

Lower arch perimeter preservation using the lingual arch

Joe Rebellato, DDS,^a Steven J. Lindauer, DMD, MS,^b Loretta K. Rubenstein, DDS,^c
Robert J. Isaacson, DDS, MS, PhD,^d Moshe Davidovitch, DDS, MMSc,^e and
Katherine Vroom, DDS^f

Richmond and Arlington, Va., and Tel-Aviv, Israel

The purpose of this investigation was to determine whether the placement of a mandibular lingual arch maintained arch perimeter in the transition from the mixed to the permanent dentition, and if so, whether it was effective at preventing mesial migration of first permanent molars, or whether this migration still occurred en masse, by increased lower incisor proclination. Thirty patients were randomly assigned to either a treatment group ($N = 14$, mean age = 11.5 years) or a control group ($N = 16$, mean age = 11.3 years). Study models, cephalograms, and tomograms of the patients, taken at the beginning and at the end of the study period, were examined. Statistically significant differences between groups were found for positional changes of mandibular first molars and incisors, and changes in arch dimensions. The results indicate that the lingual arch can help reduce arch perimeter loss, but at the expense of slight mandibular incisor proclination. (*Am J Orthod Dentofac Orthod* 1997;112:449-56.)

Dental crowding is the most common reason that patients seek orthodontic treatment. It occurs when the dental arch perimeter between the first permanent molars is insufficient to permit alignment of the erupting permanent teeth. Spontaneous increases in arch perimeter are not expected after the eruption of the first permanent molars. Decreases in arch perimeter from the mixed to the permanent dentition may occur because of mesial migration of the first permanent molars or lingual movement of the incisors.

An arch perimeter holding device, placed before normal exfoliation of the deciduous second molars, could potentially prevent mesial migration of the first permanent molars.¹⁻³ This might be indicated when crowding is present anteriorly and sufficient leeway space exists in the arch for alignment of the permanent

teeth. Theoretically, arch perimeter is preserved and the leeway space is available to decrease the severity of the crowding problem present. The lingual arch is a commonly used space maintenance appliance, thought to maintain arch perimeter by preventing mesial tipping or drift of mandibular molars. The molar positions are stabilized against the mandibular incisors by the appliance, which also prevents the incisors from tipping lingually.³

Previous studies have shown that, without space maintenance, arch perimeter is reduced after deciduous tooth loss and transition from the mixed to the permanent dentition.⁴⁻¹² It has been suggested that a lingual arch maintains arch perimeter, but that this occurs by labial movement of lower incisors as the molars migrate mesially.^{13,14} If this occurs, all mandibular teeth would migrate anteriorly as a unit while maintaining the same arch perimeter. If the lingual arch maintains arch perimeter by this mechanism, the benefit as an early treatment appliance is questionable.

The purpose of this investigation was to determine whether placement of a lingual arch could: (1) reduce dental crowding during the normal transition from the mixed to the permanent dentition, and (2) prevent the expected mesial migration of first permanent molars, or whether this migration still occurs en masse, by increased lower incisor proclination.

MATERIALS AND METHODS

Thirty patients were selected to participate in this prospective study, according to the following criteria:

This research was supported by USPHS Research Grant 1 R03 DE10002-1 from the National Institute of Dental Research, National Institutes of Health, Bethesda, Md.

^aAssistant Professor, Department of Orthodontics, Medical College of Virginia, Virginia Commonwealth University.

^bAssociate Professor, Department of Orthodontics, Medical College of Virginia, Virginia Commonwealth University.

^cAssociate Clinical Professor, Department of Orthodontics, Medical College of Virginia, Virginia Commonwealth University.

^dChairman, Department of Orthodontics, Medical College of Virginia, Virginia Commonwealth University.

^eAssistant Professor, Department of Orthodontics, University of Tel-Aviv. ^fIn private practice, Arlington, Va.

