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Short-term dentoalveolar effects of aesthetic lip bumper appliance: A longitudinal cases-series and pilot study

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ABSTRACT

Background: To investigate the short-term dentoalveolar effects on the mandibular arch of a modified, aesthetic lip bumper (ALBAa). The study sample comprised 23 patients (13 boys and 10 girls, with a mean age of 9.5 ± 1.8 years) in mixed dentition, with no previous orthodontic treatment. For each patient, a scan of the mandibular arch was digitally acquired pre-treatment (T0), and at 3 months (T1), 6 months (T2) and 9 months (T3) post-treatment. Linear intra-arch measurements, Little's irregularity index of the amount of mandibular anterior crowding, and the crown tipping values on all mandibular teeth were measured and compared statistically between time points. ANOVA and subsequent post-hoc tests were performed, considering a p-value of < 0.05 as significant.

Results: Linear intra-arch distances and crown tipping values on the mandibular teeth increased between the following time points: T0vsT1, T1vsT2, T0vsT2 and T0vsT3 ($p < 0.05$), although in the last three months of observation (T2vsT3) they only reached statistical significance at the lower incisors and lower left premolar concerning crown tipping values. There was a statistically significant decrease in anterior crowding throughout the observational period ($p < 0.05$), and this effect was equally distributed across the different time points investigated.

Conclusions: ALBAa therapy led to an increase in both linear intra-arch distances and crown tipping values, with a reduction in Little's index. The distribution of the effects reported across the observational period depended on the mechanism of action (mechanical vs. functional).

1. Introduction

Management of transverse dimensions is of paramount importance in orthodontics (Haas, 1970). Indeed, transverse deficiency is a common issue, and orthodontic treatments primarily focus on achieving proper transverse dimensions in both arches to prevent significant issues like crowding, teeth impaction, cross-bite, mandibular functional shift, and difficulty in nasal breathing (Babacan et al., 2006).

Although rapid skeletal maxillary expansion is a well-known method for increasing the perimeter and diameter of the maxillary arch, with both dentoalveolar and skeletal effects reported, the mandibular arch can only be expanded through the expansive dentoalveolar effects of orthodontic appliances (Solomon et al., 2006). In order to achieve adequate maxillary skeletal expansion in a single phase, thereby increasing the efficiency of orthodontic treatment, McNamara et al. recommend expanding first the mandibular arch and then the maxilla (McNamara, 2000). One of the orthodontic appliances most used with this aim is the lip bumper (LB), a semi-functional, removable orthodontic device that applies active forces on the lower first molars and redirects oral forces. By utilizing an extended resin shell, it effectively eliminates the centripetal pressure caused by the perioral muscles. This, in turn, allows the centrifugal forces exerted by the tongue to passively expand the mediolateral sectors, leading to the proclination of the anterior teeth. At the same time, the lip forces are directed towards the molars, facilitating their uprighting and distal inclination. Additionally, mechanical overexpansion forces are applied through a rounded stainless-steel wire on the lower first molars. Although effective, the LB depends strictly on patient compliance, as it should be worn for about

Abbreviations: ALBAa, aesthetic lip bumper appliance.

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18–20 h per day (Raucci et al., 2016; Soo and Moore, 1991)). In turn, patient compliance with an orthodontic appliance is closely influenced by how well it is accepted. This depends on both the comfort and aesthetics of the appliance (Bonnick et al., 2011), as well as the level of patient motivation (Sergl et al., 1998; Sergl et al., 2000; Doll et al., 2000). As highlighted by recent studies, young patients, like adults, are uncomfortable wearing unsightly orthodontic appliances, especially when they are visible (Rivera et al., 2000). The literature shows that aesthetic appliances are very much appreciated by patients as young as 12 years old (Walton et al., 2010), with clear aligners being the preferred option among 12–15-year-olds with respect to conventional fixed appliances (Walton et al., 2010). With this in mind, the ALBAa, a modified version of a traditional LB appliance, designed to be more aesthetically acceptable to patients, has been proposed. It consists of an anterior bumper made of fibreglass and two shells made of polyethylene terephthalate glycol (PET-G) to completely cover both lower first molars and deciduous molars (Ormco, Glendora, USA) (Bagden, 2003). The purpose of this study was to investigate the dentoalveolar effects of this appliance.

