Original Article

Short- and long-term evaluation of mandibular dental arch dimensional changes in patients treated with a lip bumper during mixed dentition followed by fixed appliances

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ABSTRACT

Objective: To evaluate short- and long-term mandibular dental arch changes in patients treated with a lip bumper during the mixed dentition followed by fixed appliances, compared with a matched control sample.

Materials and Methods: Dental casts and lateral cephalograms obtained from 31 consecutively treated patients before (T_0) and after (T_1) lip bumper, after fixed appliances (T_2), and a minimum of 3 years after fixed appliances (T_3) were analyzed. The control group was matched as closely as possible. Arch width, arch perimeter, arch length, and incisor proclination were evaluated. Repeated measures ANOVA was used to analyze changes in measurements over all four time points between treatment and control groups.

Results: Arch widths and crowding were always significantly different except at T_2-T_1. At T_1-T_0, only crowding decreased 3.2 mm while intercanine, interpremolar, and intermolar widths increased by 3.8, 3.3, and 3.9 mm, respectively. Changes at T_3-T_2 showed a significant decrease of 2.1 mm for crowding and an increase of 3.5, 2.9, 2.7, and 0.8 mm for intercanine, interpremolar, and intermolar widths and arch perimeter, respectively. Finally, at T_3-T_0, the reduction in crowding of 5.03 mm was significant and clinically important in the treated group. The differences between intercanine, interpremolar, and intermolar widths were also significant (2.1, 3.8, and 3.6 mm, respectively). All those differences favored the treated group.

Conclusions: Mandibular dental arch dimensions were significantly changed after lip bumper treatment. At follow-up, all arch widths were slightly decreased, generating an increase of 0.4 mm in crowding, considered clinically irrelevant. Overall changes remained stable after an average 6.3-year follow-up. (*Angle Orthod.* 2016;86:753–760.)

KEY WORDS: Lip bumper; Dental arch dimensions; Long-term; Mixed dentition; Stability

INTRODUCTION

The amount of crowding in cases having tooth-size/dental arch length discrepancy is an important factor when deciding between extraction[1] and nonextraction orthodontic treatment. Because of mandibular anatomical constraints, the mandibular dental arch usually

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Table 1. Characteristics of Participants

	Sample Size			Average Age (yr/mo)				Crowding (mm)			
Group	Total	Male	Female	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3
Treated	31	12	19	9.04 ±1.63	11.1 ± 1.52	13.42 ± 1.73	19.7 ± 2.37	−5.4 ± 2.71	−1.1 ± 1.45	0.00	−0.36 ± 0.42
Control	20	10	10	9	12.1 ± 0.31	13.95 ± 0.22	20	−4.72 ± 2.48	−3.61 ± 2.18	−3.35 ± 3.2	−5.89 ± 2.12

serves as a guideline to determine required changes in the maxillary dental arch.[2]

In cases with borderline crowding that might benefit from lip support or a full smile, often a nonextraction treatment is initiated. One available appliance used to gain additional dental arch space in the mandibular arch in such a case is the lip bumper.[3] The primary purpose of this appliance is to reduce dental arch crowding[4,5] through an increase in arch width and length[4–8] by altering the equilibrium between lips, cheeks, and tongue.[3,9]

Recently, a systematic review[10] summarized lip bumper effects, reporting significant increases in deciduous or permanent intercanine width[4,5]; deciduous intermolar,[4] premolar,[6,8] and intermolar width[8]; arch perimeter; and arch length.[4] Concomitantly, a decrease of crowding was noted.[4] Various authors have questioned the short- and long-term stability of lip-bumper-related changes. Werner et al.,[11] evaluating dental arch stability at 2 years posttreatment reported significant stable arch width increases. Vargo et al.[12] showed a significant posttreatment decrease in intermolar width, arch length, and perimeter after an average of 0.9 ± 0.4 years, but net increases were statistically significant for all measurements except arch length. Long-term stability was reported after an average of 7.9 years with rapid palatal expansion[13] and after an average of 8.6 years in another sample treated without rapid palatal expansion.[2] Although arch widths decreased, net gains were maintained for all measurements.

