Skeletodental changes in the adolescent accruing from use of the lip bumper

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The lip bumper, a rigid tooth-borne appliance that holds the lower lip away from the anterior teeth, has achieved common usage in many orthodontic circles. Its purpose is to reduce lower anterior crowding,[1-3] increase arch circumference[1-6] and move the permanent molars distally.[4,7-9] When its treatment goals are met, it can simplify the banded phase of treatment and decrease the need for extracting permanent teeth since tooth-size/arch-size discrepancies have been reduced or eliminated. Use of the lip bumper may also shorten treatment time and enhance stability of the result.[1-3]

Arch changes produced by the lip bumper have been investigated, but until recently the focus has been on documenting mesial movement of the incisors and distal movement of the molars.[4,7-9] Cetlin and Ten Hoeve[1] and Ten Hoeve[2] showed that increase in arch circumference is due in large part to increase in arch width. Nevant[10] and Osborn[11] described the use of lip bumpers as adjuncts to fixed appliance treatment. They reported labial tipping of the incisor crowns, distal tipping of the molar crowns, and an increase in arch width. Nevant also reported a significant decrease in incisor irregularity. Subjects in these studies were treated by multiple clinicians without consistency of lip bumper fabrication or uniformity of age at treatment.

The present study was undertaken with two aims: one, to measure the effects of lip bumper treatment on development of the dental arches using a single appliance design and a single, experienced practitioner; and two, to evaluate the

Abstract

Cast and cephalometric analyses were performed to measure the effects of treatment with a lip bumper. The lip bumper was fabricated from an 0.045 inch wire with shrink tubing and no acrylic shields. Nine of the 32 patients were evaluated two years after the comprehensive phase of treatment. Patients were in the mixed dentition stage of development (mean age of 9.9 yrs). A single orthodontist designed all the appliances and treated all the cases. There was significant expansion between the canines, first premolars, second premolars and molars, with the greatest expansion occurring between the first premolars. Cephalometric analysis revealed that the molars underwent angular uprighting but did not move bodily. Incisor irregularity decreased 60% during this phase of treatment. The retention cases revealed that the arch depth decreased, perhaps due to loss of leeway space, but arch widths all were broader, especially in the anterior segment, than at the end of the lip bumper phase. Incisor irregularity also remained trivial ($\bar{x}$ = 0.3 mm), suggesting appreciable stability.

Key words

Lip Bumper • Incisor Irregularity • Expansion • Cast • Cephalometrics

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Figure 1
The lip bumpers were constructed of .045 inch blue Elgiloy® wire with shrink tubing. Each was adjusted with approximately 2 mm of clearance to the lower incisors and adjusted vertically to the gingival third of the tooth.

Figure 2
Incisor irregularity index was the sum of the five straight-line distances between the anatomic contacts of the six anterior teeth.

Figure 3
Locations of points used in measurement of arch width parameters. A-A', intercanine width; B-B', width between first premolars; C-C', width between second premolars; D-D', intermolar width.

Figure 4
Arch depth, midline measurement from A to B.

