The Relationship Between the Curve of Spee, Relapse, and The Alexander Discipline

Sal Carcara, C. Brian Preston, and Ossama Jureyda

Exaggerated curves of Spee are frequently observed in dental malocclusions that present with deep vertical overbites. During orthodontic treatment, such excessive curves of Spee are usually leveled and, in most instances, this leveling will result in a reduction of the anterior overbite. The Alexander Discipline provides a good example of modern straight-wire orthodontic techniques that purport an ability to treat abnormal variations in the depth of the occlusal plane. The records of 31 randomly selected patients treated by nonextraction with the Alexander Discipline were studied. The results show that the Alexander Discipline levels the curve of Spee in Class II, Division I deep-bite cases and that when relapse occurs, the curve of Spee returns to a lesser extent than was present before orthodontic treatment. With the Alexander Discipline, a pretreatment curve of Spee that is not completely level posttreatment has a slightly higher incidence and magnitude of relapse than a pretreatment curve of Spee that is completely level posttreatment. This study indicated that, based on the pretreatment curve of Spee, there is no ability to predict relapse in mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length in Class II, Division I deep-bite cases treated with the Alexander Discipline.

(Semin Orthod 2001;7:90-99.) Copyright © 2001 by W.B. Saunders Company

Exaggerated curves of Spee\textsuperscript{1,2} are frequently observed in dental malocclusions that present with deep vertical overbites. As a part of orthodontic treatment, such excessive curves of Spee are usually leveled during orthodontic treatment, and, in most instances, this leveling will, in turn, result in a reduction of, if present, deep anterior overbites. Clinicians who adhere to the Tweed\textsuperscript{3} philosophy of orthodontic treatment use continuous arch wires that incorporate reverse curves of Spee to produce flat occlusal planes. Accordingly, arch leveling occurs mostly by an extrusion of the lower premolar teeth in conjunction with a minimal intrusion of the mandibular incisor teeth. In contrast to the earlier approach, advocates of sectional arch orthodontic mechanics\textsuperscript{2,4} treat deep curves of Spee by intrusion of mandibular incisors while, usually, allowing the lower premolars to erupt into occlusion.

A review of the literature reveals that there is disagreement among the proponents of the various orthodontic techniques that are used to level deep curves of Spee.\textsuperscript{4-8} The discussion revolves around which leveling technique produces the most effective overbite correction as well as the most stable long-term treatment outcomes. Those orthodontists who primarily use sectional arches to produce flat occlusal planes believe that leveling with continuous arch wires tends to extrude the posterior teeth, which, in most instances, will cause an increase in the lower facial height. They further believe that, in individuals with strong muscles of mastication, the orthodontically extruded buccal segments will tend to relapse after the orthodontic treatment.\textsuperscript{4,5,9} This relapse would lead to the recurrence of anterior deep bites. When a reverse
curve of Spee is placed in a continuous arch wire for the purpose of arch leveling, this results in an almost automatic tendency for the mandibular incisors to flare labially. Contrary to this viewpoint, Ferguson states that a reverse curve of Spee in an arch wire does not in itself cause the lower incisor teeth to flare unless the arch is allowed to act beyond the stage at which the occlusal plane is flat. Orthodontists who use Tweed’s leveling technique argue that the extrusion of premolars and molars provides a stable change while, on the other hand, the intrusion of the lower incisors often relapses to produce an increased overbite.

Radiographic cephalometric studies showed that both the Ricketts and modified Tweed techniques can successfully correct deep dental overbites. These studies concentrated on overbite correction only and neither analyzed study models to evaluate how effectively the curves of Spee were leveled, nor did they evaluate the long-term stability of the results that were produced.

The present article reflects the findings of a study that was designed to evaluate the long-term outcomes of a representative sample of orthodontic patients who were treated according to the Alexander Discipline. Irrespective of the philosophy and mechanical principles of the orthodontic technique used, one of the primary objectives of orthodontic treatment is to obtain a level occlusal plane. In this article, leveling will be defined as the process of bringing the incisal edges of the anterior teeth and the buccal cusp tips of the posterior teeth into the same horizontal plane.