In previous papers,[14,15] long-term stability of maxillary dental changes after placing a transpalatal arch in the mixed dentition followed by fixed appliances was evaluated. The purpose of the current retrospective clinical study was to also evaluate, in this same sample, short- and long-term dental changes in the mandibular arch after lip bumper treatment. A nontreated control group was used to factor out normal dentoalveolar changes. The null hypothesis asserted that there was no significant difference in intra-arch dimensions in patients treated with a lip bumper in the mandibular arch compared with a control group.

MATERIALS AND METHODS

Appropriate ethical approval was secured from the Health Research Ethics Board of the University of Alberta (Pro00052522), the Burlington Growth Center of the University of Toronto (February 2015), and the Health Research Ethics Board of the Second University of Naples (0003573/2015; February 2015).

Subjects were selected based on these inclusion criteria:

- Class I or II malocclusion,
- mild-to-moderate mandibular dental arch crowding (<6 mm),[16]
- mixed dentition,
- ≤9 years old before treatment start,
- cervical vertebral maturation stage[17] 1 or 2 before treatment start.

Exclusion criteria were

- previous orthodontic treatment,
- craniofacial anomalies,
- extraction treatment.

Sample Characteristics

Because no lip bumper was used on five patients from the original treatment sample,[14,15] the final treated sample consisted of 31 consecutively treated patients (12 boys and 19 girls) between 1995 and 2007 gathered from a private orthodontic practice in Naples, Italy. The control sample, derived from the Burlington Growth Center in Toronto, Canada, consisted of 10 boys and 10 girls closely matched for age, cervical vertebral maturation, sex, and observation periods. The inclusion criteria were similar except that no orthodontic treatment was provided.

Dental casts and lateral cephalograms were obtained at four time points: before lip bumper (T_0), after lip bumper (T_1), after fixed appliances (T_2), and a minimum of 3 years after fixed appliances, with an average 6.3-year follow-up (T_3). The mean ages are reported in Table 1.

Treatment Protocol

All patients had two-phase active treatment. The first phase (T_0–T_1), lasted about 2 years; each patient was treated with a lip bumper, a 0.045-inch, round, stainless steel wire (American Orthodontics, Sheboygan, Wisc) with U-loops mesial to the first permanent molars. It was positioned at the gingival level 2 mm buccal to the teeth. The appliance was inserted passively into the molar tubes at the first visit and then the anterior loop was activated 1.5 mm every 40

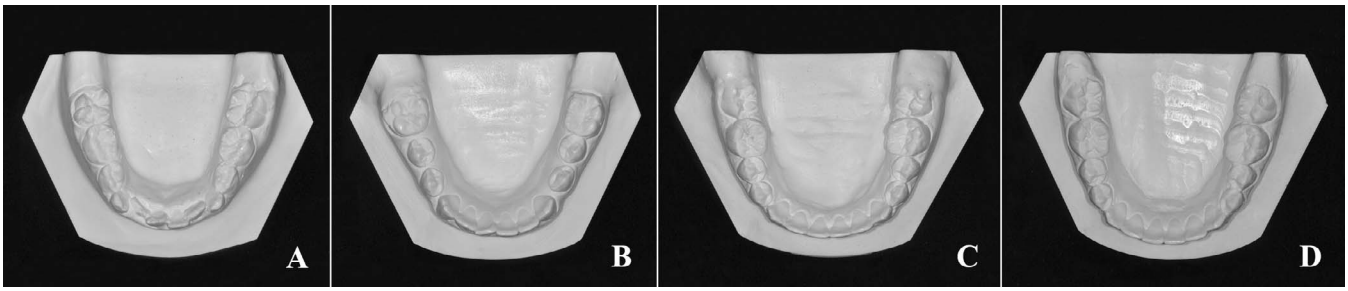

Figure 1. Mandibular dental casts at the four time periods: before treatment (A); post-lip bumper (B); post-fixed appliances (C); follow-up (D).

