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Mixed-Dentition Orthodontic Treatment: Outcomes and Timing

Kayhan L. Mashouf, DMD, MSD; Cameron K. Mashouf, DDS, MS; and Sean Laraway, PhD

ABSTRACT The efficacy of early orthodontic intervention has been debated for decades. There is a notion that treatment rendered in mixed dentition must be followed by another phase of treatment in permanent dentition. This study investigates the effects of mixed-dentition treatment using a fixed appliance protocol in a sample of 205 patients. The purpose was to identify the benefits of early treatment and to establish how often a second phase of treatment was needed.

AUTHORS

Kayhan L. Mashouf, DMD, MSD, is a partner at Mashouf Orthodontics in San Jose, Calif.
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Cameron K. Mashouf, DDS, MS, is a partner at Mashouf Orthodontics and an adjunct associate professor in the department of orthodontics at the University of the Pacific, Arthur A. Dugoni School of Dentistry in San Francisco.
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Sean Laraway, PhD, is an associate professor in the department of psychology at San Jose State University and an adjunct faculty member in the master's program in human factors/ergonomics.
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Early orthodontic intervention in a developing malocclusion has been a contentious subject.[1] Such treatment is either initiated in primary or mixed dentition. Advocates of early treatment postulate that it prevents growth abnormalities from escalating over time, thus normalizing growth and eliminating occlusal disharmonies.[2] The potential of such treatment to reduce the need for extraction of premolars has also been proposed.[3,4] However, there are questions regarding the sustainability of early treatment outcomes. Support for delaying treatment is based on the notion that cases treated earlier will require an additional phase of treatment after complete eruption of permanent dentition.[5–7]

Decisions about treatment timing are influenced by patient malocclusion. For certain types of malocclusion, there is evidence for the effectiveness of early interception during primary or mixed dentition. The developmental problems in this category include posterior and anterior crossbite,[8,9] severe overjet that predisposes patients to incisor trauma[10] and Class III malocclusion.[11–13] In contrast, mixed-dentition treatment of Class II malocclusion has been reported to lack time- and cost-effectiveness.[14–16] Evidence as to the optimal treatment timing for crowding and open bite is unclear.[17,18]

Uncertainty about the outcomes of early treatment is perpetuated by the heterogeneity of treatment protocols employing the use of a variety of removable and/or fixed appliances.[19] Fixed appliances have been found

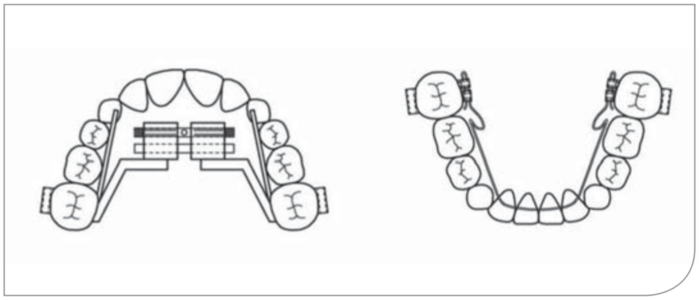

FIGURE 1A. Maxillary expansion appliance (MEA) (left) and lower lingual arch (LLA) (right).

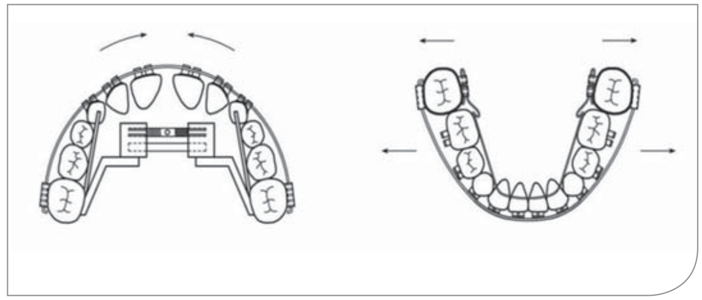

FIGURE 1B. Expanded maxilla with bonded brackets (left) and expanded permanent mandibular first molars with bonded brackets (right).

to be more efficient than removable appliances.[20] However, there are few studies that document treatment outcomes when fixed appliances are used in mixed dentition.[4,21–23] Furthermore, treatment objectives in such studies are limited, focused on early correction of skeletal components of malocclusion while postponing the correction of dental components to a later phase of treatment.[5–7] Given that most malocclusions consist of a combination of skeletal and dental components, it would be prudent to target both in an early intervention protocol.