The anatomic definition of the anteroposterior curve of occlusion is generally accepted by orthodontists as describing the curve of Spee. Some studies in the orthodontic literature propose other ways to define and measure the curve of Spee on orthodontic study models. Three-dimensional digitizers have been used to calculate the depth of the mandibular curve of Spee mathematically. Koyama, in a more practical approach to the problem, used a caliper to measure the curvature of the occlusal plane in both jaws and found the greatest pretreatment depth of the curvature to be located in the bicuspid region.

In a mechanical sense, the presence of a curve of Spee may make it possible for a dentition to resist the forces of occlusion during mastication. Although several theories have been proposed to explain the presence of a curve of Spee in natural dentitions, its role during normal mandibular function has been questioned. It has been proposed that an imbalance between the anterior and the posterior components of occlusal force can cause the lower incisors to overerupt, the premolars to infraerupt, and the lower molars to be mesially inclined. According to Root and Fidler et al. when a skeletal open bite is not present, the curve of Spee in Class II malocclusions is deeper than in other malocclusions. Although an exaggerated curve of Spee is often observed in Class II, Division I relationships, it is not unique to this type of malocclusion.

Andrews noted that the occlusal planes in nonorthodontically treated and ostensibly normal occlusions varied from being generally flat to having a slight curve of Spee. This finding led him to believe that the presence of a curve of Spee could be associated with postorthodontic treatment relapse. Andrews concluded, “even though not all of the orthodontic normals had flat planes of occlusion, I believe that a flat plane should be a treatment goal as a form of overtreatment.” A deep curve of Spee may make it almost impossible to achieve a Class I canine relationship though it may also result in occlusal interferences that will manifest during mandibular function.

To date, there are little or no data that quantify the amount of arch leveling that occurs with orthodontic treatment, or the long-term, postorthodontic treatment relapse of the curve of Spee. It is perhaps worthwhile noting that very little research has been undertaken to determine the most effective, and stable, method of leveling a deep curve of Spee.

Numerous studies have been performed to quantify the amount and type of postretention relapse that occurs after orthodontic treatment. In general, these studies have noted posttreatment increases in overjet, overbite, mandibular incisor crowding, along with decreases in arch length and arch width. Investigations have also been undertaken to determine whether untreated normal occlusions undergo the same changes that are observed in treated cases. At the same time, very little research has been performed to evaluate the...
long-term stability of leveling the curve of Spee, and few, if any, studies have attempted to correlate the pretreatment curve of Spee with postretention changes in other aspects of the occlusion.

The primary purpose of the present investigation was to determine the effectiveness of the Alexander continuous arch wire technique in leveling the curve of Spee in Class II, Division I deep bite cases. A second purpose of the study was to determine the long-term stability of the leveling of the curve of Spee achieved with the Alexander Discipline. A third objective of the research was to determine whether a relationship exists between the presence of a deep curve of Spee before orthodontic treatment and the relapse that takes place in a number of occlusal traits. The traits studied included the mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length.

The sample for this retrospective study consisted of 31 patients, 22 female and 9 male, randomly selected from the records of orthodontic patients treated in the private practice of Dr. R.G. "Wick" Alexander, in Arlington, Texas. The average age of the patients at the start of treatment was 12 years and 6 months. The average treatment time for the sample was 2 years and 1 month whereas the average time from T1 to T2 record taking was 2 years and 5 months. Each case was treated by nonextraction and met specific criteria for inclusion in the study. These selection criteria included the presence of a Class II skeletal (ANB > 4°) and at least a half-cusp Class II molar relationship, an overbite of 50% or greater as measured from the initial (T1) study models, and a curve of Spee measuring 2 mm or more. Only cases with complete records were selected for this study. These records consisted of dental casts taken pretreatment (T1), post-treatment (T2), and postretention (T3). The posttreatment (T2) records were taken 2 months after debonding at a mean age of 14 years and 11 months. The final (T3) records were taken at an average of 7 years and 5 months after the removal of the fixed retainer, which was at an average of 11 years and 5 months after the debonding of the patient. All 31 patients were treated by a single operator, Dr. R.G. "Wick" Alexander, who used a fully preadjusted fixed orthodontic appliance with a 0.018" slot size according to the Alexander Discipline. Dr. Alexander’s patients were selected for this study because he is the recognized authority for this technique, a goal of his treatment is to level any curve of Spee that is present in the mandibular arch, and complete long-term records were available for the present study.