days. The patients were asked to wear the bumper 18 hours per day, except during meals and sports. Eruption of all permanent teeth (except second and third molars) marked the beginning of the second phase (T_1–T_2). Treatment lasted approximately 2 years, with standard edgewise appliances (0.022-inch slot) to finalize the occlusion. The third phase (T_2–T_3) consisted of a follow-up evaluation at least 3 years after the end of active treatment. This phase included a period of passive retention with a fixed canine-to-canine retainer that lasted at least 2 years.

Dental Cast Measurements

The anatomic landmarks on the dental casts at the four time periods (Figure 1) were marked with a black 2H pencil with a 0.5-mm tip; the distances were measured with a digital calipers. The following measurements were obtained: intercanine, interpremolar, and intermolar widths; arch length; arch perimeter; and crowding.

Intercanine (C) and interpremolar (Pr) widths were evaluated between the inner lingual points on the gingival margin of the deciduous or permanent canines and first deciduous molars or premolars, respectively.[18] Intermolar width (M) was measured between the point of intersection of the lingual groove with the cervical gingival margin at the first molars[19] (Figure 2).

Arch length (L) was measured as the perpendicular distance from the most facial point on the most prominent central incisor to a line connecting the mesial contact points of the permanent first molars[18] (Figure 3).

Arch perimeter (P) was evaluated as the sum of the distances between points on the mesial aspect of the permanent first molars, on the distal side of the canines and central incisors[18] (Figure 4). A point halfway between the adjacent permanent teeth centered buccolingually on the alveolar process represented unerupted teeth.

Crowding (A) was evaluated as the tooth-size/arch-length discrepancy. Any crowding (>0 mm) at T_3 was considered relapse. Once marked, the occlusal surface of each dental cast was photocopied. Each case was copied in sets of four mandibular arches.

Cephalometric Analysis

The only cephalometric measurement made was mandibular incisor inclination (IMPA),[20] the angle between the long axis of the most prominent incisor and the mandibular plane (Go-Gn).

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS version 22; IBM Corp, Chicago, Ill) was used for data analysis. Measuring all 31 treated and 20 control dental casts and lateral cephalograms twice within a 1-week period by two different operators determined reliability of the method. The measurement error was calculated with Dahlberg's formula for cephalometric measurements and an intraclass correlation coefficient (ICC) for model measurements. For continuous variables, means and standard deviations were calculated. An independent samples *t*-test was used to compare both groups at each of the four assessed time points. To analyze changes in measures over all four time points (T_1–T_0, T_2–T_1, T_3–T_2,

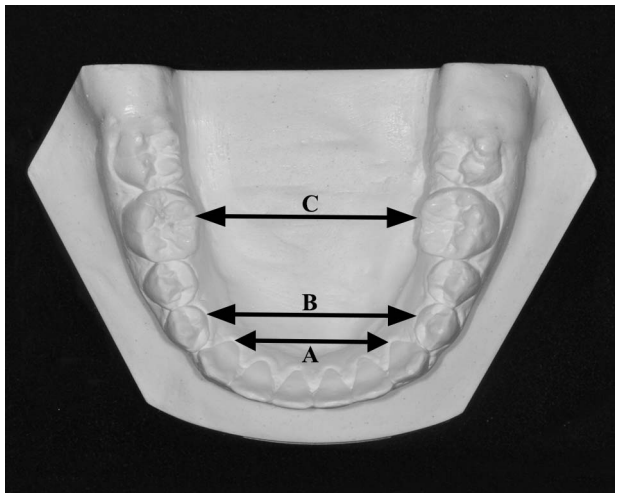

Figure 2. Arch width measurements: intercanine width (A); interpremolar width (B); intermolar width (C).