Reprint requests to: Dr. Joe Rebellato, MCV/VCU Department of Orthodontics, 520 N. 12th St., PO Box 980 566, Richmond, VA 23298-0566.

Copyright © 1997 by the American Association of Orthodontists.
0889-5406/97/\$5.00 + 0 8/1/75940

(1) Both mandibular second deciduous molars were present with some clinical mobility, (2) mandibular crowding was 3 mm or more, (3) permanent molar relationships were end-on to Class I (end-on molars would have flush mesial planes and Class I mandibular molars were up to 4 mm mesial of flush mesial plane¹⁵), (4) overbite was 1 mm or greater, (5) mandibular plane inclination was average (MP-SN) of $32^\circ \pm 6^\circ$, and (6) the lower lip was less than 4 mm ahead of Rickett's E line.¹⁶ Informed consent was obtained from all parents or legal guardians.

Patients were excluded from the study if they had any congenitally or prematurely missing teeth. Only European American patients were selected, because ethnic differences in mean skeletal patterns^{17,18} and mean differences in arch length and tooth sizes between European Americans and African Americans¹⁹ have been reported.

Subjects were randomly assigned to two groups. The treatment group contained 14 patients (mean age = 11.5 years; mean follow-up period = 10.5 months) and had only mandibular lingual arch appliances placed. The lingual arch appliance used in the treatment group was a passive 0.032-inch stainless steel wire, which contacted the cingulae of the lower incisors. The control group contained 16 patients (mean age = 11.3 years; mean follow-up period = 12.5 months) who received no treatment and served as controls. All patients were observed at least monthly.

Records for this study consisted of one baseline cephalometric radiograph, one tomographic radiograph of the randomly selected left or right buccal segment, and study models. One trained technician exposed all radiographs on a Quint Sectograph Cephalometer (Denar Corporation, Anaheim, Calif.). Patients were shielded with lead aprons and thyroid collars. All films were obtained with rare earth screens and collimation where appropriate.

Records were repeated after both mandibular premolars were at least 90% erupted. The 90% eruption was defined as the distal marginal ridge of the premolar being within 1 mm of the mesial marginal ridge of the first permanent molar. In this time, eruption of the premolars and most of space loss were expected to have occurred.^{8,9,20,21}

Mandibular structures in both the cephalometric and tomographic films were superimposed by using Björk's structural superimposition method.²²⁻²⁴ Changes in tooth position were measured at the center of resistance (C_{Res}) of the incisors and molars, at the incisal edge of the mandibular central incisors, and at the cusp tip of the molar in one quadrant of the mandibular arch. The cusp tip of the molar was defined at the mesiobuccal cusp of the mandibular first molars. The C_{Res} was placed arbitrarily at the bifurcation of

molar roots and a point a third of the root length apical to the alveolus in the incisor teeth.²⁵

The C_{Res} , incisal edge, and cusp tip were identified on the original films and transferred to the follow-up films by superimposing a tooth on itself. Changes in tooth position between the initial and follow-up films were measured relative to the functional occlusal plane (FOP). The FOP was also transferred forward, based on superimposition of the mandible on itself. The FOP was drawn as a line bisecting the occlusal contacts of the maxillary and mandibular teeth with the teeth in occlusion. Mesial or extrusive movements of the incisal edge, cusp tip, or C_{Res} points were recorded as positive values; distal or intrusive movements were negative values.

Rotational tooth movements were measured by using a best fit long axis drawn through the C_{Res} of the incisors and molars. Angular changes in the long axes from initial to follow-up films were recorded in degrees relative to the FOP. The long axis of each tooth was transferred forward by superimposing on the tooth itself. Crown-mesial/root-distal rotations of the molars and crown-facial/root-lingual rotations of the incisors were recorded as positive values.