The Alexander technique was also selected for this study, over other preadjusted appliance techniques, because of its unique prescription, and its biomechanical principles that assist with mandibular incisor control during arch leveling. The unique features of the prescription include a −5° torque built into the mandibular incisor bracket base to maintain the lower incisors upright over the basal bone. In addition, a −6° distal tip is incorporated into the mandibular first molar buccal tube to facilitate molar uprighting, and create arch length to help reduce lower incisor flaring. The early use of rectangular wire, as is required in this system, makes it easier, than is the case with some other orthodontic techniques, to control the position of the lower incisors from the outset of treatment.

After the initial leveling phase of treatment the upper and lower first arch wires are replaced with "working arch wires" constructed from 0.016 × 0.022 inches or 0.017 × 0.025 inches stainless steel. The maxillary arch wire has an accentuated curve of Spee, and the mandibular arch wire has a reverse curve of Spee, placed into it to facilitate arch leveling. Other than the initial arch wires, all remaining arch wires include omega loops placed 1 to 2 mm anterior to the first or second molar tubes. These omega loops allow all of the arch wires, after the initial arch wires, to be actively tied back with 0.014-inch stainless steel ligatures. The finishing arch wires in both arches are constructed from 0.017 × 0.025 inch stainless steel wires. The upper and lower arch wires are bent to incorporate an accentuated or a reverse curve of Spee respectively. A goal of the Alexander technique is to have the 0.017 × 0.025 inch stainless steel finishing arch wire placed in both arches as early as possible during treatment. The early placement of this relatively heavy lower arch wire makes it possible for the curve of Spee to be flat during most of the active treatment. Each stainless steel arch wire is heat-treated before insertion to increase the stiffness of the wire. At the end of treatment the bands are removed and retention appliances are inserted. In all of the 31 patients
selected for this study the mandibular canine-to-
canine fixed retainer was removed after the third molars were either extracted or had erupted normally into occlusion. This occurred at a mean time of 3 years and 4 months after appliance removal. At the time of the removal of the fixed retainer, selective interproximal stripping was performed on each patient to decrease the tendency for relapse of lower incisor crowding.32

Three sets of study casts (T1, T2, and T3) were collected for each of the 31 randomly selected patients. The 93 sets of study models were each assigned a random number that made it possible for a single investigator to measure each set in a random blind fashion. The curve of Spee in this study was measured in the mandibular buccal occlusion between the center of the incisal edge of the central incisor anteriorly and the distobuccal cusp tip of the first molar posteriorly.27 By using a standard palatometer (GPM, Switzerland), the depth of the curve of Spee was measured on each side of the mandibular arch as being the vertical distance from the buccal cusp tip of the most infraoccluded premolar, to the occlusal plane previously described.27

The curves of Spee were measured on both the left, and the right, sides of each of the 93 mandibular models included in this study. The resulting sets of 93 left and 93 right measurements were compared statistically by means of a paired t test. The results indicated that there were no significant statistical differences (P > .05) between these pairs of measurements, curve of Spee on the right side versus curve of Spee on the left side, for each of the 31 patients at T1, T2, and T3. The average of the right and left curves of Spee for each patient at the three different time intervals was therefore used for further definitive statistical analysis and comparison.

The following measurements were made by a single operator in a random blind fashion and directly on study casts for each patient at three time intervals (T1, T2, T3): mandibular intercanine width,46 overbite,46 overjet,46 mandibular incisor irregularity index,45 and mandibular arch length.44

To test whether the curve of Spee remained unchanged from T1 to T2, and from T2 to T3, paired t tests were calculated. To compare the incidence of relapse (T2–T3) of the curve of Spee in the patients that were completely level at T2 with those that were not completely level at T2, a two-sample t test was calculated to compare the proportion of relapse occurrence. To compare the magnitude of relapse (T2–T3) of the curve of Spee in the patients that were completely level at T2 with those that were not completely level at T2, two independent samples’ t test was calculated.

The treatment effects (T1 vs. T2) and relapse (T2 vs. T3) of five variables (mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length), were calculated with paired t tests. A Pearson correlation coefficient and regression analysis was then performed to determine the predictive power of the pretreatment curve of Spee (T1) on the relapse of the five variables studied (T2–T3).