2. Material and methods

2.1. Study design and description of sample

The study was designed as a prospective longitudinal experimental study without a control group. It was approved by the University of Ferrara Postgraduate School of Orthodontics Ethics Committee and registered as protocol n°3/2015.

The study sample comprised University of Ferrara Postgraduate School of Orthodontics patients recruited prospectively and consecutively who met the following inclusion criteria:

1. Young patients aged between 7 and 11 in late mixed dentition.
2. The need for transverse lower arch decompensation before rapid maxillary skeletal expansion: transverse deficiency was identified as a McNamara index ≤ 31 mm in the maxillary arch (McNamara, J. A. 2000) and Wilson Curve of ≥ 1.5 mm in the mandibular arch (Chung, 2019).

Patients with craniofacial syndromes and previous orthodontic treatment were excluded.

The study sample thereby comprised 23 patients (13 boys and 10 girls, with a mean age of 9.5 years ± 1.8 years). For each patient, initial records were acquired. Data recorded were demographic characteristics (sex and age), digital models, intra- and extra-oral photos, panoramic radiograph and cephalogram.

2.2. Treatment protocol

Each patient recruited for the study was treated primarily with an ALBAa to decompensate the mandibular Wilson curve. The ALBA used is composed of a round 0.045-inch SS archwire whose anterior part is encased in a bumper made of quartz crystal microbalance (QCM) fibreglass (Tecnident, São Carlos, Brazil) (Fig. 1A–B), 1.5 mm away from the vestibular surfaces of the lower incisors (Fig. 1C). The posterior part of the stainless-steel arch is U-shaped at the deciduous lower second molars, with the final portion being embedded in two shells made of PET-G (1.5 mm, Scheu-dental, Iserlohn, Germany), completely covering the lower first molars and both deciduous lower first and second molars (Fig. 1D).

All patients were treated by the same orthodontist (LL). They were asked to wear the appliance for 20 h per day, except during meals and oral hygiene procedures. Follow-up visits were scheduled monthly. The appliance, passive upon delivery, was activated by about 1.5 mm transversely for each hemiarch at each appointment to ensure an adequate amount of transversal expansion.

Patients were monitored after delivery of the appliance (T0) with follow-ups at 3 (T1), 6 (T2) and 9 (T3) months, when alginate impressions of the lower arch were acquired and then digitized in STL. format using a 3-Shape D800 extraoral scanner (3 Shape, Copenhagen,