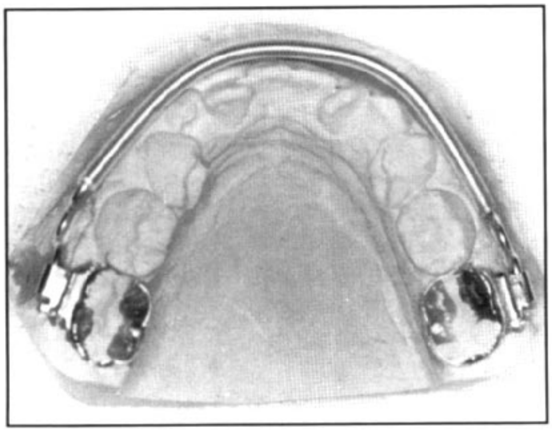

Figure 1

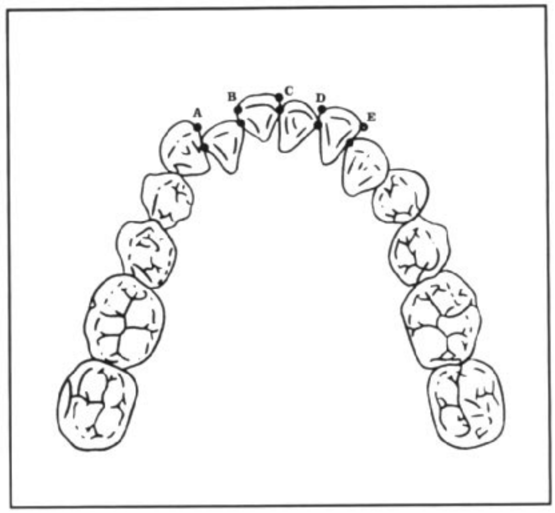

Figure 2

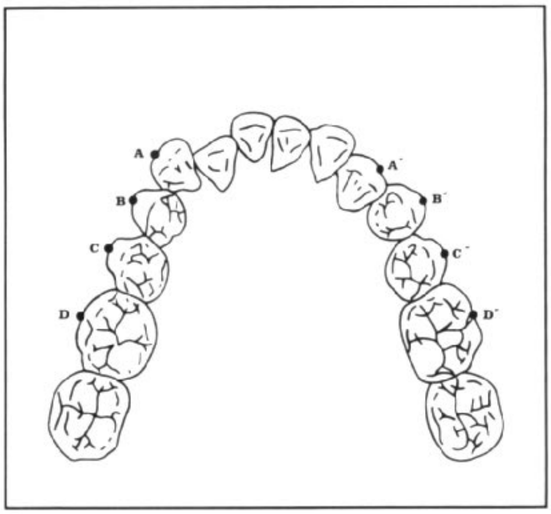

Figure 3

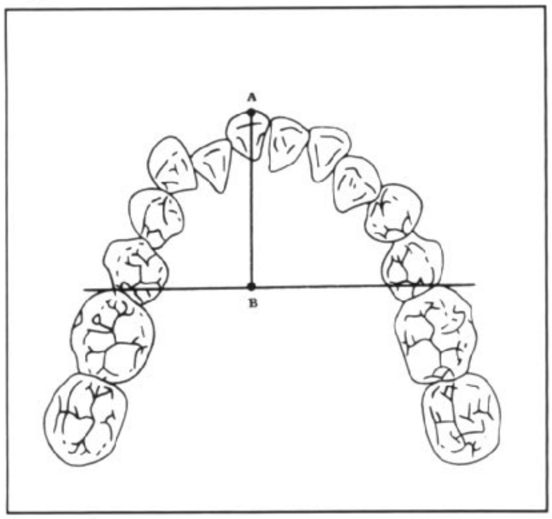

Figure 4

posttreatment stability of results obtained with the lip bumper followed by fixed mechanotherapy.

Material and methods

Full-mouth dental study models and standardized lateral cephalograms of 32 patients were obtained from one orthodontist who uses the lip bumper as a conventional approach to enhance lower anterior tooth alignment in the early phase of comprehensive orthodontic therapy. All cases were in the mixed dentition stage of development, with no second molars erupted. Each patient had either a skeletal and dental Class I or II sagittal relationship with normal vertical dimensions. No patients had obvious skeletal or dental asymmetries, as determined by clinical evaluation. Each had 4 to 8 mm of crowding in the lower incisor region. Patients received various treatment procedures in the maxillary arch, including headgear and transpalatal arches. The maxillary transpalatal arches were adjusted to control rotation of the maxillary first molars and, in some cases, for expansion.

The lip bumpers (Figure 1) were constructed on casts prior to cementation of bands. They were constructed with 0.045-inch blue Elgiloy® wire covered with shrink tubing. Each lip bumper was fabricated in the laboratory with approximately 2 mm of clearance to the lower incisors and adjusted to approximately the gingival third of the lower incisors. Final adjustments were made mesial to the first molars at chairside. The lip bumpers were expanded so the terminal end of the wire was passive to the buccal tubes prior to engagement. Adjustments were made throughout the lip bumper phase of treatment to maintain lateral expansion and 2 to 3 mm of clearance from the lower incisors.