Changes in intermolar width, arch depth, and total arch length were measured on study models. Mesial migration of molars or lingual tipping of incisors would result in a decrease in arch depth and total arch length. Total arch length was measured as the sum of the distances between the mesial contacts of the first permanent molars to the contact between the central incisors on both the left and right sides of the arch.¹³ Distances were measured to the nearest 0.02 mm. Intermolar width was measured as the shortest distance between the mesiobuccal cusp tips of contralateral molars.^{26,27} Arch depth was the distance from a point bisecting the mesial anatomic contact points of the first permanent molars to the contact point of the central incisors.²⁸

All measurements were performed at the completion of the study to ensure uniformity of the measurement technique. The presence of the lingual arches prevented totally blind measurements, so a technician unfamiliar with the study made the measurements.

Measurements of changes in total arch length, arch depth, arch width, and molar and incisor positions were compared between the treatment and control groups. Multivariate Analysis of Variance (MANOVA) was used to test the null hypothesis that there were no differences in changes between the two groups. The null hypothesis would be rejected at a level of significance of ≤ 0.05 .

RESULTS

Fig. 1 shows the mean changes in the mandibular molar position during the study period, as measured

Lower Molar Mean Changes During Study Period (Tomographic Radiographs)

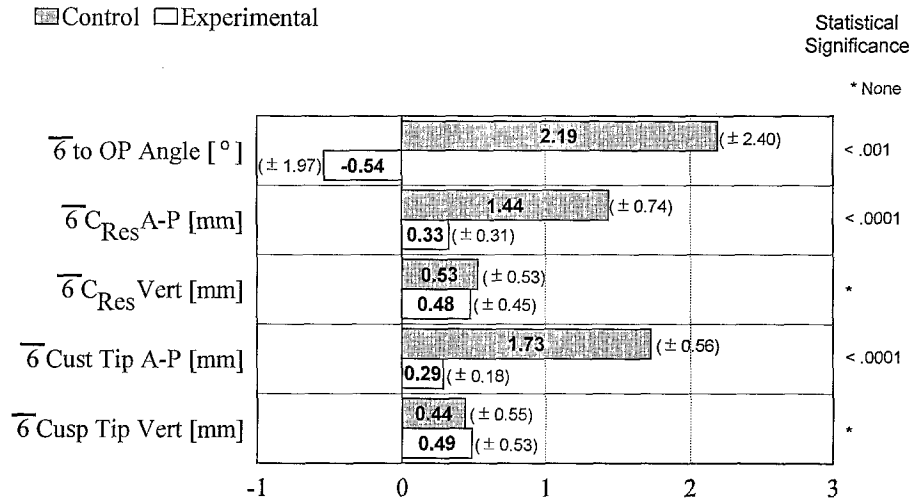


Fig. 1. Angular, vertical, and anteroposterior changes in lower molar position during study period as measured from tomograms (mean values ± standard deviations).

Lower Incisor Mean Changes During Study Period (Cephalometric Radiographs)

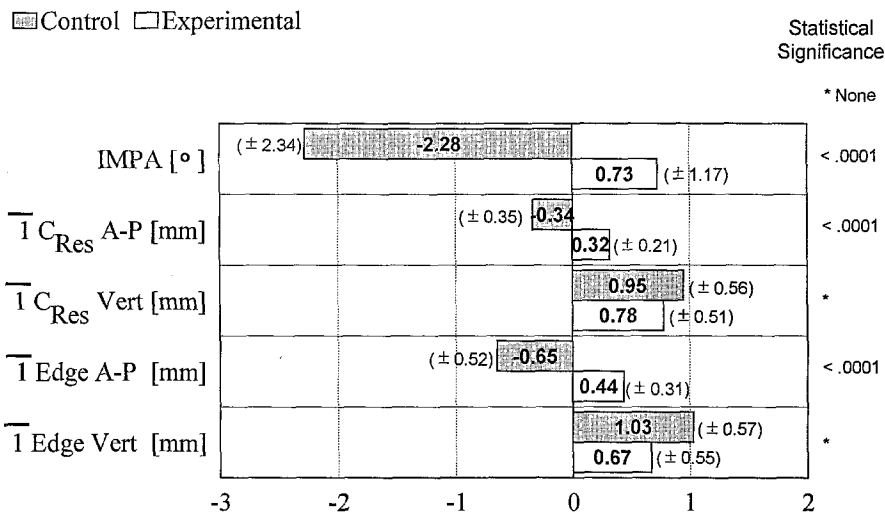


Fig. 2. Angular, vertical, and anteroposterior changes in lower incisor position during study period as measured from cephalometric radiographs (mean values ± standard deviations).