In this study, a fixed appliance protocol was used to correct both skeletal and dental components of malocclusion in patients treated in early- to mid-mixed dentition. Our aim was to explore the following questions:

- Are there any advantages of early orthodontic intervention when compared to later treatment in permanent dentition?
- To what extent can a mixed-dentition orthodontic regimen reduce the need for a second phase of treatment?

The study analyzes the effects of treatment timing (age, dental development stage) on the prevalence of tooth extraction, frequency of additional treatment phases, treatment duration and treatment cost in a sample of patients with various Angle's classifications of malocclusion (I, II and III).

Materials and Methods

Retrospective data from 205 patients consecutively treated in the same private orthodontic practice between the years 2000–2011 were analyzed. All patients started treatment between the ages of 6 and 10. Informed consent permitting access to clinical data for research had been acquired from all patients prior to treatment. The data were anonymized and approval was obtained from the Institutional Review Board (IRB) at San Jose State University to analyze these archival data.

The requirements for inclusion of a given patient's data were (1) availability of initial and final records including lateral cephalometric and panoramic (or full-mouth series) radiographs, study models and photographs and (2) radiographic evidence of all permanent teeth with the exception of teeth Nos. 20 and 29 when teeth K and T could be maintained as substitutes. Retaining healthy primary mandibular second molars has been reported to be a viable treatment option.[24] Patients were excluded from the study if they missed 10 or more appointments. Of the total 453 patient records, 205 met the inclusion criteria.

Dental development can vary substantially between individuals of the same age. Patient records were used to identify the dental development stage at the start of treatment by comparing initial radiographs to dental maturation diagrams of Schour and Massler.[25] Patients in the sample matched one of three stages of dental development: early mixed dentition 1 (EM_1), early mixed dentition 2 (EM_2) or mid-mixed dentition (MM). EM_1 was identified by full eruption of permanent first molars and central incisors in addition to minimal root formation of permanent canines and premolars. EM_2 was denoted by one-quarter to one-third root formation of canines and premolars, whereas MM was marked by one-half to three-quarter root formation of these teeth. Three trained examiners designated the dental development stage independently. When discrepancies were found, a principal investigator (CM) made the final determination. With regard to chronological age, patients were divided into three groups: <8, 8–9 and >9 years of age.

Patients had received treatment for a variety of malocclusions identified clinically as Angle's classification I, II or III. These data were obtained from patient records and all three classes of malocclusion were included in the study.

Clinical Protocol

A mixed dentition-specific fixed appliance protocol was used, designed to address skeletal and dental components of malocclusion in all dimensions (transverse, sagittal and vertical). The protocol included a maxillary expansion appliance (MEA), a lower lingual arch (LLA) and brackets bonded to specific primary teeth as well as permanent incisors. The MEA and LLA were used for the dual purposes of anchorage and expansion (**FIGURES 1A** and **1B**). These appliances provided anchorage value by stabilizing

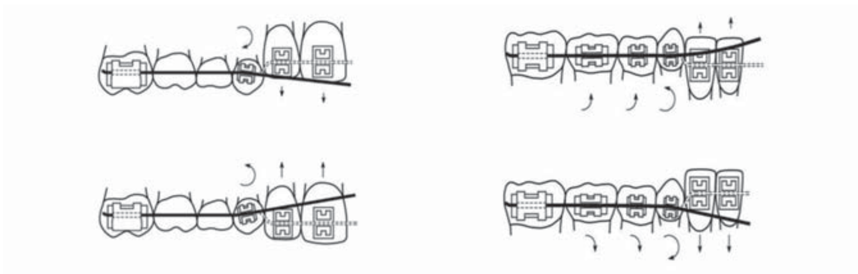

FIGURE 2. Extrusion and intrusion of maxillary incisors (left) and extrusion and intrusion of mandibular incisors (right).

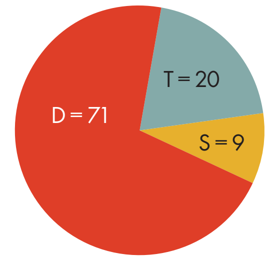

FIGURE 3. Percentage of patients in each treatment group.

the permanent first molars and guarding against iatrogenic consequences of their unintentional movements. Additionally, the MEA and LLA provided expansion capabilities for cases with inadequate transverse development and in treatment of crowding or protrusive incisors.

