Efficacy of 2 finishing protocols in the quality of orthodontic treatment outcome

Gregory J. Stock,[a] James A. McNamara, Jr,[b] and Tiziano Baccetti[c]
Ann Arbor, Mich, and Florence, Italy

Introduction: The objectives of this prospective clinical study were to evaluate the quality of treatment outcomes achieved with a complex orthodontic finishing protocol involving serpentine wires and a tooth positioner, and to compare it with the outcomes of a standard finishing protocol involving archwire bends used to detail the occlusion near the end of active treatment. **Methods:** The complex finishing protocol sample consisted of 34 consecutively treated patients; 1 week before debonding, their molar bands were removed, and serpentine wires were placed; this was followed by active wear of a tooth positioner for up to 1 month after debonding. The standard finishing protocol group consisted of 34 patients; their dental arches were detailed with archwire bends and vertical elastics. The objective grading system of the American Board of Orthodontics was used to quantify the quality of the finish at each time point. The Wilcoxon signed rank test was used to compare changes in the complex finishing protocol; the Mann-Whitney U test was used to compare changes between groups. **Results:** The complex finishing protocol group experienced a clinically significant improvement in objective grading system scores after treatment with the positioner. Mild improvement in posterior space closure was noted after molar band removal, but no improvement in the occlusion was observed after placement of the serpentine wires. Patients managed with the complex finishing protocol also had a lower objective grading system score (14.7) at the end of active treatment than did patients undergoing the standard finishing protocol (23.0). **Conclusions:** Tooth positioners caused a clinically significant improvement in interocclusal contacts, interproximal contacts, and net objective grading system score; mild improvement in posterior band space was noted after molar band removal 1 week before debond. (Am J Orthod Dentofacial Orthop 2011;140:688-95)

Orthodontic treatment generally is divided into 3 phases: initial leveling and alignment, anteroposterior correction, and detailing and finishing.[1,2] Both simple and complex protocols exist for detailing and finishing before and after fixed appliance removal. Some examples of finishing protocols include removing archwires and placing serpentine wires,[1] placing finishing bends directly in the archwire,[2] and even sectioning and removing part of the archwire.[3]

Tooth positioners, first described by Kesling,[4] are used by many orthodontists as a finishing and retention device. Actively biting or "exercising" with a positioner in place helps guide teeth into their final occlusion, increasing total tooth contacts.[5] In a series of prospective studies, however, no statistically significant increase was found in tooth contacts for positioner patients compared with Hawley retainer patients 3 months into retention.[6-9]

Several methods of measuring tooth contacts have been implemented, with varied success. One such method is the T-Scan, the data from which have been shown to be reproduced poorly.[10] Other methods include a variety of techniques for analyzing polyether[5,10] or silicone-based[6,7] occlusal registrations. Advances in optical scanning technology now allow scanning study models and other bite registrations, facilitating measurement of both tooth contacts and the interocclusal spaces between teeth with accuracy.[9]

Beyond the assessment of occlusal contacts, the overall quality of orthodontic results can be evaluated with the peer assessment rating,[11] the index of complexity, outcome and need,[12] and the objective grading system (OGS)[13] developed by the American Board of Orthodontics. Although all are suitable methods for evaluating the quality of the results, the OGS was chosen for this study because it can measure the small occlusal changes between stages of finishing.

Whereas detailed finishing protocol procedures have been used for over 50 years, it appears that these methods are shrouded by a lack of evidence or have contradictory evidence. This prospective clinical study was designed to quantify the changes to be expected from 2 finishing protocols, allowing the clinician to make more informed decisions concerning the final phases of fixed appliance treatment.

MATERIAL AND METHODS

The patients participating in this prospective controlled study were divided into 2 treatment groups. The complex finishing protocol group was composed of consecutively finished patients who received serpentine wires 1 week before debond and a tooth positioner at debond, which was to be worn actively for 2 to 4 weeks. The standard finishing protocol patients were treated with finishing bends in the archwires and then given Hawley retainers at debond.