Control Group

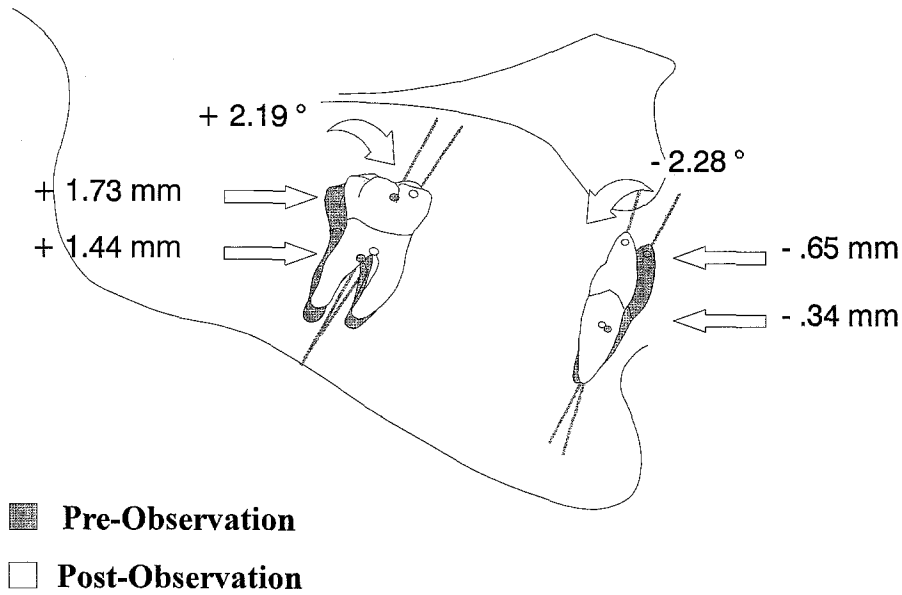


Fig. 3. Summary of positional changes of mandibular molars and incisors in control group that were significantly different ($p < 0.05$) from treatment group.

Treatment Group

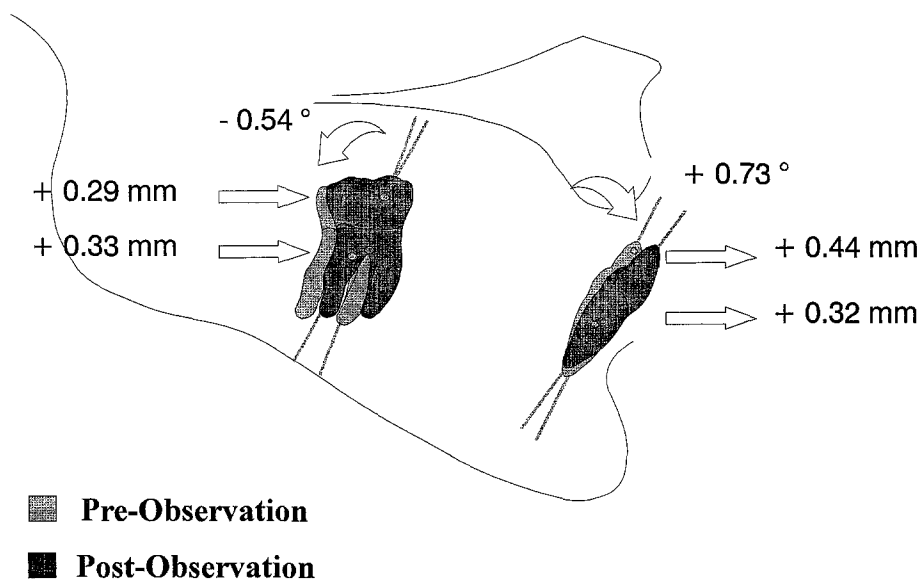


Fig. 4. Summary of positional changes of mandibular molars and incisors in treatment group that were significantly different ($p < 0.05$) from control group.