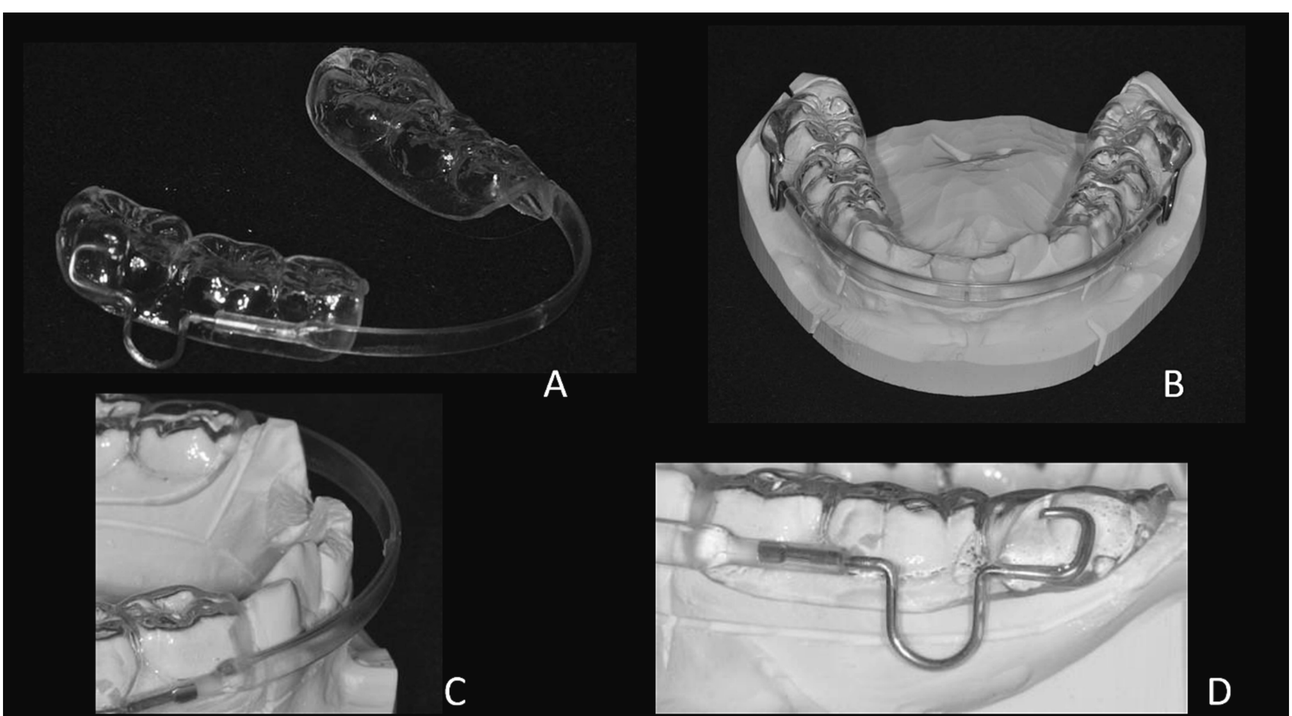

Fig. 1. Aesthetic Lip Bumper appliance. Aesthetic Lip Bumper appliance (A–B). Detail of anterior part of appliance with QCM fibreglass bumper spaced 1.5 mm from the vestibular surfaces of the lower incisors (C). Detail of posterior part, with U-shaped stainless-steel archwire and shells completely covering the lower first molar and deciduous lower first and second molars (D).

Denmark).

2.3. Digital measurement protocol

The following measurements were made on each digital scan of the mandibular arch at each time point:

2.3.1. Transverse linear measurements

- **Inter-deciduous canine width:** the distance between the cusps of the lower deciduous canines (C–C)
- **Inter-deciduous first molar width:** the distance between the occlusal fossae of the deciduous lower first molars (D–D)
- **Inter-deciduous second molar width:** the distance between the occlusal fossae of the deciduous lower second molars (E–E)
- **Inter-permanent first molar width:** the distance between the occlusal fossae of the lower first molars (6–6) (Fig. 2)

2.3.2. Amount of anterior mandibular crowding

Calculated via Little's irregularity index (Little, 1975) (Fig. 3 A).

2.3.3. Mandibular teeth tip

Vestibulolingual crown tipping values on all lower teeth.

All linear mandibular transverse distances and anterior mandibular crowding (Little's irregularity index) were measured using Orthoviewer software (3 Shape, Copenhagen, Denmark).

To assess crown tip values on mandibular teeth, we utilized digital models for each observed time point. These models were imported into VAM software (Vectra, Canfield Scientific, Fairfield, NJ, USA), enabling the identification of 100 reference points on each tooth.

For incisors and canines, six key points were marked: mesial occlusal (MO), distal occlusal (DO), vestibular gingival FACC (VG-FACC), incisal vestibular FACC (IV-FACC), vestibular FA (V-FA), and lingual gingival FACC (LG-FACC). Similarly, premolars had eight designated points, including the mesial and distal points (M and D). Molars also had eight landmarks identified, including the mediovestibular cusp (MV) and distovestibular cusp (DV).

Each point was assigned three coordinates, which were recorded on an Excel spreadsheet named "master.xls". This approach was employed to automate the calculation of crown tip values for all mandibular teeth, specifically assessing their labiolingual inclination (Fig. 3C) relative to the occlusal reference plane (Fig. 3D). This measurement method relies on the occlusal plane as a crucial point of reference (Huanca Ghislanzoni et al., 2013). This plane is defined by passing through the mesiovestibular cusps of the first molars and the centroid of the FACC (Facial Axis of Clinical Crown) lines of all other teeth, excluding canines. Utilizing the occlusal plane as a reference helps minimize measurement errors caused by tooth movement during orthodontic treatment.