The mean pretreatment (T1) curve of Spee for the 31 patients included in this study was 2.41 mm with a standard deviation of ± 0.48 mm and a range of 2.00 to 3.75 mm. The mean posttreatment (T2) curve of Spee for this sample was 0.11 mm with a standard deviation of ± 0.19 mm and a range of 0.00 to 0.50 mm. The differences between the pretreatment (T1) and posttreatment (T2) curves of Spee were highly statistically significant (P < .0001). It was concluded that in this sample of patients a meaningful degree of arch leveling was achieved with the Alexander Discipline.

The mean treatment-induced reduction in the curve of Spee was 2.30 mm with a standard deviation of ± 0.47 mm. The range of reduction of the depth of the curve of Spee from T1 to T2 was 1.50 to 3.75 mm. This corresponds to a 95.43% average reduction in the curve of Spee during treatment. Twenty-two of the 31 patients studied (approximately 71%) were completely (100%) level after treatment (T2), whereas 9 patients (approximately 29%) had a residual curve of Spee at the end of the orthodontic treatment.

The mean posttreatment (T2) curve of Spee for the 31 patients treated with the Alexander Discipline was 0.11 mm with a standard deviation of ± 0.19 mm and a range of 0.00 to 0.50 mm. The mean postretention (T3) curve of Spee for this sample was 0.48 mm with a standard deviation of ± 0.50 mm and a range of 0.00 to 1.75 mm. The mean increase in the curve of Spee from T2 to T3 was 0.37 mm with a standard
deviation of ± 0.40 mm and a range of 0.13 to 1.25 mm. The differences between the posttreatment (T2) and postretention (T3) curves of Spee, though small, were statistically significant (P < .0001).

The posttreatment (T2) curve of Spee data for the sample (N = 31) revealed two subpopulations. Twenty-two patients at T2 had curves of Spee that were completely leveled whereas nine patients had residual curves of Spee at this time. A comparison of the occurrence of relapse in the curves of Spee in these two subpopulations was calculated by using a two-sample t test. The results of this test revealed that there was a statistically significant difference (P < .05) in the occurrence of relapse of the curve of Spee in these two subpopulations. A statistically greater occurrence of relapse (88.9% vs. 50%, P < .05) was seen between those patients that were completely leveled at T2 and those that were not.

A comparison of the magnitude of relapse in the curve of Spee that takes place in these two groups between posttreatment and postretention was calculated by using two independent samples’ t test. The results of this test revealed a statistically significant difference (P < .0001) in the amount of relapse of the curve of Spee in these two subpopulations (P < .0001). Eleven of 22 patients that were completely level at T2 subsequently relapsed an average of 0.28 mm at T3, which is equal to a relapse of 11.68% of the T1 curve of Spee. By comparison, eight of the nine cases that were not completely leveled at T2 relapsed an average of 0.39 mm at T3, which is equal to 22.46% of the T1 curve of Spee.

The overall mean period of the time that elapsed from taking the initial records (T1) to taking the final records (T3) was 14 years and 4 months with a range of 7 to 28 years, 8 months. Over this period (T1-T3) the overall effect on the curve of Spee was an average reduction of −1.93 mm, which represents a mean 80.62% reduction in the original depth of this curve.

The means and standard deviations for each of the five variables measured on the study casts (mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length) at T1, T2, and T3 are reported in Table 1. The means and standard deviations for treatment changes (T2-T1), posttreatment changes (T3-T2), and overall changes (T1-T3) are shown in Table 2.

**Mandibular Intercanine Width**

A total of 77.5% of the cases showed statistically significant increases in the mandibular intercanine width during treatment (x̄ = +1.37 mm, P = .0002). The same 24 cases (77.5%) in which intercanine widths were increased during treatment showed a marginally significant postretention reduction (x̄ = −0.62 mm, P = .0505) in their intercanine widths. It should be noted that when the mandibular fixed cuspid-to-cuspid retainer was removed, interproximal enamel reduction was performed.