Control & Treatment Group

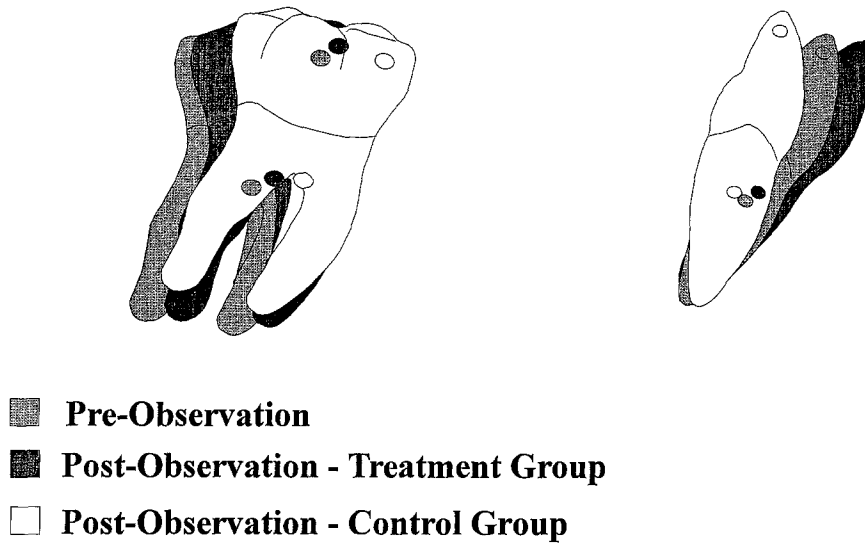


Fig. 5. Comparison of incisor and molar movements in both control and treatment groups, relative to preobservation tooth positions.

Lower Arch Mean Changes During Study Period (Study Models)

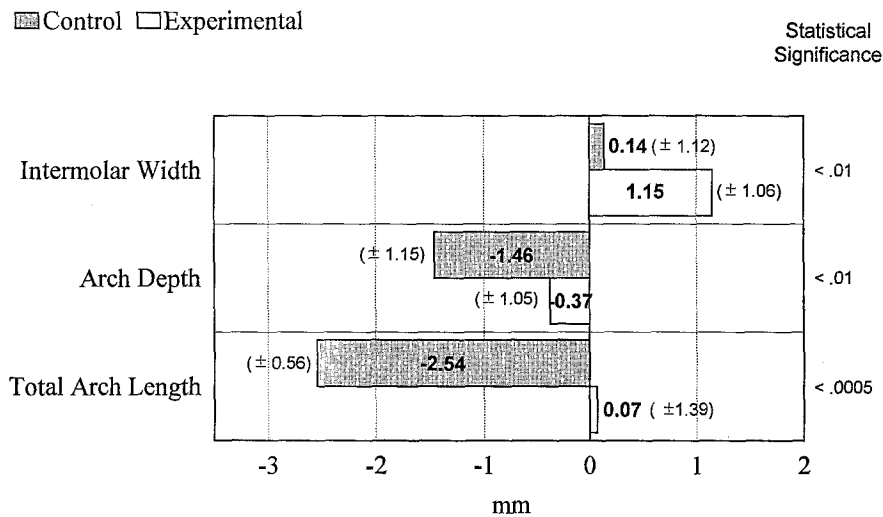


Fig. 6. Changes in arch dimensions during study period as measured from study models (mean values \pm standard deviations).

from the tomographs. In the control group, the molar tipped forward 2.19° , the C_{Res} came forward 1.44 mm, and the cusp tip came forward 1.73 mm. The measurements for the treatment group were -0.54° (backward tip), 0.33 mm, and 0.29 mm, respectively. The differences were all found to be statistically significant ($p < 0.001$). No significant differences were found in the vertical movements of either the C_{Res} or the cusp tip of the molars between the groups.