The resulting measurements, encompassing both linear and angular aspects, were then subjected to comparative analysis across the different time points (T0, T1, T2, T3).

2.4. Statistical analysis

The data was analysed using R software. The same operator conducted all measurements, including repeated measures on eight randomly selected patients to test the inter-operator reliability (repeatability). This yielded no statistically significant variations (1.2° for angular measurements and 0.13 mm for linear measurements), thereby confirming the repeatability of the measurements performed in this study.

Descriptive analysis, recording the mean and standard deviation (DS) of every measurement, was conducted. ANOVA for repeated measures and post-hoc tests were performed to evaluate the statistical significance of measurements at each time point investigated. A p-value < 0.05 was considered statistically significant.

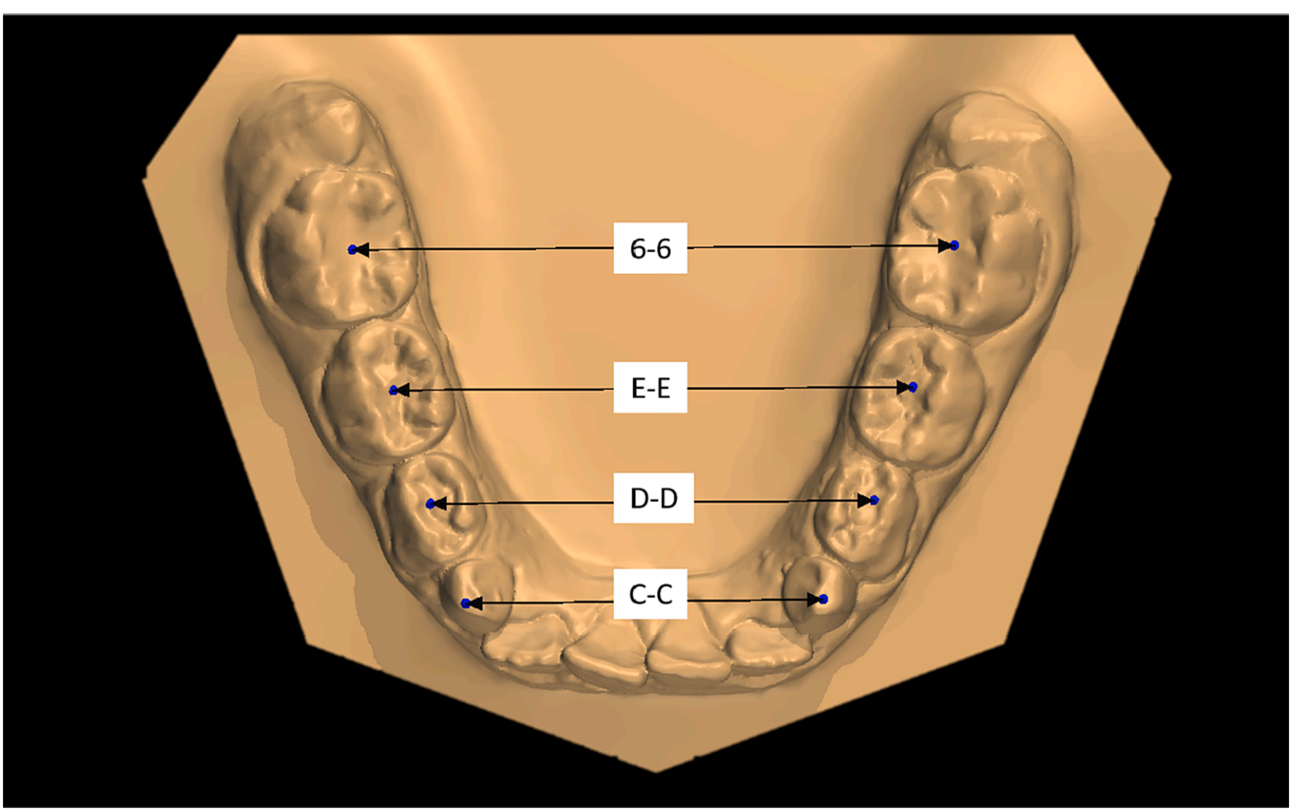

Fig. 2. Arch width measurements. Graphical representation of linear intra-arch measurements in the lower arch: between the canine cusp tips (C–C), the occlusal fossae of the deciduous lower first molars (D–D), and those of the deciduous lower second molars (E–E) and lower first molars (6–6).