**Overbite**

In all 31 patients, the overbite was reduced significantly during treatment (x̄ = −2.67 mm, P < .0001). In 74% of the cases the overbite increased significantly postretention (x̄ = +0.75 mm, P < .0001). The posttreatment mean overbite was 2.09 mm, and the postretention mean overbite was 2.84 mm.

**Overjet**

In all 31 cases the overjet was reduced significantly during treatment (x̄ = −4.09 mm, P < .0001). In 87.1% of the cases the overjet increased significantly postretention (x̄ = +1.09 mm, P = .0001). The overall mean period of the time that elapsed from taking the initial records (T1) to taking the final records (T3) was 14 years and 4 months with a range of 7 to 28 years, 8 months. Over this period (T1-T3) the overall effect on the curve of Spee was an average reduction of −1.93 mm, which represents a mean 80.62% reduction in the original depth of this curve.

The means and standard deviations for each of the five variables measured on the study casts (mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length) at T1, T2, and T3 are reported in Table 1. The means and standard deviations for treatment changes (T2-T1), posttreatment changes (T3-T2), and overall changes (T1-T3) are shown in Table 2.

**Mandibular Intercanine Width**

A total of 77.5% of the cases showed statistically significant increases in the mandibular intercanine width during treatment (x̄ = +1.37 mm, P = .0002). The same 24 cases (77.5%) in which intercanine widths were increased during treatment showed a marginally significant postretention reduction (x̄ = −0.62 mm, P = .0505) in their intercanine widths. It should be noted that when the mandibular fixed cuspid-to-cuspid retainer was removed, interproximal enamel reduction was performed.

**Overbite**

In all 31 patients, the overbite was reduced significantly during treatment (x̄ = −2.67 mm, P < .0001). In 74% of the cases the overbite increased significantly postretention (x̄ = +0.75 mm, P < .0001). The posttreatment mean overbite was 2.09 mm, and the postretention mean overbite was 2.84 mm.

**Overjet**

In all 31 cases the overjet was reduced significantly during treatment (x̄ = −4.09 mm, P < .0001). In 87.1% of the cases the overjet increased significantly postretention (x̄ = +1.09 mm, P = .0001). The overall mean period of the time that elapsed from taking the initial records (T1) to taking the final records (T3) was 14 years and 4 months with a range of 7 to 28 years, 8 months. Over this period (T1-T3) the overall effect on the curve of Spee was an average reduction of −1.93 mm, which represents a mean 80.62% reduction in the original depth of this curve.

The means and standard deviations for each of the five variables measured on the study casts (mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length) at T1, T2, and T3 are reported in Table 1. The means and standard deviations for treatment changes (T2-T1), posttreatment changes (T3-T2), and overall changes (T1-T3) are shown in Table 2.
Table 2. Treatment, Posttreatment, and Total Changes in Model Measurements

<table>
<thead>
<tr>
<th>Measure (mm)</th>
<th>Treatment Changes (T2-T1)</th>
<th>Posttreatment Changes (T3-T2)</th>
<th>Total Changes (T3-T1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Mandibular intercanine width</td>
<td>1.37</td>
<td>1.85</td>
<td>-0.62</td>
</tr>
<tr>
<td>Overbite</td>
<td>-2.67</td>
<td>1.05</td>
<td>0.75</td>
</tr>
<tr>
<td>Overjet</td>
<td>-4.09</td>
<td>2.96</td>
<td>1.09</td>
</tr>
<tr>
<td>Mandibular incisor irregularity</td>
<td>-3.66</td>
<td>3.25</td>
<td>0.98</td>
</tr>
<tr>
<td>Arch length</td>
<td>1.79</td>
<td>4.57</td>
<td>-2.16</td>
</tr>
</tbody>
</table>

Abbreviation: SD, standard deviation.

mm, P < .0001). The posttreatment mean overjet was 2.18 mm and the postretention mean overjet was 3.27 mm.

Irregularity Index

The mean pretreatment incisor irregularity was 3.97 mm; 54.5% of cases had minimal irregularity before treatment (<3.5 mm), 35.5% had moderate incisor irregularity (3.5-6.5 mm), and 9.0% had severe incisor irregularity (>6.5 mm). Treatment produced a significant decrease in the incisor irregularity (x̄ = 3.66 mm, P < .0001). Incisor irregularity increased significantly posttreatment (x̄ = 0.98 mm, P < .0001). However, 90% of cases at T3 had minimal incisor irregularity, and 10% had moderate irregularity. All 31 cases showed a net improvement in incisor irregularity from T1 to T3.