Table 2. Mean and SD of All Measures for the Four Assessment Time Points in Orthodontically Treated and Control Groups

	T_0			T_1		
	Control	Treatment	P^a	Control	Treatment	P^a
Intercanine	17.98 ± 0.30	20.83 ± 1.72	.000	15.75 ± 2.63	22.50 ± 1.44	.000
Interpremolar	21.48 ± 2.79	25.16 ± 2.12	.000	20.98 ± 2.54	28.04 ± 1.84	.000
Intermolar	28.24 ± 2.79	32.97 ± 3.01	.001	27.31 ± 2.97	36.00 ± 2.23	.000
Arch length	20.61 ± 3.34	25.99 ± 1.85	.000	19.95 ± 1.72	25.43 ± 1.48	.000
Perimeter	58.66 ± 2.31	66.46 ± 1.06	.000	59.26 ± 3.21	69.30 ± 3.99	.000
Crowding	−4.71 ± 2.48	−5.39 ± 2.70	.372	−3.61 ± 2.18	−1.06 ± 1.45	.000
IMPA	95.27 ± 7.94	93.87 ± 6.33	.493	95.03 ± 7.88	94.7 ± 4.43	.848

[a] $P < .05$; $P < .01$; $P < .001$; not significant.

and $T_3 - T_0$) between treated and control groups, repeated measures ANOVA was used. For identifying statistically significant differences, post hoc Bonferroni tests were used. The level of statistical significance set at $P < .05$ and confidence interval (CI) of 95% were considered for all statistical tests.

RESULTS

For the dental cast measurements, interreliability was ICC = 0.99 CI 95% (0.97, 0.99). The standard error for the cephalometric analysis, based on the IMPA angle calculated by Dahlberg's formula, was not considered clinically significant. Statistical analyses for the reliability and accuracy assessments were repeated after removing all outlying data points. Since they were determined to have no significant effect on the results, all data points were maintained for the analyses in this study.

Characteristics of the treated and control groups at baseline, as well as the significance of their differences at each time point, are reported in Tables 1 and 2. Table 2 shows strong statistically significant differences between the control and treatment groups ($P < .01$). However, for cephalometric measurements based on IMPA, no statistical significance was found ($P < .05$).

As can be seen from Table 2 and Appendixes 1–6, there were differences in measures between treated and control groups at baseline. Because these initial differences might have affected interpretation of the results, they were adjusted for all ANOVA models (we considered measures at T_0 as a covariant, while running ANOVA to eliminate the effect of differences at T_0). Table 3 summarizes the results of repeated measures ANOVA. For C, Pr, M, and A measures, there were significant differences between the treatment and control groups at $T_1 - T_0$, $T_3 - T_2$, and $T_3 - T_0$, but no significant difference at $T_2 - T_1$. This showed the short-term efficacy of the lip bumper (Table 3).

Regarding the effect of the bumper at $T_1 - T_0$, in the treated group some of the mandibular dental arch dimensions showed significant increases except crowding (3.2 mm decrease in the treated group; $P < .01$). The intercanine width increased by 3.8 mm and interpremolar and intermolar widths increased by 3.3 and 3.9 mm, respectively. As for the long-term effect of the lip bumper on the treated group, the changes at $T_3 - T_2$ showed a significant decrease in crowding (2.1 mm; $P < .01$) and an increase in

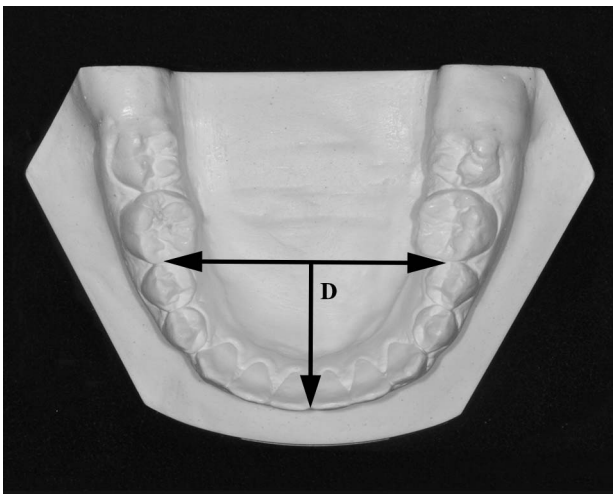

Figure 3. Arch length measurement (D).