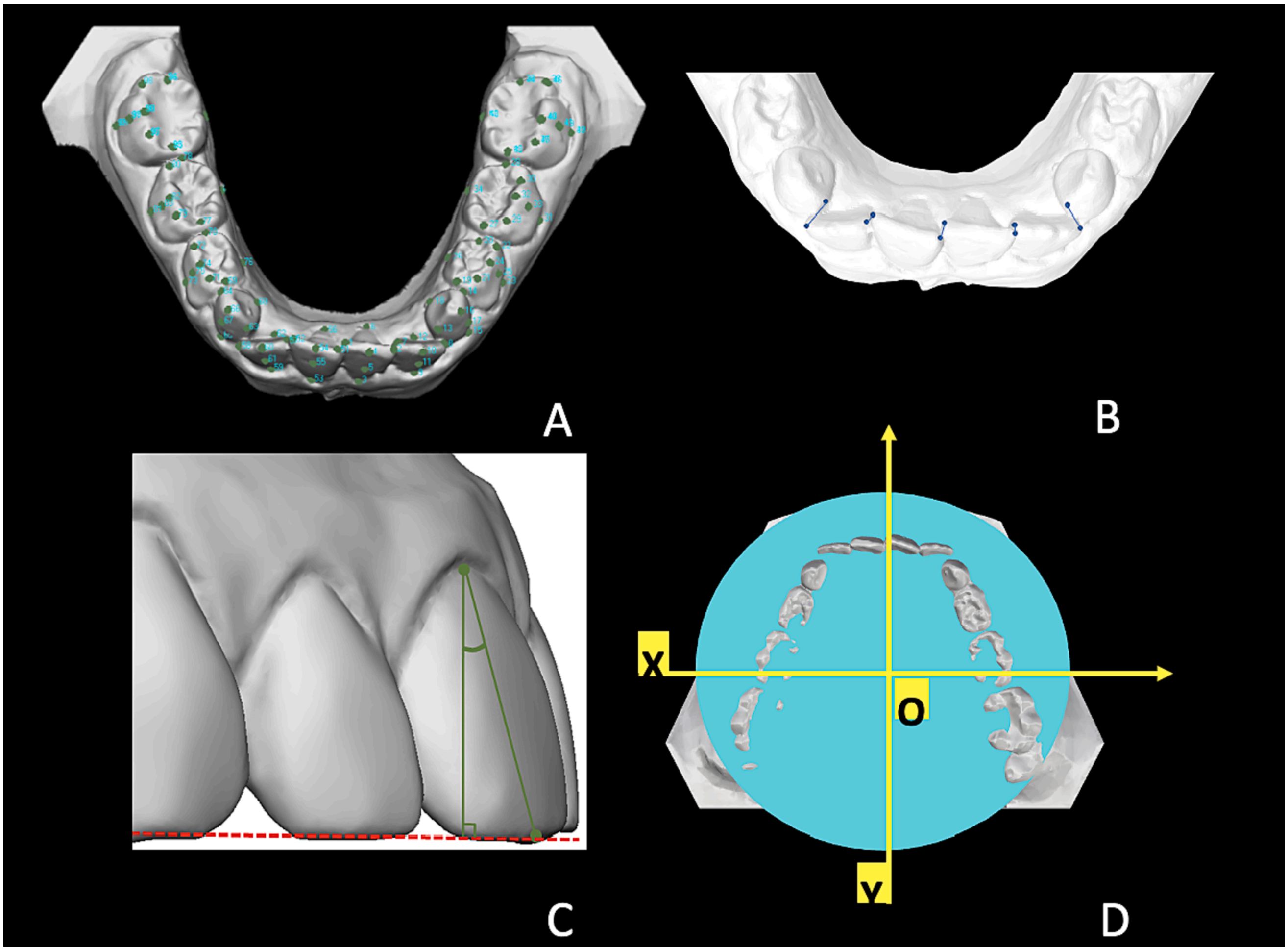

Fig. 3. Points in the lower arch on VAM 3D software. Graphical representation of Little's index measurements between anatomical contact points of anterior mandibular teeth. The index is a sum of all measurements (A). Marking of mandibular anatomical points on the lower arch using VAM software (Vectra, Canfield Scientific, Fairfield, NJ, USA) (B). Graphical representation of crown-tip measurement values (C) and the occlusal plane used as a reference (D). The latter is defined by passing through three key points: mesiovestibular cusps of the lower first permanent molars and the centroid point (0), which is, in turn, calculated based on all the FACC lines of the other teeth, with the exception of the canines.