Mean treatment time with the lip bumper phase was 2.0 years (Table 1). Due to variation in severity of the cases, treatment ranged from 0.3 years to 4.3 years. Full-banded mechanotherapy was per-

Table 1
Age characteristics of the sample (n = 32)

Start of Treatment	
Mean Age (yrs)	9.9
SD	1.33
Minimum	7.1
Maximum	13.0
End of Treatment	
Mean Age	11.9
SD	1.25
Minimum	9.7
Maximum	14.5
Duration of Treatment	
Mean Time	2.0
SD	1.01
Minimum	0.3
Maximum	4.3

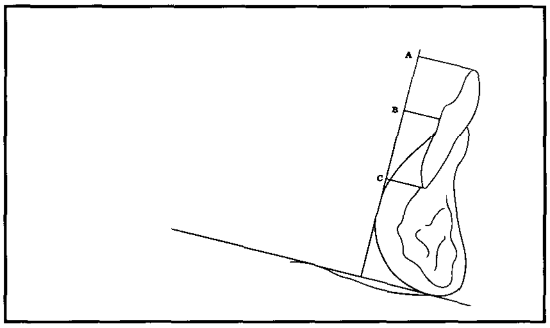

Figure 5

Figure 5
Distance of the mandibular central incisor to a line tangent of the symphyseal cortical plate and perpendicular to the mandibular plane. Three distances were recorded to assess angular and bodily changes: distance to the incisal edge (A); distance to midpoint (B); distance to apex (C).

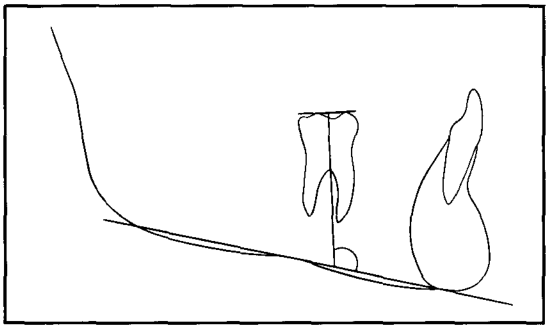

Figure 6

Figure 6
Angulation of the mandibular molar to the mandibular plane (q) was measured from the lateral cephalogram.

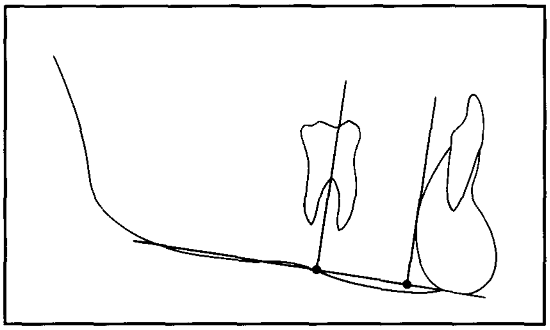

Figure 7

Figure 7
Method of measuring bodily movement of first molars.

formed on each case after the lip bumper phase. Dental study models of nine of these cases were obtained two years after the completion of active treatment. These were analyzed to quantitate the degree of stability over time. Each patient had been given a pressure-formed, clear plastic slip-on retainer at debanding with instructions to wear the retainer at night and a minimum of two hours per day. However, no assessment of compliance was made on the follow-up cases and fixed retention appliances were not used.

Cast analysis. Incisor irregularity was assessed with the method of Little.[12,13] Irregularity is the sum of the five distances between the anatomic tooth contact points from canine to canine measured parallel with the occlusal plane (Figure 2). These distances incorporate several types of irregularities, namely linguoversion, labioversion, displacement, and rotation. In proper occlusion, the anatomic contacts of adjacent teeth should abut one another; the greater the irregularity, the greater the divergences between contacts.