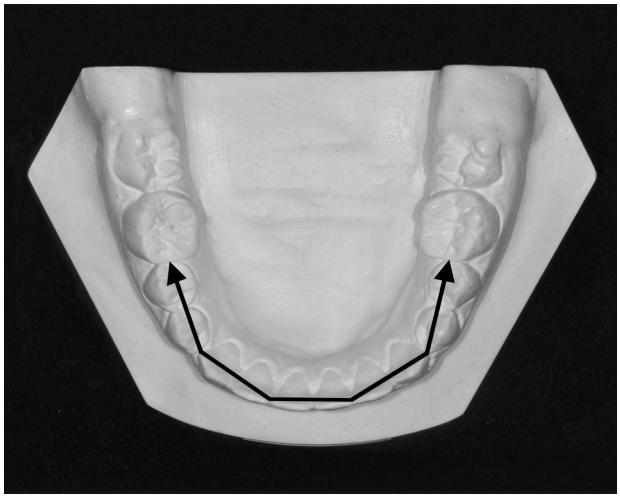

Figure 4. Arch perimeter measurement.

Table 2. Extended

	T_2			T_3		
	Control	Treatment	P^a	Control	Treatment	P^a
Intercanine	16.51 ± 1.73	23.09 ± 1.44	.000	12.79 ± 2.69	22.90 ± 1.39	.000
Interpremolar	22.21 ± 2.48	29.07 ± 1.85	.000	19.12 ± 2.18	28.91 ± 1.8	.000
Intermolar	27.87 ± 3.15	36.83 ± 2.51	.000	24.92 ± 3.26	36.60 ± 2.52	.000
Arch length	19.37 ± 3.26	24.03 ± 1.48	.000	18.96 ± 3.69	23.87 ± 1.4	.000
Perimeter	58.13 ± 2.81	68.78 ± 4.33	.000	56.97 ± 3.10	68.50 ± 4.26	.000
Crowding	−3.35 ± 3.19	0	.000	−5.89 ± 2.12	−0.36 ± 0.42	.000
IMPA	95.94 ± 7.76	95.00 ± 5.51	.618	94.99 ± 7.42	95.43 ± 4.61	.798

[a] $P < .05$; $P < .01$; $P < .001$; not significant.

intercanine width (3.5 mm; $P < .001$), interpremolar width (2.9 mm; $P < .001$), intermolar width (2.7 mm; $P < .001$), and arch perimeter (0.8 mm; $P < .001$).

From baseline to long-term follow up to $T_3 - T_0$ in the treated group, the reduction of crowding was strongly significant and clinically important in the treated group (5.03 mm; $P < .001$), while differences between the other measures (C, Pr, and M) were also significant (2.06 mm, 3.75 mm, and 3.62 mm, respectively). While comparing the treated and control groups, we found that all those differences favored the treated group (Table 3). To examine the effect of sex on the treatment differences, an extra covariate was added to the ANOVA model. No changes in significance of differences were observed after adjusting for sex (Table 4).