In the maxillary arch, brackets were bonded to primary canines and permanent incisors. In the mandibular arch, brackets were bonded to primary canines, primary molars and permanent incisors. Extrusion and intrusion tips were utilized for correction of open bite and overbite (FIGURE 2). Additional mechanics were used for treatment of sagittal and vertical components of malocclusion. Headgear and Class II elastics were used for correction of Class II malocclusion, whereas Class III elastics were used for correction of Class III malocclusion. A vertical pull chin cup was utilized in cases of excessive vertical facial growth. Details of this protocol are described elsewhere.[26]

Treatment Objectives/Outcomes

Occlusal and dental objectives were defined as Class I molar relationship, overjet/overbite of 2 to 3 mm, and a minimum of 25 mm of space in each quadrant to accommodate the developing permanent canines and premolars. Treatment was considered complete when these objectives were accomplished. Patients had their appliances removed, were fitted with retainers and were monitored through the complete eruption of permanent dentition. Patients who did not require additional treatment in the permanent dentition were referred to as the D (definitive) group. The treatment of this group of patients was considered definitive based on the maintenance of optimal occlusal relationships and alignment of teeth as well as patient satisfaction. The concept of considering patients' values and preferences in evaluating treatment outcomes has been validated.[27,28]

For a subset of patients referred to as the T (transitional) group, the initial phase of treatment was incomplete. These patients transitioned into an additional phase of treatment contiguous with the initial phase. The additional treatment involved bonding brackets to permanent canines and/or premolars after they had erupted. Another subset of patients referred to as the S (separate treatment) group required a separate second phase of treatment during adolescence. When additional treatment was deemed necessary, patients and parents were informed and their consent was obtained.

Treatment outcomes were evaluated based on the need for extraction of teeth, number of phases necessary to achieve optimal outcomes, treatment duration and treatment cost. Treatment duration was measured by months and included the length of time for the initial treatment phase (D group) and subsequent phases of treatment (T and S groups). Treatment cost was determined using the sum of fees for all phases.

Data Analysis

For categorical variables, chi-square tests were used to compare percentages. For 2 x 2 contingency tables, odds ratios and their 95% confidence intervals (CI) were used as measures of effect size.[29] For higher-level contingency tables, Cramér's V values were used as measures of effect size. For numerical variables, one-way ANOVAs were used to compare three group means, followed by Tukey HSD post-hoc tests when appropriate. Independent-samples t tests (two-tailed) were used to compare the means of two groups. Cohen's d standardized mean difference values (using the pooled standard deviation as the denominator) were used to quantify differences between group means. For all null hypothesis significance tests, the significance level was set to 0.05. G*Power[30] (v. 3.1) was used to determine sufficient sample sizes for statistical tests to detect a medium effect with power of 0.80. For the 2 x 2 chi-square tests, the required sample size was n = 88. For the 3 x 3 chi-square tests, the required sample size was n = 133. For the one-way ANOVAs, the required sample size was n = 159.

Results

The sample of 205 patients was almost equally split by gender, consisting of 103 females and 102 males. The mean age of the sample was 8.6 years, SD = 0.7. The mean age for females and males was 8.6 years (SD = 0.7) and 8.7 years (SD = 0.7), respectively. Less than 1 percent (n = 2) of patients in the sample needed extraction of teeth. The difference in proportions of extraction and nonextraction was statistically significant,

TABLE 1

Descriptive Statistics for Patients in the Three Treatment Groups

		Variable					
		Starting age	D duration	T duration	S duration	Total duration	Total fee (USD)
Treatment groups	*n*	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
D	145	8.6 (0.7)	24.1 (6.8)	–	–	24.1 (6.8)	\$5,015 (\$458)
T	41	9.0* (0.6)	23.2 (7.6)	16.4 (7.6)	–	39.6* (7.3)	\$5,723* (\$396)
S	19	8.3† (0.5)	22.8 (7.0)	–	12.9 (6.4)	35.7* (8.8)	\$6,729*† (\$1,217)
Total sample	205	8.6 (0.7)	23.8 (7.0)	–	–	28.6 (10.0)	\$5,315 (770)

Dollar values have been rounded to the nearest whole number. Ages are expressed in years. Treatment durations are expressed in months. *Indicates a significant difference from D ($p < .05$). †Indicates a significant difference from T ($p < .05$).