Mandibular arch widths were measured with sliding calipers (to the nearest 0.1 mm) across the canines, first and second premolars, and permanent first molars (Figure 3). For the canines, arch width was measured from the cusp tip of one canine to that of the contralateral canine[14] and from the buccal gingival margin between the most prominent portions of the canines. Comparison of these cusp and gingival widths gives an idea of whether the canines were moved bodily versus crown tipping.[15] The deciduous canines were present in the pretreatment casts in most cases. Arch width across the premolars (4-4 and 5-5) was assessed in the pretreatment casts at the level of the deciduous first and second molars. Measurements were made from the buccal gingival margin at the most prominent portion of one tooth to the same point on the contralateral tooth. Intermolar width was measured from the buccogingival margin at the buccal groove of one molar to the homologous point on the contralateral molar.

Arch depth was measured as described by Moyers.[16] A brass wire was placed in the contact points of one first molar to the mesial contact point of the contralateral tooth. One beak of the caliper was placed on the incisal edge of the most anterior incisor and the other beak distal of and perpendicular to the brass wire (Figure 4).

Cephalometric analysis. Measurements from the lateral cephalograms assessed incisor and molar positions before and after lip bumper

Table 2
In-treatment changes assessed from the mandibular dental cast and cephalometric analysis.

Variable	n	Mean change⁺	SD	Paired t-test
Cast Analysis				
Arch Width				
3-3 at Cusp Tips	26	1.56	1.78	4.5**
3-3 at Buccal Surfaces	25	2.06	1.43	7.2**
4-4	30	4.12	1.67	13.5**
5-5	30	1.60	1.48	5.9**
6-6	33	1.00	1.63	3.5**
Arch Depth	33	0.21	1.45	0.8
Incisor Irregularity	29	-3.83	3.20	6.4**
Cephalometric Analysis				
IMPA (degrees)	31	2.40	4.43	3.0**
1L at Incisal Edge	31	0.15	1.44	0.6
1L at Midpoint	31	-0.02	1.15	0.0
1L at Apex	31	-1.05	1.48	3.9**
6L Angle	31	4.11	5.32	4.3**
6L Distance	31	-0.55	1.54	2.0

⁺Post-minus-pretreatment change, so positive values are increases.
* P < 0.05
** P < 0.01

therapy. Where right and left images of the mandibular first molars and incisors were present, an effort was made to trace the images of the right side. Lower incisor angulation was measured as the angle formed by the long axis of the incisor to the mandibular plane (IMPA).[17] Bodily movement was measured as the distance from the reference plane constructed tangent to the posterior margin of the symphysis and perpendicular to the mandibular plane. Distances from this plane to the apex, to the midpoint between the incisal edge and apex, and to the incisal edge were measured (Figure 5).

A plane tangent to the occlusal surface of the first molar was constructed, and a perpendicular line was drawn passing through the furcation. The superior-anterior angle was measured to assess molar angulation (Figure 6). A second reference point was constructed by forming a tangent to the posterior portion of the symphysis and perpendicular to the mandibular plane. The distance between these two reference points along the mandibular plane was the bodily movement of the molar (Figure 7).

Cephalometric superimposition was employed to confirm the overall changes in molar and incisor positions. The bony landmarks described by Björk[18,19] as areas of minimal remodeling were used as reference points (i.e., inferior lingual surface of the mandibular symphysis and the outline of the inferior alveolar canal).

Paired t-tests were used to assess whether differences pre- to posttreatment achieved statistical significance (alpha = 0.05; two-tail).[20]

Repeatability accuracy was calculated as the "estimate reliability."[21] Estimate reliability is the variance of the true measures in the population (of which the samples in the study represent a random sample) in relation to the total variance. In other words, the value is the variance among measurements due to true differences divided by this value plus the variance due to the mean of the errors of measurement. Estimate reliability—within the context of the variance-component model of the analysis of variance—represents the intraclass correlation between the pairs of repeated measurements. All variables in the present study had intraclass correlations exceeding 0.96. The variable measured most consistently was intercanine width; the least accurate was position of the mandibular incisor root apex.