Arch Length

A total of 64.5% of the cases showed a slightly significant increase in arch length because of treatment (x̄ = 1.69 mm, P = .04) whereas 87.1% of the cases showed a significant decrease in arch length posttreatment (x̄ = 2.16, P < .0001). The Pearson correlation coefficient was calculated by comparing the T1 curve of Spee with the posttreatment changes (T3-T2) observed for each of five variables (mandibular intercanine distance, overbite, overjet, mandibular incisor irregularity, and arch length) and revealed no statistical correlation (P > .05). Follow-up regression analyses revealed no ability to predict relapse in any of the five factors mentioned earlier based on the T1 curve of Spee (P > .05).

Discussion

The important contribution that leveling the curve of Spee makes toward the success of orthodontic treatment has been well documented in the literature.18,19,20-28,32,34,40 There is, however, no general agreement as to the most appropriate biomechanical principles that should be used to accomplish stable long-term arch leveling. Two important studies have been performed to compare the use of sectional versus continuous arch leveling mechanics in the treatment of deep-bite cases.16,17 Dake and Sinclair in a comparison of Ricketts' and Schudy's treatments of adolescent Class II deep-bite low-angle nonextraction cases, concluded that both operators' techniques were effective in overbite correction, and that these changes remained stable after an average posttreatment period of 4 years and 6 months.

Weiland et al, in a study of 50 adult low-angle deep-bite cases, concluded that in adult patients the Burstone's segmental arch technique is superior to conventional continuous arch wire techniques when arch leveling by incisor intrusion is indicated. The earlier-mentioned studies compared the effectiveness of overbite correction as measured on cephalometric radiographs. Neither study used study models to measure the curve of Spee nor to measure the effectiveness or long-term stability of leveling the curve of Spee. The present study was prompted by the recognition of a need for a long-term study-model analysis of the effectiveness and stability of leveling the curve of Spee.

Findings reported in the literature dealing with the stability of orthodontic treatment are often contradictory, in large part, because of the fact that investigators group malocclusions that require different treatment strategies together. Further, the orthodontic records that are used in outcomes studies often belong to patients who were treated by both experienced and inexperienced operators. It is also an unfortunate fact that detailed outcomes goals are not regu-
larly established for orthodontic patients before the start of their treatment. Lastly, assessments of relapse are often qualitative and do not allow for quantitative comparison. By defining strict guidelines for the selection of cases treated by a single experienced operator with clearly defined goals, the present study attempted to overcome at least some of the earlier shortcomings.

The effectiveness of arch leveling achieved with the Alexander Discipline was determined by comparing T1 and T2 curve of Spee data by using a paired t test. Results of the paired t test indicated a statistically significant change \((P < .0001)\) in the curve of Spee during treatment. It was concluded that the Alexander Discipline is an effective preadjusted continuous arch wire technique for leveling a curve of Spee in Class II, Division I nonextraction deep-bite cases in which the initial curve of Spee was in the range of 2 to 4 mm. Seventy-one percent of the cases studied were leveled completely, whereas 29% had a slight residual curve of Spee at T2. For the latter cases the mean curve of Spee remaining at the end of treatment was 0.11 mm. A residual curve of Spee of 0.11 mm is probably clinically insignificant based on the qualitative observations of the posttreatment study models. The T2 models all exhibited Class I molar and canine relationships with properly finished buccal occlusions, and normal overjets and overbites.\(^{18}\)

A question that cannot be answered by this study is how the curve of Spee was leveled. Several investigators\(^{4,5,9,10,11,16,17}\) have reported on the negative effects of continuous arch wire mechanics. These effects include a flaring of the lower incisors, an extrusion of the mandibular molars, and an opening of the occlusal mandibular plane. Some features of the Alexander Discipline, including the \(-5^\circ\) of torque in the lower incisors and the \(-6^\circ\) of distal tip in the mandibular molars, are specific and probably unique among the preadjusted appliance prescriptions. These unique features, along with biomechanical principles such as the use of heat-treated arch wires with omega stops tied back to the molar tubes, could play a role in preventing the untoward side effects seen with some other straight-wire techniques.