TABLE 2

Frequencies and Percentages for Dental Development Stage and Chronological Age Groups by Treatment Groups and Starting Age

		Treatment groups				Starting age
		Total *f*	D *f* (%)	T *f* (%)	S *f* (%)	*M* (*SD*)
Dental development stage groups	EM_1	65	49 (75%)	10 (15%)	6 (9%)	8.5 (0.7)
	EM_2	79	57 (72%)	14 (18%)	8 (10%)	8.7 (0.7)
	MM	61	39 (64%)	17 (28%)	5 (8%)	8.7 (0.7)
Chronological age groups	<8	35	28 (80%)	1 (3%)	6 (17%)	7.6 (0.4)
	8–9	108	76 (70%)	20 (19%)*	12 (11%)	8.5 (0.3)*
	>9	62	41 (66%)	20 (32%)*†	1 (2%)	9.5 (0.2)*†
	Total	205	145 (71%)	41 (20%)	19 (9%)	8.6 (0.7)

Percentages are within-row and are rounded to the nearest whole number. Ages are reported in years.*Indicates a significant difference from <8 ($p < .05$). †Indicates a significant difference from 8–9 ($p < .05$).

$\chi^2(1) = 197.1$, $p < .0001$ (95% CI for the percentage of extractions = 0.04% to 3.7%).

FIGURE 3 depicts the percentage of patients in each treatment group. Group D comprised 71 percent of patients in the sample for which definitive outcomes were achieved in one phase of treatment. Significantly fewer patients required additional treatment, with T and S groups comprising 20 percent [$\chi^2(1) = 58.2$, $p < .0001$] and 9% [$\chi^2(1) = 96.8$, $p < .0001$] of the sample, respectively. **TABLE 1** depicts the descriptive statistics for each treatment group in relation to starting age, treatment duration and fees. Statistically significant differences were found between groups with regard to mean starting age, $F(2, 202) = 6.8$, $p = .001$. Groups D and S were significantly younger than group T at the start of treatment ($p = .01$, $d = 0.53$, 95% on the mean difference = –7.4 to –1.4 months; and $p = .002$, $d = 1.17$, 95% on the mean difference = 4.0 to 11.9 months, respectively). Groups D and S did not differ significantly in starting age ($p = .20$, $d = 0.47$, 95% on the mean difference = –0.6 to 7.8 months).

Patients in the three treatment groups differed significantly in treatment duration, $F(2, 202) = 79.5$, $p < .0001$. Group D had a significantly shorter treatment duration than did group T ($p < .0001$, $d = 2.1$, 95% CI on the mean difference = –17.9 to –12.8 months) and group S ($p < .0001$, $d = 1.7$, 95% CI on the mean difference = –16.2 to –8.9 months). Groups T and S did not differ significantly in treatment duration ($p = .36$, $d = 0.35$, 95% CI on the mean difference = –1.5 to 7.2 months).

There were significant fee differences among the treatment groups, $F(2, 202) = 92.7$, $p < .0001$. The mean fee for group D was significantly lower than group T ($p < .0001$, $d = 1.7$, 95% CI on the mean difference = –\$863.91 to –\$553.40) and

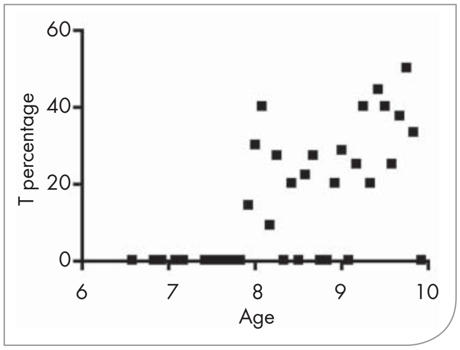

FIGURE 4. Percentage of patients in T group relative to starting age.