DISCUSSION

The results of this study increased our understanding of mandibular dental arch dimensional changes and their short- and long-term stability among growing patients treated with the lip bumper followed by fixed appliances. Analysis of the lip bumper effects in the mixed dentition followed by fixed appliances showed statistically and clinically significant increases in arch widths and decreases in crowding after an average 6.3-year follow-up. Generally, the greatest arch width gain has been suggested to occur in the premolar area and the smallest either in the canine[6,12,14,15] or the molar area.[5,8,11,13] In contrast, expansion in the treated group was greater in the posterior area of the arch than in the anterior, with an increase of 3.0, 2.9, and 1.7 mm for molars, premolars, and canines, respectively, probably due to periodic bumper activation including expansion associated with molar derotation. Crowding changes in the treated cases were significantly different from the decreases displayed in the controls. Reduction in dental crowding, seen in the treated group, can be ascribed to increases in arch widths and not by the 0.2° incisor proclination reported, that was statistically and clinically irrelevant and less than what has been reported elsewhere.[4,6,11] However, the crowding value could be overestimated because of the measurement used to calculate tooth-size/arch-length deficiency, that probably underestimated perimeter (straight segments not accounting for some on the anterior mandibular arch curvature). In agreement with previous studies,[13] arch length decreased, indicating a probable mesial movement of the molars into the E-space. However, compared with controls, the arch length decrease was less than would be otherwise expected, indicating some preservation of the E-space. The decrease may be considered insignificant, in contrast to previous findings,[4] which indicated an increase in arch length of 2.19 and 2.47 mm, respectively, using lip bumpers with acrylic shields. Our study showed a decrease of 0.6 mm, indicating that our lip bumper treatment did not produce mandibular incisor proclination as a bumper with an acrylic shield might have. The observed decrease may reflect a positive treatment effect because greater mandibular arch length decreases are normally expected during the mixed dentition. The lip bumper increased mandibular perimeter as expected.[4,11,12] In the treated group, the perimeter increase, statistically not significant, was 2.84 mm more closely related to arch width than to arch length changes, as previously reported.[12] In contrast, Davidovitch et al.[4] attributed most increases in perimeter to incisor proclination and molar distalization.

After the fixed appliances, no tendency to relapse was observed. Arch widths continued to increase slightly, solving the residual crowding of 1.06 mm. Only perimeter and arch length decreased because of space closure. Moreover, in this sample, attempts were made, during fixed appliance treatment, to maintain the arch dimensions and form achieved after lip bumper treatment, to enhance stability because the arch form card used for bending archwires was derived from the dental cast after lip bumper treatment.

After the follow-up period, when all subjects had ended or nearly finished their active facial growth periods (as determined by the CS6 cervical vertebral maturation assessment), all treated dental arch widths

Table 3. Mean and SD of Changes in Measures Over the Four Assessment Time Points in Orthodontically Treated and Control Groups

	T_1-T_0			T_2-T_1		
	Control	Treatment	P[a]	Control	Treatment	P[a]
Intercanine	−2.23 ± 2.26	1.65 ± 1.29	.000	0.75 ± 2.10	0.59 ± 0.86	.715
Interpremolar	−0.50 ± 3.17	2.88 ± 1.67	.000	1.22 ± 1.67	1.10 ± 1.50	.655
Intermolar	−0.93 ± 3.18	3.02 ± 2.40	.000	0.55 ± 1.19	0.73 ± 1.21	.394
Arch length	−0.66 ± 1.94	−0.55 ± 0.66	.814	−1.12 ± 1.81	−0.51 ± 1.70	.229
Perimeter	0.60 ± 10.51	2.84 ± 0.60	.300	−0.57 ± 1.09	−1.40 ± 1.71	.059
Crowding	1.10 ± 2.48	4.33 ± 2.40	.000	0.26 ± 2.96	1.05 ± 1.44	.204
IMPA	0.72 ± 4.15	0.18 ± 3.53	.624	0.82 ± 4.62	0.50 ± 3.28	.773

[a] $P < .05$; $P < .01$; $P < .001$; not significant.

were slightly reduced at the molar, canine—and least at the premolar—region by around 0.2 mm, generating an increase of 0.4 mm of crowding. These changes can be considered clinically irrelevant. Nevertheless, in the treated group (T_3-T_2), a high percentage of the intercanine (92%), interpremolar (96%), and intermolar (94%) width increases were maintained. Keep in mind that 5.4 mm of crowding had been previously alleviated.