The long-term stability of arch leveling achieved with the Alexander Discipline was determined by comparing the T2 and T3 curve of Spee data by using a paired t test. A statistically significant change \((P < .0001)\) was seen in the curves of Spee after the removal of the mandibular retention appliances. The curves of Spee increased from a mean of 0.11 mm posttreatment to a mean of 0.48 mm postretention. In other words, the curve of Spee relapsed on average 0.37 mm over a period of 7 years and 5 months after the fixed lingual canine-to-canine mandibular retainer was removed. Although the relapse in the curve of Spee may be statistically significant, it has been explained, in a clinical sense, by several investigators as being a normal physiologic process.\(^{18,27,31,32}\) It was concluded that the Alexander Discipline efficiently "over treats" Class II, Division I deep-bite malocclusions so that when the relapse occurs the curve of Spee returns to a lesser extent than was initially present. The overall long-term (T1–T3) effect of orthodontic treatment with the Alexander Discipline is an average of 80.62% reduction in the pretreatment curve of Spee. Twelve of the 31 cases studied remained 100% level over a time span of 5 to 25 years after the conclusion of orthodontic treatment. This study shows that in this sample the observed relapse of the curve of Spee \((\bar{x} = 0.48 \text{ mm})\) was minimal and that it occurred slowly over an extended period of time. The effects of this degree of relapse of the curve of Spee are probably clinically insignificant with regard to proper mandibular function, esthetics, and occlusion.

The results of a two-sample t test used to compare the proportion of relapse that took place revealed a significant difference in the incidence of relapse that occurred in the 22 cases that were completely leveled at the end of treatment (T2) and the 9 cases that were not \((P < .05)\). In addition, the results of the two independent samples' t tests also revealed a significant difference in the magnitude of relapse that occurred in the 22 cases that were completely leveled and the 9 cases that were not \((P < .0001)\). Half of the 22 cases that were completely leveled at the end of treatment showed some relapse at T3. The amount of this relapse was 11.68% of the original curve of Spee (T1) or 0.28 mm. In contrast, eight of nine (88.9%) of the cases that were not completely leveled at T2 relapsed, and the amount of relapse was 22.46% \((0.39 \text{ mm})\) of the original curve of Spee. It was concluded that in those cases treated with the Alexander Discipline that were not completely
leveled posttreatment, there is a slightly higher incidence and magnitude of relapse than in those cases that were completely leveled.

To establish whether significant treatment and posttreatment changes had taken place in mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length, preliminary statistical analyses were performed. Paired t tests were calculated to compare the pretreatment and posttreatment data and the posttreatment and postretention data.

For each of the five variables measured from the study casts, statistically significant changes occurred during treatment with the Alexander Discipline (P < .05). An evaluation of the effects of treatment on these five variables was not the primary goal of this research project. The findings did, however, detect that in association with the treatment there was a general decrease in overbite, overjet, and incisor irregularity, and an increase in mandibular intercanine width and arch length. With one exception, arch length, these results are similar to those reported by Elms et al. The increase in the arch length during orthodontic treatment that was observed in the present study was not statistically significant in the Elms et al study. In the present study, four of the five variables (overbite, overjet, incisor irregularity, and arch length) showed statistically significant (P < .05) posttreatment changes. In the present study, the mandibular intercanine width showed marginally significant (P = .0505) posttreatment changes. Although it was not a major goal of this study to investigate the relapse of mandibular occlusal traits, significant posttreatment changes were detected for all five variables studied. Although these results are similar to those found by Elms et al, the posttreatment changes noted for overbite, overjet, and the irregularity index were marginally greater in the present study than are those reported by Elms et al.

Most of the posttreatment changes noted in the mandibular intercanine width and arch length were small and probably reflect normal physiologic changes that occur with increasing age, as reported in the literature. It must, however, not be overlooked that overexpansion of the intercanine arch width in the mandible is a potential source of relapse after orthodontic treatment. Although a statistically significant posttreatment increase in incisor irregularity was observed, it is a fact that 90% of the cases at T3 had minimal incisor irregularity (<3.5 mm), and all 31 cases showed a net improvement in mandibular incisor crowding from T1 to T3.