Consecutive patients meeting the inclusion criteria were selected from a faculty private practice in Ann Arbor, Michigan (complex finishing protocol), and the Graduate Orthodontic Clinic at the University of Michigan (standard finishing protocol). To control for potential discrepancies in case complexity between the standard finishing protocol and the complex finishing protocol, a discrepancy index score was calculated on the initial treatment models for each group at the end of patient enrollment.[14] Statistical tests were performed to ensure that the samples were similar at the beginning of treatment. Inclusion criteria for this study required all participants to be treated to as near an ideal finish as possible (ie, no early debonds), to give verbal consent that the patient adhered to the prescribed protocol, and to be subjected prospectively to a complete set of serial study models.

Thirty-five consecutively finished patients meeting these inclusion criteria comprised each of the 2 finishing protocols. Of these, 1 dropped out of each sample because they transferred to an out-of-area practice during treatment. The number of patients to be enrolled in each finishing protocol group was determined with a preliminary analysis of the power of the study. The power resulted to be greater than 0.90 at an α of 0.05, with a sample size exceeding 30 patients in each group.

Table I. Demographics of the 2 groups at the observation times

Group	Age at T0 (y) Mean	SD	Age at T3 (y) Mean	SD	Difference, T3-T0 (y) Mean	SD
CFP (20 girls, 14 boys)	12.8	1.2	15.1	1.1	2.3	0.6
SFP (16 girls, 18 boys)	12.7	1.8	15.3	1.6	2.6	0.7

CFP, Complex finishing protocol; *SFP*, standard finishing protocol.

Although the patients were asked to record their approximate amounts of positioner wear, none was excluded from the study for poor compliance. These criteria were used to allow the sample to represent a normal pool of orthodontic patients. The serial study models for the complex finishing protocol included initial models (T0), before the serpentine wires (T1), at debond (T2), and after the positioner (T3). The serial study models for the standard finishing protocol included initial models (T0) and at debond (T3).

The demographic data of the 2 groups are reported in Table I.

The complex finishing protocol had the following procedure. The first phase consisted of 2 parts: molar band removal and placement of the serpentine wires. The removal of all molar bands and a transpalatal arch if present was to allow for spontaneous closure of the posterior band space during the week before debonding. Serpentine wires (Fig 1) were used to ligate the teeth together, with the assumption that subtle vertical settling of the occlusion would occur without the archwires in place.

All patients had their molar bands and archwires removed an average of 7.3 days (±1.2 days) before debond to allow for closure of band spaces and presumably initial settling of the occlusion. Each arch subsequently was ligated from second premolar to second premolar in a figure-8 pattern with an 0.008-in ligature wire (Fig 1). The next week, all fixed appliances were removed, and a tooth positioner (Fig 2) was delivered with instructions to wear it full time for 24 hours. After that, the patients were instructed to wear the positioner as much as possible for 5 days, and then 4 hours per day and at night for 2 to 3 weeks. The positioner protocol lasted an average of 18.2 days (±7.6 days).

The prescribed procedure for the standard finishing protocol sample was for the detailing and finishing to be accomplished by "artistic" archwire bends and intermaxillary elastics before debonding. Posttreatment models then were obtained at fixed appliance removal.