Results

Statistical results are listed in Table 2. There were highly significant increases in arch width at the canine, premolar and molar regions. Arch widths increased to highly significant degrees (P < 0.01) throughout the arch, but most notably at the second premolars, where the average expansion was 4.1 mm. In contrast, arch depth did not change, so the arch form became broader both in form and absolutely—which increased arch perimeter. The significant decrease in incisor irregularity also reflects this increase in arch perimeter. On average, incisor irregularity reduced 3.8 mm (i.e., a 56% reduction).

It was of interest whether the increases in arch width occurred predominately by bodily movement or crown tipping. Intercanine width measured between cusp tips incorporates both tipping and translation, while change at the gingival margin is more reflective of bodily movement. The difference, assessed from a repeated measures analysis of variance[21] was significant (P = 0.04). Gingival width ($\bar{x}$ = 2.1 mm) increased more than at the cusp tips ($\bar{x}$ = 1.5 mm), indicating that the canines were tipping and translating — but the roots were being displaced laterally even more than the crowns (i.e. the canines expanded and uprighted during treatment).

Incisor irregularity seems to have been dissipated by a combination of two factors. One, intercanine width increased, which provided the incisors more room to align and, two, the reduction of lip pressure afforded by the lip bumper allowed the incisors to procline, thereby increasing arch perimeter in this region. This latter effect is known to have occurred because IMPA increased significantly, 2.4° on the average. Changes in position of the mandibular central incisor were measured at the crown, mid-tooth, and apex to gauge the nature of the change. A repeated-measures ANOVA was highly significant (P < 0.01) between these three measures, and the difference was due to the greater lingual movement of the root apex ($\bar{x}$ = 1.2. mm) compared to the minor labial movement of the crown($\bar{x}$ = 0.1 mm).

Position of the mandibular first molar also changed with lip bumper therapy. The amount of mesiodistal repositioning ($\bar{x}$ = -0.6 mm) was suggestive (P = 0.06) and the change in axial inclination($\bar{x}$ = 4.1° of uprighting) was highly significant.

The lip bumper was not used for a set length of time; instead, it was kept in place until as much of the desired correction could be achieved. Intuitively, this should result in weak correlations between duration of treatment and amount of change. Indeed, this was the case. None of the 13 variables had a significant association with time in treatment.

Posttreatment stability. A subset of the cases was recalled two years after completion of the active phase of treatment. Although the "posttreatment" changes incorporate the orthodontic corrections following the lip-bumper phase, it can be seen that all of the changes are favorable (Table 3). Intercanine width further increased significantly, which corresponds to the further significant reduction in incisor irregularity. At recall there was, on average, just 0.3 mm of irregularity. Width across the first premolars increased about one millimeter after lip bumper therapy. Arch widths at the second premolar and first molar also increased, though not systematically (P > 0.05).

Table 3
Changes in arch dimensions following the lip-bumper phase of treatment+

Mean Variable	n	Paired change++	SD	t-test
Arch Width				
3-3 at Cusp Tips	9	0.96	1.16	2.5*
3-3 at Buccal Surfaces	9	2.38	1.26	5.7**
4-4	9	0.83	1.01	2.5*
5-5	8	0.55	0.98	1.7
6-6	9	1.07	2.11	1.5
Incisor Irregularity	9	-2.42	1.46	5.0**
Arch Depth	9	-1.76	1.32	4.0**

+This combines changes due to banded orthodontic therapy and a two-year posttreatment period.
++Post- minus-pretreatment change, so positive values are increases.
* P < 0.05
** P < 0.01

Discussion

The lip bumper—as an adjunct to full-banded treatment—can provide important treatment advantages. It broadens the arch, thus increasing arch perimeter and decreasing tooth-size/arch-size discrepancy. Noteworthy dental changes consist of (1) increases in arch width—evidently by bodily movement rather than tipping—and (2) decreases in incisor irregularity.

The present study differs from others[10,11] in the following ways:

1) The orthodontist used the lip bumper in the early mixed dentition stage of dental development so there were no cases in which the second molars had erupted.

2) A single, experienced orthodontist designed all appliances and treated all cases.

3) The orthodontist used a single type of lip bumper.