The increase in the posttreatment overbite may be attributed to a physiologic gradual return of the curve of Spee over time, as well as to other factors such as attrition and overeruption of the maxillary incisors. The latter parameters were not investigated in this study and, furthermore, it should be emphasized that the changes in overbite noted in this study were less than previously reported.

The posttreatment changes in the overjet that were noted in this study were not much different than those reported previously for Class II, Division I malocclusions. It is important to emphasize the fact that very few studies dealing with posttreatment orthodontic changes have used postretention records that could match this sample in the length of time covered (x = 11 years and 5 months; range: 7 years to 28 years and 8 months). In this respect the longer postretention time span of the cases included in this study provided more time for posttreatment relapse to take place.

Because it was shown that relapse had occurred in the five variables previously mentioned, a Pearson correlation coefficient was calculated to compare the pretreatment curve of Spee with the posttreatment changes observed for each of the five variables studied. The results of this test revealed that no statistical correlation existed between the original curve of Spee and each of the five factors of relapse (P > .05). Follow-up regression analyses revealed no ability to predict relapse in mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length based on the depth of the pretreatment curve of Spee. It should be noted that in each of these cases, interproximal enamel reduction was performed on the mandibular anterior teeth. The variable with the highest correlation was overjet r = -0.268), yet only 7.2% of the variability seen in the overjet change can be accounted for by the pretreatment curve of Spee (r² = 0.072). It is possible that if a sample with larger pretreatment curves of Spee were studied, a positive correlation could be seen between the larger pretreatment curves of Spee, and the relapse in other aspects of the occlusion posttreatment.
Although this study has shown the clinical effectiveness of using continuous arch wire mechanics to level the curve of Spee, it must be kept in mind that not every straight-wire appliance has the unique prescription that is part of the Alexander Discipline, namely the $-5^\circ$ torque in the mandibular incisor and the $-6^\circ$ distal tip built into the molar tubes. These unique appliance features may play a large role in allowing for an effective, and controlled, mandibular arch leveling as shown in this study. In addition, the mechanical principles of actively tying back a heat-treated curved arch wire may contribute to the success of the arch leveling achieved with the Alexander Discipline. It is unwise to assume that every straight-wire appliance, using continuous arch wire mechanics to level the curve of Spee, will be as successful as the one studied here. Furthermore, this study investigated the cases of not only an experienced clinician but also the authority on the Alexander Discipline.

Because only study models were evaluated, this investigation was unable to ascertain the exact process by which the curve of Spee is leveled with the continuous arch wire mechanics of the Alexander Discipline. Also, the exact process by which the slight relapse of the curve of Spee, noted in this study, occurred was not ascertained. A comprehensive cephalometric appraisal of the mechanism of arch leveling and relapse of the curve of Spee in this sample has been undertaken by Bernstein. Additionally, study model and cephalometric investigations of the curve of Spee leveling process by using incisor intrusion mechanics should also be performed. If the sample of such a study is carefully matched to the present one, valid comparisons could be made to ultimately determine the most effective biomechanics necessary to level the curve of Spee and to maintain it level in the long term.

Conclusions

1. The Alexander Discipline is an effective continuous arch wire technique for leveling the curve of Spee in Class II Division I deep-bite cases treated by nonextraction in which the initial curve of Spee is 2 to 4 mm.
2. The Alexander Discipline efficiently over-treats a pretreatment curve of Spee of 2 to 4 mm in Class II Division I deep-bite cases such that when relapse occurs, the curve of Spee returns to a lesser extent than was present before orthodontic treatment.
3. Postretention changes in overbite, overjet, and irregularity index were small and showed net improvement.
4. With the Alexander Discipline, a pretreatment curve of Spee of 2 to 4 mm that is not completely level posttreatment has a slightly higher incidence and magnitude of relapse than a pretreatment curve of Spee that is completely level posttreatment.
5. There is no ability to predict relapse in mandibular intercanine width, overbite, overjet, mandibular incisor irregularity, and arch length in Class II Division I deep-bite cases treated with the Alexander Discipline based on the pretreatment curve of Spee.

References

15. Lett RL. Overbite correction and relapse as analyzed by