Each set of study models from T1 to T3 was digitized by using an optical model scanner (3Shape RD640 3D
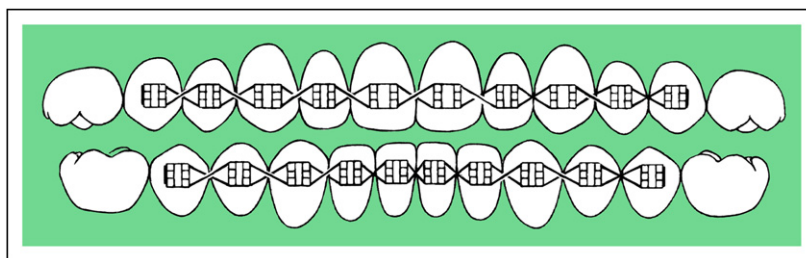
Fig 1. Placement of serpentine wires. One week before debonding, the archwires were removed as were the bands on the molars. Ligature wire then was placed in a figure-8 manner from second premolar to second premolar in both arches.
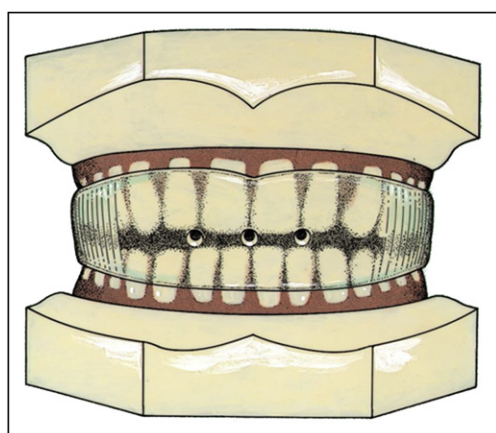
Fig 2. The tooth positioner. Impressions of both arches were taken with the fixed appliances in place. Work models were poured, trimmed, and then sent to the laboratory. The laboratory technician carved away the brackets and bands, and then reset the teeth in wax to an ideal occlusion, based on the orthodontist's instructions. The positioner then was fabricated from a resilient material such as silicone (figure adapted from McNamara and Brudon[1]).

scanner; EMS Digital Solutions, Dublin, Ireland). Models were hand-graded by using the criteria of the OGS (alignment, marginal ridges, buccolingual inclination, occlusal relationships, overjet, and interproximal contacts), except for occlusal contacts, which were calculated from the digital models by using software with an accuracy of 20 μm (Orthoanalyzer, version 2008-1; 3Shape, Copenhagen, Denmark).

Points were deducted according to the OGS protocol for each tooth not meeting the grading criteria. Deductions for each criterion were added for the final total patient score as described by the American Board of Orthodontics.[13] Models were graded randomly to prevent bias, and the OGS scores were verified by spot checks conducted by a calibrated American Board of

Orthodontics grader. Thirty-five sets of models were regraded by the lead investigator (G.J.S.) 1 month after data collection, and the results were analyzed for intra-rater reliability. Root angulation was the only measurement for which a radiograph was used rather than study models to compute an OGS score; this measure was not included in the score because of the number of panoramic films that would have been necessary to take in a relatively short period of time. Root angulation was assumed to remain relatively constant during the period studied.

Statistical analysis

Descriptive statistics including means and standard deviations were calculated for age, duration of treatment, variables at time points T0 to T3, and changes between time points for the 2 groups. The data were analyzed with a statistical software package (version 17.0; SPSS, Chicago, Ill). Statistical significance was tested at $P <0.05$, $P <0.01$, and $P <0.001$.

Because of the ordinal nature of the American Board of Orthodontics discrepancy index and the OGS scores, nonparametric statistical calculations were conducted on all data. The Mann-Whitney U test was used for analysis of initial forms and direct comparisons of the 2 protocols, and the Wilcoxon signed rank test was used to test for significant differences between the means of the complex finishing protocol at the different time intervals. An interclass correlation score of 0.953 was calculated on the 35 sets of models randomly chosen and rescored, indicating high intragrader reliability.

RESULTS

Descriptive data and statistical comparisons for the starting forms in terms of the discrepancy index scores are given in Table II. Descriptive data and statistical comparisons for the changes in the complex finishing protocol sample over time and the differences between the 2 protocols are given in Tables III and IV, respectively.