TABLE 3

Frequencies and Percentages for Malocclusion Type by Treatment Groups, Starting Age and Treatment Duration

Malocclusion type	Total *n*	D *f* (%)	T *f* (%)	S *f* (%)	Starting age *M* (*SD*)	Treatment duration *M* (*SD*)
Class I	119	85 (71%)	23 (19%)	11 (9%)	8.7 (0.7)	28.1 (9.7)
Class II	72	49 (68%)	17 (24%)	6 (8%)	8.6 (0.7)	29.1 (9.9)
Class III	14	11 (79%)	1 (7%)	2 (14%)	8.2 (0.7)	25.9 (8.2)
Total sample	205	145 (71%)	41 (20%)	19 (9%)	8.6 (0.7)	28.6 (10.0)

Percentages are within-row and are rounded to the nearest whole number.

group S ($p < .0001$, $d = 1.9$, 95% CI on the mean difference = –\$1,999.72 to –\$1,429.14). The mean fee for group T was significantly lower than group S ($p < .0001$, $d = 1.1$, 95% CI on the mean difference = –1424.40 to –587.1

TABLE 2 depicts the frequencies and percentages for treatment groups and starting age in relation to both stages of dental development and chronological age groups. Advancement in dental maturation ($EM_1 \rightarrow EM_2 \rightarrow MM$) correlated with an increased percentage of patients who underwent additional contiguous treatment (T group); however, this relationship was not statistically significant, $\chi^2(4) = 3.4$, $p = .47$, Cramér's V = 0.13. With regard to starting age, the three stages of dental development did not significantly differ, $F\ (2, 202) = 1.7$, $p = 0.18$. The relationship between chronological age groups and treatment groups was significant, $\chi^2(4) = 17.2$, $p = 0.002$, Cramér's V = 0.29. Within the T group, there was a significantly higher percentage of patients in the 8 to 9 age group than in the < 8 age group. This percentage significantly increased again in the > 9 age group. While the percentage of T patients rose with increasing age, the percentage of patients in the S group decreased. **FIGURE 4** is a graphical representation of the effect of starting age on the percentage of T group patients. Only one patient younger than 8 years old transitioned into an additional phase of treatment.

TABLE 3 provides frequencies and percentages for each treatment group in relation to Angle's classification of malocclusion. The relationship between these two variables was not significant, $\chi^2(4) = 2.3$, $p = .68$, Cramér's V = 0.08. This table also depicts starting age, treatment duration within each treatment group and total treatment duration for the three Angle's classifications. The mean starting ages were not significantly different with regard to Angle's classification, $F\ (2, 202) = 2.9$, $p = .056$. There was a decreasing trend in mean starting age from Class I → Class II → Class III. The mean total treatment duration did not significantly differ across the three malocclusion groups, $F\ (2, 202) = 0.7$, $p = .47$.

Discussion

Extraction Rate

Extraction of teeth in orthodontics is prescribed primarily to resolve issues related to crowding or protrusion. The extraction rate of less than 1 percent in this mixed-dentition sample is significantly lower than those reported in previous studies. The prevalence of extraction in permanent dentition treatment has been reported as 25 to 85 percent in the United States and 23 percent in Australia.[31,32] The significant difference in extraction rates found between patients treated in permanent dentition and our sample points to a greater potential for growth modification during the mixed-dentition stage of development.[19] Oh et al. observed a similar trend in their sample of Class II patients showing significantly lower extraction rates in early compared to late treatment groups (5.6 to 37.9 percent, respectively).[4] The further reduction of extraction rate in our sample can be attributed to the treatment protocol, one which takes full advantage of transverse growth potential by using expansion appliances.

Ratio of One-Phase/Two-Phase Treatment

There is a perception in orthodontics that early intervention should be followed by an additional stage of refinement treatment.[5] In our sample, 71 percent of patients who underwent mixed-dentition treatment did not need a second phase of treatment (**FIGURE 3**, group D). Within the subset of patients who required another phase of treatment, 20 percent transitioned into additional treatment contiguous with the first phase (**FIGURE 3**, group T) and 9 percent underwent a separate second phase of treatment (**FIGURE 3**, group S). The finding that the majority of patients completed treatment in one phase demonstrates the effectiveness of early intervention using a mixed-dentition specific treatment protocol. This runs counter to the viewpoint that mixed-dentition treatment is inherently limited, necessitating refinement at a later time.

Time and Cost-Effectiveness

Treatment durations in permanent dentition have been reported to range from 23.1 to 31 months.[33,34] In our study, the mean treatment duration of the total sample was 28.6 months, comparable to what has been found in permanent dentition (**TABLE 1**). The mean treatment duration of 24.3 months in patients for whom one phase of treatment was definitive (group D) can be considered time effective. Mean treatment durations of 39.5 and 36.8 months were excessive for patients who transitioned into additional treatment (group T) and patients who needed a separate second phase of treatment (group S), respectively. These findings are consistent with reports that two-phase treatment is less time effective than a single-phase treatment coinciding with permanent dentition.[6,7]

The cost-effectiveness of mixed-dentition treatment in this sample was measured in relation to the median fee of $5,200 reported by orthodontists for permanent dentition treatment.[35] Patients in group D paid a mean treatment fee of $4,961, whereas mean treatment fees for groups T and S were $5,647 and $6,811, respectively (**TABLE 1**). Treatment was cost-effective for group D, which underwent one phase of treatment. The financial benefit of early treatment that is limited to one phase has been reported elsewhere.[36] For groups T and S, mixed-dentition treatment was not cost-effective.