The contention that this appliance increases arch depth was not borne out by these data (Table 2). While there was a significant change in axial inclination of the mandibular first molar (ca. 4° of uprighting), there was no systematic change in length of the arch. Johnston[22] has shown that a 4° change in molar angulation converts to a millimetric change in molar position of 0.7 mm, which is close to the 0.6 mm observed in this study. On the other hand, this change was sufficiently variable among patients that it did not achieve statistical significance (P = 0.06). These findings augment those of Nevant et al.[10] who likewise found no distal movement of the mandibular molar with this kind of lip bumper, though, as here, the molar did upright with the center of rotation near the crown. In contrast, lip bumpers fitted with acrylic shields on the labial wire evidently do drive the mandibular molars distally,[1,4,10,11] probably because of the greater surface area of the bumper against the mentalis musculature.

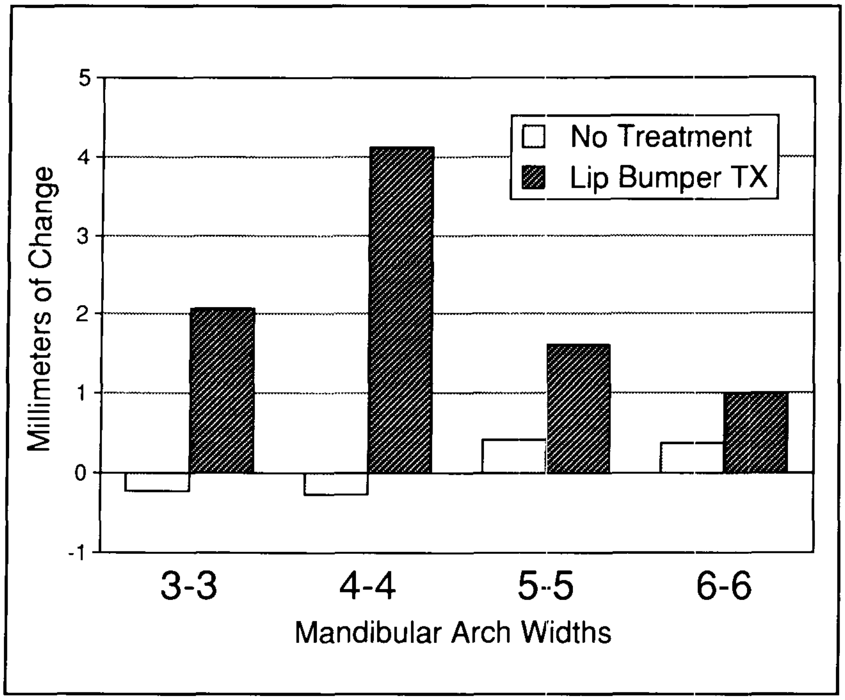

Figure 8

Figure 8
Histogram contrasting the differences in average arch expansion seen with the lip bumper against those predicted in the absence of treatment (i.e., growth alone).

Subtelny and Sakuda[4] and Bergersen[7] each found that the mandibular first molar uprighted and/or moved distally, apparently from the lip musculature's pressure on the labial bow. Bergersen reported a significant correlation between the duration of lip bumper therapy and the amount of distal movement. Nevant and coworkers[10] provided the important distinction that distal movement of the molar—which typically is undesirable since it worsens the sagittal molar relationship—depends on appliance design. Lip bumpers with an acrylic shield processed onto the labial bow do indeed drive the molar distally (apparently because of the greater surface contact with the lip musculature), but the appliance without a shield does not. This led Bergersen to label the lip bumper an "anchorage protection device," particularly when used in conjunction with Class II elastics in subsequent phases of treatment.

In the present study, only four cases exhibited distal molar movement, and all of these changed less than 1.5 mm. Most cases (18/31) showed no change during treatment. The other nine cases moved mesially during treatment, to a maximum of 4 mm. Inspection of the extreme cases showed that they were the ones with the greatest leeway space, and the mandibular molar drifted forward to close the space created by exfoliation of the deciduous buccal teeth.