Table II. Comparison of starting forms (American Board of Orthodontics discrepancy index scores)

Discrepancy index measures	Complex finishing protocol n = 34		Standard finishing protocol n = 34		Complex vs standard protocols	
	Mean	SD	Mean	SD	Mean difference	Significance
Overjet	0.82	1.03	0.91	1.14	−0.09	NS
Overbite	2.00	2.26	2.00	2.13	0.00	NS
Openbite	0.74	2.04	0.38	1.58	0.36	NS
Crowding	0.91	1.29	1.18	1.14	−0.27	NS
Occlusion	2.09	2.04	2.41	2.69	−0.32	NS
Crossbites	0.29	0.87	0.76	1.21	−0.47	*
Cephalometrics	3.24	3.98	4.41	5.54	−1.17	NS
Other complexities	0.35	1.25	0.06	0.34	0.29	NS
Total score	10.44	6.24	12.11	6.46	−1.67	NS

NS, Not significant.
*$P <$0.05.

Table III. Changes in complex finishing protocol during time of observation (T3-T1)

American Board of Orthodontics measures	Deband; serpentine wires (T1) n = 34		Debond; deliver positioner (T2) n = 34		End of positioner wear (T3) n = 34		Significance	
	Mean	SD	Mean	SD	Mean	SD	T1-T2	T2-T3
Alignment/rotations	2.32	1.39	2.47	1.42	1.53	0.96	NS	‡
Marginal ridges	5.06	2.44	4.47	1.75	3.79	1.65	NS	*
Buccolingual inclination	2.35	1.92	2.29	2.57	2.18	2.41	NS	NS
Overjet	3.00	1.65	2.26	1.78	1.97	1.59	†	NS
Occlusal contacts	7.91	2.88	7.32	3.19	3.15	3.04	NS	‡
Occlusal relationships	0.71	0.87	0.65	0.95	1.47	1.60	NS	†
Interproximal contacts	2.41	2.02	1.82	1.68	0.59	1.02	*	‡
Total OGS score	23.76	6.56	21.29	6.80	14.68	7.28	†	‡

NS, Not significant.
*$P <$0.05; †$P <$0.01; ‡$P <$0.001.

When the discrepancy index scores were compared overall for the 2 treatment groups, the groups were similar clinically at T0. When the subscores were examined by category (Table II), only 1 variable (crossbite) had a statistically significant difference; however, the significance level was only $P = 0.03$. Additionally, the mean crossbite subgroup score for each group was less than 1, meaning that both groups averaged less than 1 tooth in crossbite at T0. Thus, the 2 groups were well matched for complexity at T0.

Analysis of treatment effects

Time-related changes in the complex finishing protocol are given in Table III. The distribution of OGS scores at molar band removal and serpentine wire delivery (Fig 3, *A*) shows that, after the majority of orthodontic treatment, most patients achieved an OGS score between 20 and 30.

From T1 to T2 (band removal and serpentine wire to debond), an interval typically of 1 week, several slight but statistically significant changes occurred in the complex finishing protocol group, with an overall reduction in the OGS score of 2.5 points ($P <$0.01).

Improvements were seen in overjet (−0.73) and interproximal contacts (−0.59) at T2. No significant changes were observed in the other 6 variables considered. The distribution of OGS scores at debond (Fig 3, *B*) illustrates how the distribution of OGS scores shifted slightly to the left, indicating mild improvements in the scores after band removal and serpentine wire insertion.

The most significant improvements in the occlusion were noted between T2 and T3 (debond to end of positioner wear), with a decrease in the overall OGS score from 21.3 to 14.7 points, a change that was highly statistically significant ($P <$0.001). In the subcategories, highly significant ($P <$0.001) improvements were seen in occlusal contacts (−4.1), interproximal contacts (−1.2), and alignment and rotations (−1.0). Marginal ridge alignment improved slightly as well (0.7; $P <$0.01). Interestingly, occlusal relationships worsened slightly (0.8; $P <$0.01). No changes were noted in the

Table IV. Comparison of complex finishing and standard finishing protocols during time of observation

