB	6.02	2.43	4.38	1.80	-1.64(1.56)	0.001[a]*	-2.33	-0.86	-0.00
N-S:Spp	9.90	3.64	9.87	3.42	-0.03(1.69)	0.730 [b]	-0.81-	0.76	0.17
S-N:Go-Me	37.97	4.26	38.37	5.29	0.40(3.36)	0.600 [a]	-1.46	1.36	0.11

C-C: Inter-canine width, Ca4-Ca4**:**Inter-premolar width, Gr6-Gr6:Inter-molar width, Palatal height**,** HOWE: basal bone width according to Howe analysis**.** AP:J-J: Alveolar process height, J-J: Maxillary width, AJ-AJ: Alveolar width, RApical-LApical:Inter-apical width, RBC-LBC:Inter-cusp width. SNB: Sagittal mandibular jaw position, SNA: Sagittal maxillary jaw position,ANB: The angle between upper and lower jaw in sagittal plane, S-N: Spp: Vertical maxillary jaw position, S-N:Go-Me:Vertical mandibular jaw position.

[a]**:** paired sample t test

[b]: Wilcoxon test.

*: significant difference at the 0.05 level

Table 4: The skeletal and dentoalveolar changes of the TEP group studied on casts, frontal and lateral cephalometric radiograph

611

612

The variable	BEP	TEP	Difference Mean(SD)	P .value	95% Confidence Interval of the Difference		Effect size
	Mean(SD)	Mean(SD)			Min	Max	
C-C	2.37(1.14)	2.12(1.16)	0.25(0.18)	0.532 [a]	-7.53	6.18	0.082
Ca4 - Ca4	2.62(1.52)	3.20(2.40)	-0.58(0.20)	0.122 [a]	-9.64	8.16	0.06
Gr6 - Gr6	2.65(1.14)	3.17(2.04)	-0.52(0.25)	0.165[a]	-9.50	8.28	0.04
Palatal height	-4.92(3.80)	-4.08(3.11)	-0.84(0.10)	0.061[a*]	-12.17	15.34	0.11
HOWE	4.25(3.37)	3.49(1.94)	0.76(0.48)	0.193 [a]	-12.14	11.54	0.00

RAP:J-J	1.77(1.65)	-0.82(0.81)	2.59(0.08)	0.040 a*	-3.38	5.03	0.26
LAP:J-J	1.37(1.22)	-1.00(0.84)	2.37(0.00)	0.000 a*	-2.74	4.57	0.36
J-J	3.27(1.51)	2.30(1.73)	0.97(2.25)	0.543 a	-6.28	7.86	0.10
AJ-AJ	2.62(1.32)	-1.87(1.82)	4.49(2.05)	0.030 a*	-5.97	5.32	0.03
RApical-LApical	3.7(2.4)	-2.22(3.63)	5.92(1.23)	0.020 a*	-6.96	11.64	0.73
RBC- LBC	4.05(2.14)	3.45(2.23)	0.60(0.09)	0.401 a	-12.21	10.67	0.07
SNA	-0.52(1.86)	-0.77(1.28)	0.25(0.58)	0.765 a	-0.23	-3.78	0.87
SNB	0.87(1.38)	0.87(1.06)	0.00(0.22)	0.500 a	0.03	5.36	0.90
ANB	-1.39(1.49)	-1.64(1.56)	0.25(0.05)	0.223 a	-5.62	3.67	0.29
N-S:Spp	-0.32(2.51)	-0.03(1.69)	-0.29(0.36)	0.271 a	-3.07	-1.67	0.99

S-N:Go-Me	-0.03(3.02)	0.40(3.36)	-0.43(0.00)	0.000 a*	-2.44	-0.70	0.96

C-C: Inter-canine width, Ca4-Ca4:Inter-premolar width, Gr6-Gr6:Inter-molar width, Palatal height, HOWE: basal bone width according to Howe analysis. AP:J-J: Alveolar process height, J-J: Maxillary width, AJ-AJ: Alveolar width, RApical-LApical:Inter-apical width, RBC-LBC:Inter-cusp width. SNB: Sagittal mandibular jaw position, SNA: Sagittal maxillary jaw position,ANB: The angle between upper and lower jaw in sagittal plane, S-N: Spp: Vertical maxillary jaw position, S-N:Go-Me:Vertical mandibular jaw position.