Increases in arch perimeter in the anterior segment were accomplished by expansion of the canines and proclination of the incisors (IMPA increased significantly). Importantly, though, the incisors were not "dumped" forward into an unstable position; the crowns were retained over basal bone and the increase in IMPA was achieved by rotating the roots lingually. This is beneficial since it allows the roots to move into the center of the alveolar trough, but the reason for the phenomenon remains unclear. Similarly, the increase in intercanine width occurred to a large extent by uprighting these teeth; that is, the gingival width increased significantly more than that between the cusp tips, suggesting that the canines were transposed buccally under influence of the appliance while also becoming more upright.

Increases in arch width also took place in the buccal segments. The first premolars experienced the greatest increase with the second premolars and the molars showing lesser increases. Increase in premolar width may be explained by greater buccal eruption of the premolars due to elimination of cheek pressures.[15,23] Expansion in the molar region was primarily due to buccolingual uprighting or correction of root torque. Molar expansion also is due to the fact that archwire was expanded and, upon engagement, exerted an expansive force on the molars.

On the other hand, arch widths change during the transitional dentition even in the absence of treatment, primarily because the permanent teeth erupt at somewhat different positions than their deciduous counterparts and drift mesially with time.[24-29] Figure 8 compares the observed increases in arch width with the lip bumper against two-year increments tabulated by Moorrees[25] over the average age interval of the present study (ages 10 to 12, sexes pooled). In each instance, increases in the treated cases are several-fold greater than expected in the absence of therapy.

Incisor irregularity averaged 6.8 mm at the start of treatment and was reduced 56% – to 3.0 mm – when the lip bumper was removed. This amount of correction compares very favorably with the trivial improvement (ca. 0.3 mm) expected during this age interval in the absence of treatment.[25] This guided decrease in the arch-size/tooth-size discrepancy in the anterior arch segment is one of the preeminent merits of lip bumper therapy. Following comprehensive treatment and a follow-up interval of two years, irregularity was trivial ($\bar{x}$ = 0.3 mm) at the recall examination. The incisor irregularity index decreased significantly (another 45% on average) from the lip bumper phase to posttreatment recall, indicating that the space gained in arch circumference was effectively used for tooth alignment.

A shortcoming of the present design is that we cannot distinguish postretention relapse from the orthodontic changes that occurred from the lip bumper phase of treatment. Still, the nature of the changes (Table 3) all are favorable and in directions predicted by subsequent mechanics. There was significant continued expansion, notably across the canines and first premolars. Arch depth decreased, probably during the full-banded phase of treatment. The decrease in arch depth can be attributed to molar settling and mesial migration of the molars due to loss of the deciduous second molars ("leeway space") and uprighting of the incisors. This incisor uprighting, along with a slight expansion of the intercanine width, may have resulted in regression of imbrication in the anterior segment.

Conclusions

This study evaluated the effects of lip bumper therapy on the mandibular arch. Several conclusions can be drawn:

1) The lip bumper can be used effectively to obtain expansion and decreased incisor irregularity in the mandibular arch.

2) The lip bumper, as adjusted in the present study, did not flare the lower incisor in the conventional sense.

3) The lip bumper caused the lower permanent molars to upright rather than to move bodily.

Acknowledgments

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Commentary: Skeletal changes accruing from the lip bumper

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When I read this manuscript for the first time an intriguing thought crossed my mind: many of us use lip bumpers – some use them often – yet we know so little about how they really work. Very little has been written about lip bumpers, and most of that is in the form of anecdotal reports that have not been exposed to scientific scrutiny. There are, perhaps, a half dozen or so clinicians who consistently claim to obtain excellent results; some exceptionally skilled or dedicated even show their superb results from using lip bumpers. But for most of us ordinary mortals and clinical orthodontists, lip bumpers are largely a hit or miss proposition. Sometimes they appear to help, other times they appear to be totally ineffective, and there is no reliable way to predict the results for particular patients.

Long before this manuscript was written, in my capacity as a Postgraduate Program Director, I attempted to resolve some of the uncertainty regarding lip bumper use by initiating a longitudinal study. From the beginning, our ambitions as researchers were greater than our ability to control the sample. Our prospective study was compromised with a mix of retrospective cases but even at that we fell short of our stated sample size goal. By the end of the predetermined time period, our sample had shrunk even further. What a humbling experience! From an initial group of over 100 "carefully selected" (to control for all sorts of variables) cases, we concluded the study two years later with barely 20 useful, documented cases.