American Board of Orthodontics measures	*Standard finishing protocol, debond (ST3) n = 34*		*Complex finishing protocol, debond (CT2) n = 34*		*Complex finishing protocol, end of positioner wear (CT3) n = 34*		*Significance*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*ST3-CT2*	*ST3-CT3*
Alignment/rotations	2.18	1.14	2.47	1.42	1.53	0.96	NS	*
Marginal ridges	3.00	1.94	4.47	1.75	3.79	1.65	‡	*
Buccolingual inclination	4.29	2.83	2.29	2.57	2.18	2.41	†	†
Overjet	2.38	1.84	2.26	1.78	1.97	1.59	NS	NS
Occlusal contacts	7.50	3.12	7.32	3.19	3.15	3.04	NS	‡
Occlusal relationships	1.65	2.44	0.65	0.95	1.47	1.60	*	NS
Interproximal contacts	2.00	1.60	1.82	1.68	0.59	1.02	NS	‡
Total OGS score	23.00	6.89	21.29	6.80	14.68	7.28	NS	‡

NS, Not significant.
*$P <0.05$; †$P <0.01$; ‡$P <0.001$.
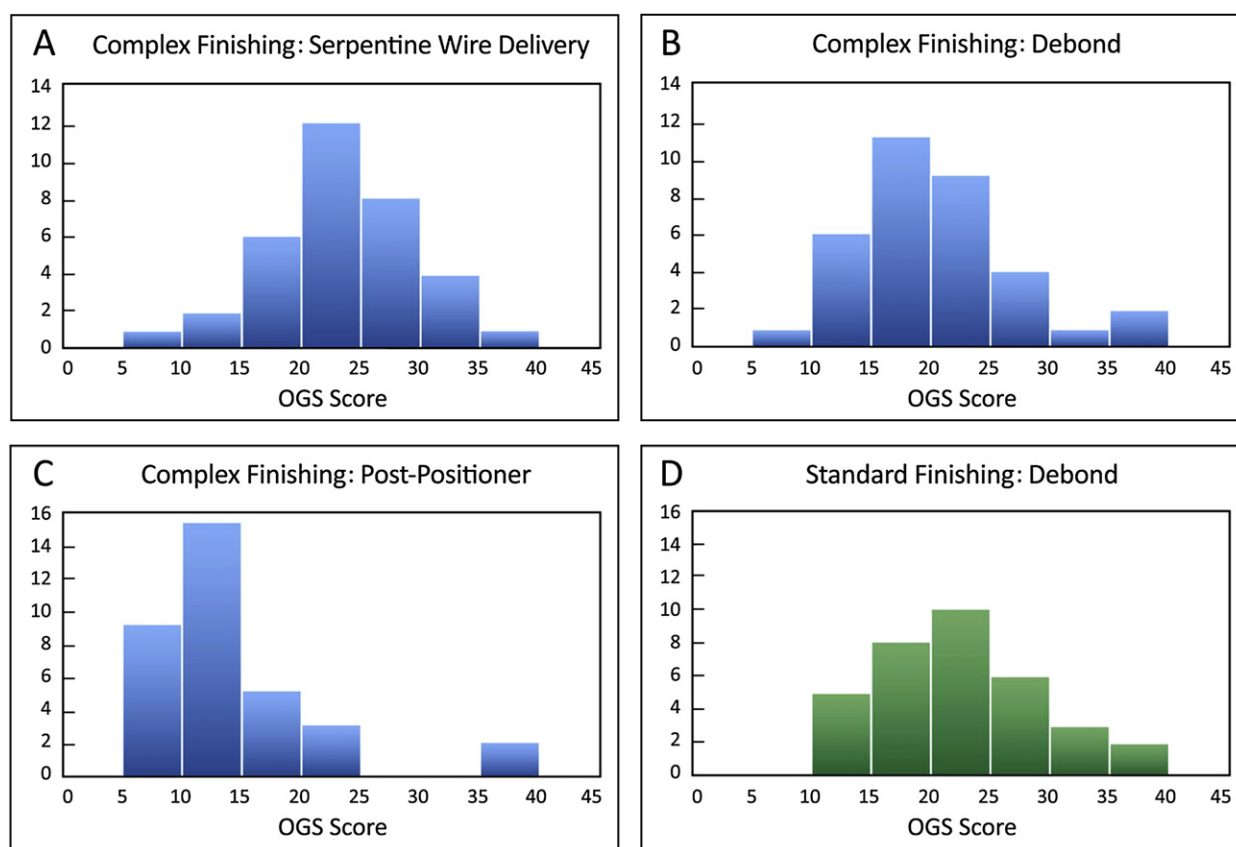
Fig 3. A, Complex finishing protocol, distribution (number of patients) of OGS scores at T1; **B,** complex finishing protocol, distribution (number of patients) of OGS scores at T2; **C,** complex finishing protocol, distribution (number of patients) of OGS scores at T3; **D,** standard finishing protocol distribution (number of patients) of OGS scores at T3.