[a]: independent samples

[b]:Mann–Whitney U test

*: significant difference at the 0.05 level

613

614 Table 5: Comparison of changes between the two groups studied on the casts, frontal and lateral
615 cephalometric radiograph

616

The variable	BEP	TEP	Difference Mean(SD)	P. value	95% Confidence Interval of the Difference		Effect size
	Mean(SD)	Mean(SD)			Min	Max	
C-C	33.02 (2.24)	33.57	-0.55(0.6	0.143 b	-0.85	1.9	0.01

		(2.13)	9)			5	
Ca4 - Ca4	39.90 (2.75)	40.92 (2.83)	-1.02(0.88)	0.251 [a]	-0.76	-2.81	0.03
Gr6 - Gr6	51.80 (3.16)	52.67 (2.29)	-0.87(0.87)	0.327 [a]	-0.89	2.64	0.02
Palatal height	38.77 (4.01)	(4.81) 37.60	1.17(1.17)	0.841 [a]	-4.00	1.67	0.01
HOWE	44.73 (3.41)	44.65 (2.82)	0.08(0.99)	0.934 [a]	-2.08	1.92	0.00
RAP:J-J	8.32 (1.96)	6.20 (1.41)	2.12(0.54)	**0.000** [a]	-3.22	-1.02	0.28
LAP:J-J	8.22 (1.93)	6.12 (1.58)	2.10(0.55)	**0.000** [a]	-3.23	0.96	0.27
J-J	64.60 (2.32)	64.32 (3.76)	0.28(0.98)	0.273 [a]	-4.27	-0.27	0.12
AJ-AJ	59.97(2.71)	58.05 (3.30)	1.92(0.95)	**0.031** [a]	-2.86	1.01	0.02
RApical-LApical	54.62(4.12)	49.32 (4.81)	5.30(1.28)	**0.000** [a]	2.70	7.88	0.31

RBC- LBC	57.35(3.98)	57.82 (3.73)	-0.47(0.92)	0.605 [a]	-1.39	2.34	0.00
SNA	80.30 (3.51)	78.40 (3.37)	1.90(1.09)	0.096 [a]	-4.10	0.30	0.07
SNB	76.72 (3.58)	74.02 (3.89)	2.70(1.18)	**0.021** [a *]	-5.09	-0.30	0.12
ANB	3.58 (1.56)	4.38 (1.80)	-0.80(0.52)	0.111 [a]	-0.22	1.92	0.06
N-S:Spp	7.35(2.83)	9.87 (3.42)	-2.52(0.99)	**0.012** [b*]	0.51	4.53	0.14
S-N:Go-Me	39.74 (5.69)	38.37 (5.29)	1.37(1.65)	0.863 [a]	-2.16	4.86	0.01

C-C: Inter-canine width, Ca4-Ca4**:**Inter-premolar width, Gr6-Gr6:Inter-molar width, Palatal height**,** HOWE: basal bone width according to Howe analysis**.** AP:J-J: Alveolar process height, J-J: Maxillary width, AJ-AJ: Alveolar width, RApical-LApical:Inter-apical width, RBC-LBC:Inter-cusp width. SNB: Sagittal mandibular jaw position, SNA: Sagittal maxillary jaw position,ANB: The angle between upper and lower jaw in sagittal plane, S-N: Spp: Vertical maxillary jaw position, S-N:Go-Me:Vertical mandibular jaw position.

[a]**:** independent samples

[b]:Mann–Whitney U test

[*]: significant difference at the 0.05 level

617 Table 6: Comparison of changes between the two groups after treatment studied on the casts, frontal and
618 lateral cephalometric radiograph

619

620