Fig. 2 shows the mean changes in the mandibular incisor positions during the study period, as measured from the cephalometric radiographs. In the control group, the incisor angulation change was -2.28° (backward tip), the C_{Res} came back 0.34 mm, and the incisal edge came back 0.65 mm. The data for the treatment group indicated 0.73° of forward tip of the incisor, 0.32 mm advancement of the C_{Res} , and 0.44 mm advancement of the incisal edge. These differences were all found to be statistically significant ($p < 0.0001$). No significant differences were found in the vertical movement of either the C_{Res} or the incisal edge of the central incisors between the groups.

Figs. 3 and 4 summarize the statistically significant differences between the treatment and control groups, as measured from the radiographs. Fig. 5 is a visual comparison of the incisor and molar movements in both the control and treatment groups, relative to the preobservation tooth positions.

Fig. 6 shows mean dimensional arch changes during the study period, as measured from the study models. All differences between the treatment group and the control group were found to be statistically significant ($p < 0.01$). Intermolar width increased by 1.15 mm in the treatment group, as compared with only 0.14 mm in the control group. Arch depth decreased by a lesser amount in the treatment group (0.37 mm) than in the control group (1.46 mm). A decrease in total arch length of 2.54 mm in the control group was found, whereas the treatment group actually had a slight increase of 0.07 mm.

DISCUSSION

Changes in arch dimension and tooth position were measured from study models and radiographs. Study model measurements can show intraarch space gain or loss, but are inadequate at detecting anterior or posterior movement of teeth relative to the mandible itself. Cephalometric radiographs

were used to record the sagittal movements of the central incisors relative to the mandible. Björk's natural reference structures were used as markers for superimposition.²²⁻²⁴ The tomographic cephalograms that recorded molar movements were also superimposed by using this technique, but had additional accuracy due to the increased detail visible, when overlapping anatomic structures are not present.

The purpose of this study was to determine whether the placement of a lingual arch before the loss of the deciduous second molars could prevent loss of arch perimeter during the transition to the permanent dentition. Conclusions regarding arch perimeter changes could be drawn from the data collected on movement of molars and incisors, and changes in intermolar width, arch depth, and total arch length. Arch perimeter was not measured directly because no technique has yet been described to obtain this measurement in an accurate and objective fashion.

The manner in which molar and incisor movements affect arch perimeter merits some discussion. Movement of the molar crowns in a mesiodistal direction can be easily conceptualized as affecting arch perimeter in a ratio of 1:1, i.e., a 1 mm mesial movement of a molar crown can lead to an arch perimeter decrease of 1 mm. If both molars are taken into account, a 2 mm decrease in arch perimeter could be anticipated. However, this interpretation does not necessarily apply to incisor movements. Germane et al.²⁹ used a mathematical model to demonstrate how a 1 mm facial movement of the incisors does not necessarily translate into a 1 mm gain per side for a net increase of 2 mm in arch perimeter. In fact, it was found that a 1 mm advancement of the incisors tended to result in an approximate total gain of 1 mm in arch perimeter. They also showed that a 1 mm increase in intermolar width only contributed approximately 0.27 mm to arch perimeter. In an individual patient, of course, arch perimeter is defined by a complex, three-dimensional interaction between location of interproximal contact points, tooth angulations, arch width and length, and curve of Spee.

If symmetrical movements are assumed to occur at contralateral molars, the data shown in Fig. 3 suggest that approximately 4 mm of total lower arch perimeter are lost during the exchange of deciduous second molars for second permanent

premolars. The loss appears to occur primarily by mesial movement of the first permanent molar into the leeway space. If the placement of a lingual arch prevents this event, the possibility exists that crowding could be reduced or eliminated with this procedure.