scores for buccolingual inclination and overjet. The distribution of OGS scores after positioner wear (Fig 3, *C*) demonstrates the significant improvement for the complex finishing protocol, although 2 patient outliers did not improve appreciably from debond. The complex finishing protocol sample included consecutively finished patients. The actual duration of positioner wear for each patient was not measured.

Differences between the complex and the standard finishing protocols

Both the complex and the standard finishing protocol groups were evaluated at appliance removal (Table IV). The distribution of OGS scores for the standard finishing protocol at debond (T3) is shown in Figure 3, *D*.

With regard to the overall scores of both groups at debond, the standard finishing protocol had a score of 23.0 points, and the complex finishing protocol scored 21.3 points; these scores were not different statistically. The major difference between the groups was in marginal ridge discrepancy, with scores of 3.0 points for the standard finishing protocol and 4.5 points for the complex finishing protocol (*P* <0.001). Differences also were seen in buccolingual inclination (standard, 4.3; complex, 2.3; *P* <0.01) and occlusal relationships (standard, 1.7; complex. 0.7; *P* <0.05).

When comparing the standard finishing protocol with the complex finishing protocol at the end of active treatment for both groups, we found several significant differences. The complex finishing protocol had significantly fewer points lost due to both lack of occlusal contact (standard, 7.5; complex, 3.2; *P* <0.001) and interproximal contact (standard, 2.0; complex, 0.6; *P* <0.001); this group had a highly significant lower total OGS score (standard, 23.0; complex, 14.7; *P* <0.001) as well. The complex finishing protocol lost 2.2 points because of buccolingual inclination, and the standard finishing protocol lost 4.3 points (*P* <0.01). The standard finishing protocol lost 2.2 points for alignment and rotations, but the complex finishing protocol only lost 1.5 points (*P* <0.05). The standard finishing protocol still lost fewer points because of marginal ridge discrepancies (standard, 3.0; complex, 3.8; *P* <0.05).

DISCUSSION

In this prospective longitudinal study, we compared the effects of a complex finishing protocol over time with a standard finishing protocol of archwire bends to fine-detail the occlusion. In the complex finishing protocol, the additive effects of molar band removal, the placement of serpentine wires, and the wearing of a tooth positioner on final occlusal detailing were analyzed for the first time.

One week before debond, all molar bands were removed to allow for the posterior band space to close spontaneously, presumably due to the pull of the transseptal fibers connecting the teeth. Light ligature wires then were placed in a serpentine configuration after archwire removal to allow for minor vertical settling of the occlusion before band removal.[1]

A significant overall reduction in OGS scores was observed from T1 (23.8) to T2 (21.3; Table III), meaning that this part of the finishing protocol had a mild positive effect in improving the occlusion. The 2.5-point reduction was due primarily to decreased average scores in 2 areas: overjet and interproximal contacts. After serpentine wire placement, 0.7 fewer points were lost due to overjet discrepancies. The slight loss of anterior maxillary torque by removing a finishing archwire and tightly lacing the dentition most likely can explain this occurrence. OGS points lost because of interproximal spacing decreased by −0.6 points on average, primarily in the posterior regions.