A possible explanation for the observed stability is that the major changes in arch dimensions were primarily achieved during the lip bumper phase, whereas only small changes occurred after fixed appliance use. Usually, the greater the tooth expansion, the greater the relapse, but if physiological and not mechanical expansion is achieved, dental relapse may be limited.[9] Primarily, cheek and lip muscular pressures are involved, suggesting that smaller changes with fixed appliances help keep the correction stable. Stability of results might also be a function of good intercuspation, with which all patients were finished. These favorable outcomes are well related to the long-term stability of the maxillary arch previously reported in the same sample.[14,15]

Comparing the outcomes of this study with similar investigations is difficult because long-term dental arch changes in patients treated with the lip bumper in the mixed dentition followed by full fixed appliances have rarely been documented and not directly compared.

Table 4. Summary of Repeated Measures ANOVA Models for Orthodontically Treated and Control Groups

	Treatment vs Control Group Difference, P Value[a]	
Measures	Unadjusted	Adjusted for Sex
Intercanine	.000	.000
Interpremolar	.001	.004
Intermolar	.000	.001
Arch length	.304	.199
Perimeter	.206	.455
Crowding	.000	.000
IMPA	.467	.526

[a] $P < .05$; $P < .01$; $P < .001$; not significant.

Ferris et al.[13] reported greater postretention decreases in molar, premolar, and canine widths of 1.5, 1.2, and 0.9 mm, respectively, while Solomon et al.[2] reported significant decreases of 1.2 mm only for premolars, whereas canine and molar widths lost 0.4 and 0.6 mm, respectively, of the treatment increase. Both studies[2,13] reported higher relapse than did ours, probably because of the greater mechanical expansion achieved.

Limitations

This study has some limitations. Sample size of the control group is one, being smaller than the treated group due to a lack of available matching records in the longitudinal growth study. However, the available control group was matched for age, sex, cervical vertebral maturation, and dental malocclusion. Moreover, the average 6.3-year follow-up included a 2-year retention period; thus, 10 patients from the treatment group were only about 2 years out of retention. Finally, the term "crowding," defined as a tooth-size/arch-length discrepancy, is ambiguous.[16]

CONCLUSIONS

- After lip bumper treatment, a significant increase in dental arch widths was observed, along with a significant reduction in crowding and no change in arch length.
- After fixed appliance treatment, slight increases in arch widths were registered, alleviating any residual crowding.
- At the out-of-retention follow-up, all arch widths had decreased slightly, generating 0.4 mm of increased crowding. These changes can be considered clinically irrelevant, especially since 5.4 mm of initial crowding had been previously alleviated.
- Overall changes remained stable after an average 6.3-year follow-up after the end of fixed appliances.

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Table 3. Extended

	T_3-T_2			T_3-T_0		
	Control	Treatment	P^a	Control	Treatment	P^a
Intercanine	−3.71 ± 2.53	−0.19 ± 0.33	.000	−5.20 ± 2.55	2.06 ± 1.52	.000
Interpremolar	−3.08 ± 2.78	−0.16 ± 0.31	.000	−2.37 ± 3.46	3.75 ± 1.85	.001
Intermolar	−2.95 ± 2.72	−0.23 ± 0.53	.000	−3.33 ± 4.20	3.62 ± 2.64	.000
Arch length	−1.16 ± 1.79	−0.15 ± 0.32	.000	−1.65 ± 2.90	−2.11 ± 1.96	.498
Perimeter	−1.16 ± 1.79	−0.28 ± 0.59	.014	−1.65 ± 2.89	2.04 ± 5.11	.113
Crowding	−2.54 ± 3.34	−0.36 ± 0.42	.001	−1.17 ± 3.31	5.03 ± 2.57	.000
IMPA	0.00 ± 1.80	−0.19 ± 3.03	.801	1.55 ± 6.15	2.00 ± 5.41	.938

[a] $P < .05$; $P < .01$; $P < .001$; not significant.

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APPENDIXES 1–6. Mean of measurements according to time point for treated and control groups.