On the basis of the mean values shown in Figs. 3 and 4, the data support the idea that the lingual arch exerts its greatest effect by preventing the mesial migration of the first permanent molars after the second deciduous molar is exfoliated. It is clear, however, that this comes at the expense of slight mandibular incisor proclination. The long-term stability of this treatment outcome after the lingual arch is removed remains unsolved because rarely will a lingual arch be all the treatment that is needed in most cases.

Addressing the associated problem of interarch relations is also important. Does the mesial movement of the first permanent molar really allow a mixed dentition, flush terminal plane to become an Angle Class I occlusion? According to the findings of Bishara,⁸ this outcome is not as prevalent as is often believed. Only about half the flush terminal planes in his sample spontaneously became Class I with the loss of the second deciduous molar. The work of Björk and Skieller³⁰ with implants clearly shows that the upper dentition can migrate mesially with the lower dentition, leaving the interarch dental relationships virtually unchanged.

Thus the problem of alleviating crowding in the mixed dentition by placement of a lingual arch may only alter the form that the malocclusion manifests. Some lingual arch patients could conceivably stay Class II with reduced crowding. Left untreated, they may have been more crowded, but they may also have become Class I. There has been little reported on the interactive component of interarch relations concurrent with leeway space management for crowding. Flush terminal plane dentitions therefore might benefit from some form of orthodontic treatment, in addition to the placement of a lingual arch. The lingual arch would be used to alleviate crowding while other concurrent, or subsequent, treatment would be instituted to achieve a Class I relationship.

Results from this study show that mandibular lingual arches can help to reduce the arch perimeter loss that occurs during the transition from the mixed to the permanent dentition. However, it does come at the expense of slight mandibular incisor proclina-

tion and anterior movement of the C_{Res} of the lower incisors. If these are not favorable side effects, other treatment modalities may need to be used to achieve the desired results.

CONCLUSION

This study was designed to examine the effects of mechanical intervention on mandibular first permanent molar mesial migration during the development of the late mixed and early permanent dentition. The results of the study suggest that passive lower lingual arches are effective at reducing the mesial molar migration and subsequent loss of arch length occurring in the transition from the late mixed dentition to the early permanent dentition. This comes at the expense of slight mandibular incisor advancement and tipping, which may or may not be desirable, depending on ultimate treatment goals.