Significant settling of the occlusion and a reduction in interproximal contacts were noted after treatment with the tooth positioner, 2 areas where tooth positioners are claimed to be particularly effective.[5,15] The number of points lost from lack of occlusal contact dropped substantially (−4.2) between T2 and T3. Interproximal contact point loss was also reduced significantly (−1.2). Marginal ridge alignment improved as well, with 0.7 fewer points lost for marginal ridge discrepancies. Counterintuitively, a statistically significant increase in points lost due to occlusal relationships was noted. After positioner wear, there was a mean increase in the occlusal relationship discrepancy of 0.8 points. Despite this slight worsening in the OGS score, a statistically and clinically significant net decrease of −6.6 points lost after the 1-month positioner protocol was observed.

These results confirm the findings of some earlier research on the use of tooth positioners but conflict with several preconceived notions about the appliance. The ability of the positioner to increase interocclusal contact has been researched extensively in the last few years. Durbin and Sadowsky[5] found a statistically significant increase in total tooth contacts after 3 months of positioner wear, as did Horton et al[7] after 2 months of tooth perfector wear. Haydar et al[6] did not find a significant difference in tooth contacts after 3 months of positioner wear when compared with patients with Hawley retainers.

On the basis of the results of our study, the decrease of over 4 OGS points for occlusal contacts because of positioner wear could easily be significant enough to improve a case to the level deemed board quality. Park et al[16] performed the only other study examining tooth positioner effects using American Board of Orthodontics criteria, and they found no significant difference in the OGS occlusal contacts subscore compared with the controls at fixed appliance removal. They did not, however, compare occlusal contacts before and after the tooth positioner protocol for the treatment group.

Another relevant finding involves the claim by some authors that a tooth positioner can either result in rotations of teeth or allow old rotations to relapse.[17,18] The results of our study indicate that not only were alignment and rotations maintained, but also they actually improved by a mean of 0.9 points by following the prescribed positioner protocol.

When the ends of the active treatments of the standard finishing protocol (debond) and the complex finishing protocol (after 1 month of positioner wear) were compared, a highly clinically and statistically significant dissimilarity between the 2 groups (8.3 points) was observed, with average scores of 23.0 for the standard finishing protocol and 14.7 for the complex finishing protocol. The major changes leading to this difference were in the category of occlusal contacts; the standard finishing protocol lost 4.4 more points than did the complex finishing protocol. Another category where a difference was noted was interproximal contacts; the standard finishing protocol lost 2.0 points, 1.4 more points than did the complex finishing protocol.

This study illustrates that a significant improvement in the quality of case finish can be expected with the complex finishing protocol tested. The majority of the improvement in the results occurred with the tooth positioner, with only mild improvement observed when the molar bands were removed and the serpentine wires were placed. During the week before debonding, slight decreases were noted in overjet and interproximal spacing. From a clinical standpoint, the key factor appears to be the removal of the bands posteriorly rather than the placement of the serpentine wires. The majority of spaces at the serpentine wire delivery time occurred adjacent to the molars, and serpentine wires are only attached from second premolar to second premolar. It is unlikely that any spacing was present in the canine or premolar regions in either arch because an elastomeric chain extending from first molar to first molar was used in both arches to eliminate interproximal spacing.

The ability of the tooth positioner to close both interocclusal and interproximal spaces is the most dramatic effect of the protocol, a finding that has significant clinical implications. The remaining statistically significant effects of the complex finishing protocol might be too subtle to be relevant if looked at individually, but the combined effects elicit a clinically significant improvement in the results.

It is a concern that the occlusal relationship appeared to worsen, albeit only slightly, after 1 month of positioner wear. It appears that the reason for this worsening can be attributed to 6 patients whose relationship worsened by 3 or more points after positioner wear. In these patients, the overall OGS score only decreased by an average of 1.3, compared with the highly significant net decrease of 6.6 points lost for the entire complex finishing protocol sample. There might be other factors resulting in this increase, including lack of positioner wear or poor compliance with prescribed biting exercises. The complex finishing protocol patients considered in this study were treated prospectively and consecutively; none was excluded because of poor compliance. If this small number of patients had been excluded, the overall OGS score presumably would have been lower in the complex finishing group.