ANOVA considering the "time effect" was calculated for each repeated measure, and in all cases yielded a statistically significant result ($p < 0.05$). Therefore, post-hoc tests considering different time points were performed for each type of measurement analysed.

3. Results

3.1. Transverse distances

The variation in mandibular intra-arch linear measurements and the respective post-hoc test results across the observational period are reported in Table 1. Positive values indicate an increase due to the expansion effect and arch development in the medial and posterior sectors. A statistically significant increase in each measurement was observed when comparing T0vsT1, T1vsT2 and T0vsT2 time points ($p < 0.05$), although no significant variations were found for the T2–T3 interval ($p > 0.05$) (Table 1).

3.2. Crown tip measurements

Variations in crown tip were recorded for all mandibular teeth at each time point, and the respective post-hoc test results are reported in Table 2. In particular, statistically significant increases were observed when comparing time points T0vsT1, T1vsT2 and T0vsT2 ($p < 0.05$). No significant variations were reported for the interval T2–T3 ($p > 0.05$), except for at the lower incisors (teeth 3.1, 4.1, 3.1, 3.2) and the left mandibular premolars (teeth 3.4 and 3.5) ($p < 0.05$) (Table 2).

3.3. Crowding

Table 3 shows the mean values for Little's irregularity index and the respective SD at each time point, together with post-hoc testing results. A statistically significant decrease in the amount of crowding was observed across the observation period ($p < 0.05$). This effect was equally distributed across the various time intervals, reaching statistical significance at each time point (Table 3).

4. Discussion

All patients treated with the ALBA displayed both anterior and transverse expansion of the mandibular arch, in line with that reported in the literature (Grossen and Ingervall, 1995). In the posterior sectors, the ALBAa exploits the principle of the super elastic plate and allows transverse expansion. The average increase in width between the first deciduous molars was greater (4.38 ± 0.24 mm) than that recorded at the level of the second deciduous molars (4.23 ± 0.2 mm). In contrast, the smallest transverse expansion occurred at the deciduous canines, with a net increase of about 2.54 ± 0.12 mm, a value greater than that

Table 1
Means (mm) and SD (mm) of inter-arch linear measurements at each time point investigated. Statistical comparison was performed between time points T0, T1, T2 and T3. P < 0.05 was considered significant.

Linear intra-arch widths	T0 vs. T1			T0 vs. T2			T0 vs. T3			T1 vs. T2			T1 vs. T3			T2 vs. T3		
	Mean	SD	P value	Mean	SD	P value	Mean	S	P value	Mean	S	P value	Mean	S	P value	Mean	S	P value
C–C	1.25	0.07	<0.05	2.27	0.09	<0.05	2.54	0.12	<0.05	1.02	0.09	<0.05	1.30	0.12	<0.05	0.27	0.13	0.181
D–D	2.32	0.14	<0.05	4.05	0.18	<0.05	4.38	0.24	<0.05	1.73	0.18	<0.05	2.06	0.24	<0.05	0.33	0.25	1.00
E–E	2.33	0.97	<0.05	3.98	0.12	<0.05	4.23	0.20	<0.05	1.65	0.13	<0.05	1.90	0.20	<0.05	0.25	0.20	1.00
6–6	1.94	0.10	<0.05	3.28	0.13	<0.05	3.50	0.17	<0.05	1.34	0.13	<0.05	1.56	0.17	<0.05	0.23	0.18	1.00

(C–C: inter-deciduous canine width; D–D: inter-deciduous first molar width; E–E: inter-deciduous second molar width; 6–6: inter-permanent first molar width) SD: standard deviation.