Treatment Response Based on Timing of Intervention

Literature on optimal timing of early to mid-mixed-dentition treatment is scant. According to Bjork, the stage of dental maturation is a more reliable indicator than chronological age for the timing of orthodontic intervention in mixed dentition.[37] In our study, the progression of dental development from $EM_1 \rightarrow EM_2 \rightarrow MM$ coincided with a linear increase in patients who transitioned into additional treatment (group T, **TABLE 4**). However, the relationship between dental development stage and treatment groups did not reach statistical significance.

Chronological age proved to be a more valuable predictor for treatment timing than the dental development stage, a finding which contradicts Bjork's statement. The earlier the age when treatment began, the more likely it was to yield definitive outcomes in one phase. Mixed-dentition treatment was definitive for 80 percent of patients who started treatment prior to age 8, 70 percent between the ages of 8 and 9 and 66 percent when treatment began after 9 years of age (**TABLE 2**, group D). In contrast, more patients transitioned into additional treatment as age increased (**TABLE 2**, group T). Notably, only one patient in group T was younger than 8 years old at the onset of treatment, indicating age 8 as a cut-off point (**FIGURE 4**). In our sample, starting treatment prior to age 8 almost completely eliminated the need to transition into an additional second phase. The increased likelihood of obtaining definitive treatment outcomes in younger mixed-dentition patients may be attributed to a higher rate of cellular and connective tissue adaptation[38] or to greater patient compliance among elementary school-age children.[39] For the patients in group S, a younger starting age did not prevent the need for a separate second phase (**TABLE 2**). The etiological factors that subject this subgroup of patients to additional treatment require further study.

> Findings are consistent with reports that two-phase treatment is less time effective than a single-phase treatment coinciding with permanent dentition.

Treatment Response Based on Angle's Classification

Angle's classification (I, II and III), an indicator of the occlusal relationship in the sagittal plane, has been mentioned as a factor in the timing of treatment. Early treatment of Class II malocclusion has been reported as less effective than treatment done at the onset of the adolescent growth spurt.[14–16] On the contrary, early interception of Class III malocclusion has been reported as highly effective.[11–13] In this study, no correlation was found between Angle's classification and the number of treatment phases or duration of treatment, demonstrating that early treatment of Class I, II and III malocclusions was equally effective. This finding highlights the adaptability of growth and the potential for its modification in early to mid-mixed dentition. A decreasing trend in the starting age from Class I → Class II → Class III suggests that patients with Class II and III seek treatment earlier than do those with Class I malocclusion (**TABLE 3**). This could be due to the more noticeable facial presentation of Class II and Class III malocclusions at an early age.

Limitations

The lack of a control sample is a limitation of this study. Future studies on this topic would benefit from using randomized controlled trials or study designs that include clear comparison groups to evaluate the merits of different treatment protocols for early orthodontic intervention.

Conclusion

Early orthodontic intervention in mixed dentition reduced the need for extraction of teeth to less than 1 percent and was equally effective for all three Angle's classifications of malocclusion. These advantages were partially offset by the need for a second phase of treatment in 29 percent of patients. Within this subset of patients, 20 percent transitioned into additional treatment and 9 percent underwent a separate second phase of treatment. Starting treatment at a younger age made patients less likely to transition into additional treatment but did not help avoid a separate treatment phase. Further research is needed to identify the etiological factors that predispose patients to a separate phase of treatment. Given its ability to nearly eliminate the need for extraction and its effectiveness across various malocclusions, mixed-dentition treatment can be a viable alternative to treatment initiated in permanent dentition. The pros and cons of early versus late treatment strategies should be presented to prospective patients, allowing them to make informed decisions regarding their preference in treatment timing. ■

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THE CORRESPONDING AUTHOR, Kayhan L. Mashouf, DMD, MSD, can be reached at klm@drmashouf.com.