REFERENCES

1. Ghafari J. Early treatment of dental arch problems: I. space maintenance, space regaining. *Quint Int* 1986;17:423-52.
2. Proffit WR. *Contemporary orthodontics*. 2nd ed. St Louis: CV Mosby; 1993.
3. Singer J. The effect of the passive lingual archwire on the lower denture. *Angle Orthod* 1974;44:146-55.
4. Baume LJ. Physiological tooth migration and its significance for the development of occlusion. *J Dent Res* 1950;29:331-7.
5. McDonald RE, Avery DR. *Dentistry for the child and adolescent*. 3rd ed. St Louis: CV Mosby; 1978.
6. Brauer JC. A report of 113 early of premature extractions of primary molars and the incidence of closure of space. *ASDC J Dent Child* 1941;8:222-4.
7. Seward FS. Natural closure of deciduous molar extraction spaces. *Angle Orthod* 1958;35:85-94.
8. Richardson ME. The relationship between the relative amount of space present in the deciduous dental arch and the rate and degree of space closure subsequent to the extraction of a deciduous molar. *Dent Pract* 1965;16:11-8.
9. Northway WM, Wainright RL, Demirjian A. Effects of premature loss of deciduous molars. *Angle Orthod* 1984;54:295-329.
10. Clinch LM. A longitudinal study of the results of premature extraction of deciduous teeth between 3-4 and 13-14 years of age. *Dent Pract* 1959;IX:109-26.
11. Foster HR, Wylie WL. Arch length deficiency in the mixed dentition. *Am J Orthod* 1958;44:464-76.
12. Davey KW. Effect of premature loss of primary molars on the anteroposterior position of maxillary first permanent molars and other maxillary teeth. *ASDC J Dent Child* 1967;34:383-94.
13. Nance HN. The limitations of orthodontic treatment: I, mixed dentition diagnosis and treatment. *Am J Orthod* 1947;33:177-223.
14. Nance HN. The limitations of orthodontic treatment: II, diagnosis and treatment in the permanent dentition. *Am J Orthod* 1947;33:253-301.
15. Bishara SE, Hoppens BJ, Jakobsen JR, Kohout FJ. Changes in the molar relationship between the deciduous and permanent dentitions: a longitudinal study. *Am J Orthod Dentofac Orthop* 1988;93:19-28.
16. Ricketts RM, Bench RW, Gugino CF, Hilgers JJ, Schulhof RJ. *Bioprogressive Therapy*. Denver: Rocky Mountain Orthodontics; 1979.
17. Cotton WN, Takano WS, Wong WW, Wylie WL. Downs analysis applied to three other ethnic groups. *Angle Orthod* 1951;21:213-20.
18. Enlow DH, Pfister C, Richardson E, Kuroda T. An analysis of black and caucasians' craniofacial patterns. *Angle Orthod* 1982;52:279-87.
19. Merz ML, Isaacson RJ, Germane N, Rubenstein LK. Tooth diameters and arch perimeters in a black and a white population. *Am J Orthod Dentofac Orthop* 1991;100:53-8.
20. Owen DG. The incidence and nature of space closure following the premature extraction of deciduous teeth: a literature survey. *Am J Orthod* 1971;59:37-49.
21. Giles NB, Meredith HV. Increase in intraoral height of selected permanent teeth during the quadrennium following gingival emergence. *Angle Orthod* 1963;33:195-206.

22. Björk A. Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method. *J Dent Res* 1963;42:400-11.
23. Cook PA, Southall PJ. The reliability of mandibular radiographic superimposition. *Br J Orthod* 1989;16:25-30.
24. Björk A. Prediction of mandibular growth rotation. *Am J Orthod* 1969;55:585-9.
25. Smith RJ, Burstone CJ. Mechanics of tooth movement. *Am J Orthod* 1984;85:294-307.
26. Burstone CE. A study of individual variation in mandibular bicanine dimension during growth. *Am J Orthod* 1952;38:848-65.
27. Cohen JT. Growth and development of the dental arches in children. *J Am Dent Assoc* 1940;27:1250-60.
28. Nevant CT, Buschang PH, Alexander RG, Steffen JM. Lip bumper therapy for gaining arch length. *Am J Orthod Dentofac Orthop* 1991;100:330-6.
29. Germane N, Lindauer SJ, Rubenstein LK, Revere JH, Isaacson RJ. Increase in arch perimeter due to orthodontic expansion. *Am J Orthod Dentofac Orthop* 1991;100:421-7.
30. Björk A, Skieller V. Facial development and tooth eruption: an implant study at the age of puberty. *Am J Orthod* 1972;62:339-83.

AVAILABILITY OF JOURNAL BACK ISSUES

As a service to our subscribers, copies of back issues of the *American Journal of Orthodontics and Dentofacial Orthopedics* for the preceding 5 years are maintained and are available for purchase from the publisher, Mosby-Year Book, Inc., at a cost of \$11.00 per issue. The following quantity discounts are available: 25% off on quantities of 12 to 23, and one third off on quantities of 24 or more. Please write to Mosby-Year Book, Inc., Subscription Services, 11830 Westline Industrial Dr., St. Louis, MO 63146-3318, or call (800)453-4351 or (314)453-4351 for information on availability of particular issues. If unavailable from the publisher, photocopies of complete issues are available from University Microfilms International, 300 N. Zeeb Rd., Ann Arbor, MI 48106 (313)761-4700.