Table 2
Mean (°) and SD (°) of crown tip at each time point investigated. Statistical comparison between torque measurements (°) at time points T0, T1, T2 and T3. P < 0.05 was considered significant.

	T0 vs. T1			T0 vs. T2			T0 vs. T3			T1 vs. T2			T1 vs. T3			T2 vs. T3		
	Mean	SD	p value	Mean	SD	p value	Mean	SD	p value	Mean	SD	p value	Mean	SD	p value	Mean	SD	p value
31	2.46	0.38	<0.05	4.45	0.46	<0.05	6.30	0.63	<0.05	2.00	0.46	<0.05	3.84	0.63	<0.05	1.85	0.65	<0.05
32	2.17	0.50	<0.05	4.15	0.63	<0.05	6.78	0.86	<0.05	1.97	0.63	<0.05	4.61	0.86	<0.05	2.63	0.89	<0.05
33	3.19	0.19	<0.05	5.59	0.23	<0.05	5.97	0.31	<0.05	2.40	0.23	<0.05	2.78	0.31	<0.05	0.38	0.32	1.00
34	6.47	0.27	<0.05	11.07	0.36	<0.05	12.24	0.47	<0.05	4.60	0.36	<0.05	5.78	0.47	<0.05	1.18	0.47	<0.05
35	5.30	0.20	<0.05	9.39	0.26	<0.05	10.83	0.37	<0.05	4.09	0.26	<0.05	5.53	0.37	<0.05	1.44	0.39	<0.05
36	4.57	0.18	<0.05	8.24	0.23	<0.05	8.43	0.31	<0.05	3.67	0.23	<0.05	3.86	0.31	<0.05	0.19	0.32	1.00
41	2.14	0.37	<0.05	3.79	0.45	<0.05	5.98	0.62	<0.05	1.66	0.45	<0.05	3.84	0.62	<0.05	2.18	0.63	<0.05
42	2.20	0.57	<0.05	4.26	0.72	<0.05	7.13	0.99	<0.05	2.05	0.71	<0.05	2.05	0.97	<0.05	2.87	1.00	<0.05
43	3.37	0.19	<0.05	5.73	0.24	<0.05	6.04	0.32	<0.05	2.37	0.24	<0.05	2.67	0.31	<0.05	0.31	0.32	1.00
44	6.82	0.26	<0.05	11.41	0.35	<0.05	12.60	0.48	<0.05	4.60	0.35	<0.05	5.78	0.48	<0.05	1.18	0.50	0.107
45	5.57	0.28	<0.05	9.85	0.34	<0.05	10.85	0.51	<0.05	4.28	0.35	<0.05	5.28	0.51	<0.05	1.00	0.52	0.332
46	4.70	0.20	<0.05	8.11	0.25	<0.05	8.48	0.34	<0.05	3.42	0.25	<0.05	3.79	0.34	<0.05	0.37	0.35	1.00

Table 3
Mean and SD of Little's irregularity index at each time point investigated. Statistical comparison between Little's index measurements (mm) at T0, T1, T2 and T3. P < 0.05 was considered significant.

Comparison between time points	Mean	SD	P value
T0 vs. T1	−1.32	0.24	<0.05
T0 vs. T2	−2.38	0.29	<0.05
T0 vs. T3	−3.55	0.39	<0.05
T1 vs. T2	−1.06	0.29	<0.05
T1 vs. T3	−2.23	0.38	<0.05
T2 vs. T3	−1.17	0.39	<0.05