Results from our meager sample were not very different from those of the current study. In broad brushstrokes, we concluded that changes in anterior teeth were a bit more consistent than distal movement of the molars. Overall changes were not clinically significant because we had predetermined parameters or magnitudes of changes. This, of course, should be clearly differentiated by the reader, because the statistical significance is a function of sample size and is influenced by it more than by any other characteristic of the sample.

My own experience studying lip bumpers has helped me better appreciate the present authors' report. Their sample size, 32 cases, is more impressive than it may appear on the surface. They exercised good quality control in the construction of the appliance and activation was accomplished by a single individual. These steps contribute to a significant reduction in the "background noise" of such research. In other words, the observed results can be viewed and interpreted with more confidence.

Let us look at and read between the lines of the presented materials. Sophisticated readers are always interested in information about the sample characteristics. Table 1, together with the description of materials, gives an excellent overview of the sample used in the study. A majority of the patients were about 10 years old at the beginning of lip bumper treatment, and 12 years old at the end of treatment. Standard deviation of age at both the beginning and end of treatment was approximately 10% of the mean while the stated ranges correspond quite well with what might be encountered in an orthodontic office. A similar observation could be made for the duration of treatment.

The authors reported some interesting results and I would like to bring into sharper focus two changes from the cast analysis and two from the cephalometric analysis. First, arch depth increased 0.21 mm, with a variability expressed as a standard deviation of 1.45. In its most basic interpretation, this indicates that in about 70% of the sample (20 individuals) arch depth changed from -1.24 to +1.66 mm. By the same statistical reasoning it could also be speculated that there were two or three individuals in which the change was more than two standard deviations – a decrease of 3 mm or an increase of 3 to 4 mm. This is no longer insignificant clinically because this would likely help the clinician decide on an extraction versus a nonextraction treatment plan. It is equally intriguing to speculate why there was such a variability, in spite of what appeared to be a normally distributed sample, with many nondiscriminate variables well controlled.

The incisor irregularity index predictably decreased, shown both by the statistical significance and by the clinical impressions. Yet it should be understood that there were some cases in which the irregularity did not change or, perhaps, even became a bit worse. This should be offset by recognizing that in some cases a terrific improvement must have taken place. Given the stated conditions of the study, one may again ask: why?

Cephalometrically, it was interestiong to observe that the variability of mandibular incisor position (IMPA) was as prominently present as it has been reported in many other studies. One cannot escape the conclusion that, no matter which appliance, philosophy or protocol we follow, we cannot predictably affect the IMPA. Looking further into incisal changes during the lip bumper therapy, one observes that when we look at an incisor as if it were an axis, its mid point hardly moves at all while its incisal edges and apical area move in opposite directions by almost like amounts. Why would the apices move lingually when the appliance purports a flaring tooth movement, presumably by the labially directed tongue pressue in absence of the balancing lip pressure in lingual direction.?

An additional "pearl" of the study is the compiliation of a two-year posttreatment measurement for a smaller group of cases (n=9). There were no real surprises in this subsample and one could say that the treatment changes were somewhat reduced. Such changes are generally expected and we simply call them relapse. It is interesting, however, that the arch depth collapses slightly, together with a decrease in improvement of incisor irregularity. A few wise people, students of posttreatment and postretention cases, would undoubtedly comment that they expected such a relapse, regardless of the appliance or techniqe used.

Many years ago during one of his lectures, Alton Moore held in his hands a set of study cases of a severe malocclusion. He was discussing what would happen to the case if treated one way versus another. He asked the audience to describe how the case would look if it were treated by the group's favored approach. He then lifted the casts over his head and said: "Look at this. This is what it will eventually come back to. If we are lucky, maybe not quite as much!" It appears that our clinical successes with lip bumpers do not escape this prophecy. Scott Werner and coworkers at least gave us a window in which one group of lip bumpers could be observed.

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