The outcomes of the complex finishing protocols in terms of quality of occlusion deserve to be appraised in the long term, once patients wear retention appliances. Different retention protocols might lead to different results as to the stability of the supplementary quality of treatment outcomes elicited by the tooth positioner.

CONCLUSIONS

This prospective study on finishing protocols for fixed appliance orthodontic therapy study showed the following.

1. After the removal of the molar bands in each arch, a mild amount of band space closure occurred posteriorly during the week before appliance removal.
2. The serpentine wires did not have a clinically significant effect in allowing settling of the occlusion.
3. Patients treated with a tooth positioner at debond showed highly significant improvements in interocclusal contacts and closure of interproximal spaces.
4. Treatment with a tooth positioner resulted in a highly statistically and clinically significant improvement in OGS scores. Orthodontists who desire to finish their patients to board quality standards on a routine basis might want to consider including a tooth positioner as part of their typical finishing protocol.

REFERENCES

1. McNamara JA Jr, Brudon WL. Orthodontics and dentofacial orthopedics. Ann Arbor, Mich: Needham Press; 2001.
2. McLaughlin RP, Bennett JC, Trevisi HJ. Systemized orthodontic treatment mechanics. St Louis: Mosby; 2002.

3. Haltom T. Finishing and retention procedures in the Alexander discipline. Semin Orthod 2001;7:132-7.

4. Kesling HD. The philosophy of the tooth positioning appliance. Am J Orthod Oral Surg 1945;31:298-304.

5. Durbin DS, Sadowsky C. Changes in tooth contacts following orthodontic treatment. Am J Orthod Dentofacial Orthop 1986;90:375-82.

6. Haydar B, Ciger S, Saatci P. Occlusal contact changes after the active phase of orthodontic treatment. Am J Orthod Dentofacial Orthop 1992;102:22-8.

7. Horton JK, Buschang PH, Oliver DR, Behrents RG. Comparison of the effects of Hawley and perfector/spring aligner retainers on postorthodontic occlusion. Am J Orthod Dentofacial Orthop 2009;135:729-36.

8. Sauget E, Covell DA Jr, Boero RP, Lieber WS. Comparison of occlusal contacts with use of Hawley and clear overlay retainers. Angle Orthod 1997;67:223-30.

9. Gazit E, Lieberman MA. Occlusal contacts following orthodontic treatment. Angle Orthod 1985;55:316-20.

10. Razdolsky Y, Sadowsky C, BeGole E. Occlusal contacts following orthodontic treatment: a follow-up study. Angle Orthod 1989;59:181-5.

11. Richmond S, Shaw WC, Roberts CT, Andrews M. The PAR index (peer assessment rating): methods to determine outcome of orthodontic treatment in terms of improvement and standards. Eur J Orthod 1992;14:180-7.

12. Daniels C, Richmond S. The development of the index of complexity, outcome and need (ICON). J Orthod 2000;27:149-62.

13. Casko JS, Vaden JL, Kokich VG, Damone J, James RD, Cangialosi TJ, et al. Objective grading system for dental casts and panoramic radiographs. Am J Orthod Dentofacial Orthop 1998;115:589-99.

14. Cangialosi TJ, Riolo ML, Owens SE Jr, Dykhouse VJ, Moffitt AH, Grubb JE, et al. The ABO discrepancy index: a measure of case complexity. Am J Orthod Dentofacial Orthop 2004;125:270-8.

15. Vorhies JM. Short, intensive use of tooth positioners and an appraisal of the results. Angle Orthod 1960;30:248-54.

16. Park Y, Hartsfield JK, Katona TR, Roberts EW. Tooth positioner effects on occlusal contacts and treatment outcomes. Angle Orthod 2008;78:1050-6.

17. Cottingham LL. Gnathologic clear plastic positioner. Am J Orthod 1969;55:23-31.

18. Proffit WL, Fields HW, Sarver D. Contemporary orthodontics. 4th ed. St Louis: Mosby; 2006.