recorded by Grossen and Ingervall (1995). The inter-permanent first molar width values recorded in this study are also higher than those reported in the literature (Grossen and Ingervall, 1995; Osborn et al., 1991; Werner et al., 1994; Moin and Bishara, 2007; O'Donnell et al., 1998; Bjerregaard et al., 1980), although lower than those reported by Cetlin and Ten Hoeve (Cetlin et al., 1983). Intra-arch expansion was not evenly distributed over time, with 53 % of the total gain occurring in the first 3 months of treatment, 39 % during the following 3 months, and only 8 % in the last 3 months of therapy. The gains were statistically significant in the first six months of observation, but not in the last time interval. Crown tip in the posterior sectors increased significantly, with the greatest variation observed at the deciduous first molars, which displayed an average increase in crown tip values that was approximately 2° greater than that recorded at the deciduous second molars (12.24° ± 0.47° for the left and 12.6° ± 0.48° for the right deciduous first molars and 10.83° ± 0.37° for the left and 10.85° ± 0.51° for the right deciduous second molars, respectively). The permanent first molars, on the other hand, displayed an average angular increase of 8.43° ± 0.31° on the left and 8.48° ± 0.34° on the right, respectively. Indeed, as highlighted in the literature, one of the side effects of the Lip Bumper is the distal inclination of the first permanent molar, which could lead to eruptive alterations of the second permanent molars (Ferro et al.,2011). In contrast, the smallest variation in crown tipping was recorded at the canines, with increases of 5.97° ± 0.31° on the left and 6.04° ± 0.32° on the right. To best of our knowledge, no other recent studies have analysed the variation in crown tipping values of on the lateral teeth in mixed dentition after LB treatment. Indeed, at the central incisors a proclination of 6.3° ± 0.63° on the left and 5.98° ± 0.62° on the right was recorded, while 6.78 ± 0.86° of proclination was recorded for the left lateral incisor and 7.13° ± 0.99° for the right.

Regarding the proclination effect on anterior teeth, 34.5 % occurred in the first 3 months of treatment, 29.5 % in the next 3 months, and 36 % in the last 3 months. However, 53.25 % of the total posterior transverse expansion occurred in the first 3 months of treatment, 39.5 % in the following 3 months and only 7.25 % in the last 3 months of therapy. Similarly, crown tipping values for the posterior teeth increased significantly across the various time intervals, except for that pertaining to the last three months of observation.

This contrasts with the effects of ALBAa therapy in the anterior arch, as gains were equally distributed between the various time points, and invariably statistically significant. The effect of proclination of the anterior teeth is to cause a reduction in anterior crowding, as evaluated by Little's index (Little, 1975). Little's index is reduced thanks to a combination of two factors: both the increase in the inter-canine width, and the elimination of the labial pressure on the anterior sector of the arch. This allows the incisors to procline through lingual action, increasing the perimeter of the arch in this area consistently throughout therapy (Moin and Bishara, 2007). Indeed, our analysis revealed that about 37 % of the total reduction in crowding occurred in the first 3 months of treatment, 30 % in the following 3 months, and 33 % in the last 3 months of therapy. This reduction in Little's index is in line with that reported in the study by Werner et al. (Werner, 1994), whereas Ferris et al. reported a greater reduction (Ferris et al., 2005).

There are some limitations associated with this study: it only involved patients treated with the ALBA, and it would be interesting to carry out further research to compare its effectiveness with respect to a control group treated with traditional LB. Therefore, it is not feasible to directly ascribe these study findings to either the enhanced ALBA design or the significant patient compliance with its usage. In addition, the variation in verticality and divergence was not analysed, and this could be a key factor. Furthermore, no data regarding long-term stability of results are available at this time, so the effects of ALBA on the incidence of lower second molar impaction could not be assessed. Hence, this should be considered a pilot study, but nonetheless one that prompts further investigation.

5. Conclusions

The ALBAa allows predictable expansion of the mandibular arch in each dimension investigated. All intra-arch measurements increased during therapy, especially the distance between the deciduous molars. This effect was accompanied by an increase in crown tipping values and a reduction in crowding, by way of anterior teeth proclination.

The greatest changes were seen in the first six months of therapy, especially those based on a mechanical mechanism, whereas the functional effect guaranteed by the resin bumper provided a more gradual, evenly distributed change.

Ethics approval and consent to participate

Ethical approval of the institutional review board of the Postgraduate School of Orthodontics of the University of Ferrara and the informed consent release were obtained.

Consent for publication

Not applicable.

Availability data and materials

The datasets used and/or analyzed during the current study is available from the corresponding author on reasonable request.

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Author contributions

LL: Conception and design of the study; MLDI: Acquisition of data; FA and GP: Drafting the manuscript; LL, MP and FC: Revising the manuscript critically for important intellectual content; MP, FA, GP, FC, MLDI and LL: Approval of the version of the manuscript to be published.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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