Evaluation of 3 retention protocols using the American Board of Orthodontics cast and radiograph evaluation

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Introduction: The purpose of this study was to quantify tooth movement among different retention protocols after the orthodontic appliances were removed. **Methods:** A total of 90 patients were evaluated using the American Board of Orthodontics discrepancy index and the cast and radiograph evaluation at debond and the 1-year recall. These patients were equally divided into 3 retention protocols: upper Hawley/lower Hawley, upper Hawley/lower bonded, and upper Essix/lower bonded. The patients were then equally grouped by extraction or nonextraction treatment and case complexity. Paired *t* tests were used to compare the paired sample means. Analysis of variance tests were used to compare the means for more than 2 groups. A 2-sided 0.05 alpha level was used to define statistical significance. **Results:** The upper Hawley/lower bonded showed the greatest amount of settling, and the upper Essix/lower bonded had the least settling, but these differences were statistically insignificant. The differences between the extraction and nonextraction treatments were not significant. The group with low discrepancy index scores showed significantly more settling than did the group with high discrepancy index scores. **Conclusions:** The cast and radiograph evaluation variables that improved overall were marginal ridges, overjet, occlusal contacts, interproximal contacts, root angulation, and total cast and radiograph score. The cast and radiograph evaluation variables that worsened were alignment/rotation, buccolingual inclination, and occlusal relationship. Extraction or nonextraction treatment led to no real difference in settling. The discrepancy index, or initial case complexity, was the greatest factor in determining the improvement of occlusion or settling during the retention phase. (Am J Orthod Dentofacial Orthop 2013;144:16-22)

Settling is the natural vertical and horizontal movement of teeth into functionally stable interocclusal contacts after orthodontic treatment. It is important to remember the principles behind a stable occlusion. Andrews' 6 keys to occlusion[1] have been used in determining aspects of a stable occlusion. He stated that a complete and proper occlusion included molar interarch relationship, mesiodistal crown angulation, labiolingual crown inclination, absence of rotation, tight contacts, and curve of Spee. The periodontal ligament and connective tissues also influence the stability of the dentition if no circumferential supracrestal fiberotomies are performed, since they are altered during orthodontic treatment.[2-4] Many authors have looked at the stability of the dentition after the orthodontic appliances have been removed and found that the overall stability and functionality of the occlusion improve during the retention period.[5,6] However, some authors have found that the overall occlusion worsened during the retention period.[7]

Studies have evaluated the change in occlusal contacts by settling during the retention period.[8,9] They found that the number of occlusal contacts increased. One study showed that the increase in occlusal contacts was entirely attributed to changes in the posterior segment,[8] whereas another study showed slight increases in the anterior segment along with the previously stated increase in the posterior segment.[9]

If one is going to evaluate tooth movement during the retention period, it is important to know how different types of retention affect these tooth movements. It

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has been found that the maxillary removable Hawley appliance results in greater improvement of the occlusion through settling than do maxillary removable clear overlay retainers.[10] One difficulty in evaluating improvement of occlusion during the retention period is to quantify positive or negative tooth movements. The cast and radiograph evaluation (CRE), formerly the objective grading system, was created by the American Board of Orthodontics (ABO) to evaluate excellence of occlusion for board certification.[11] Alignment/rotation, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts, and root angulation are the variables evaluated with the CRE. This method is applicable for consistently quantifying improvement or worsening after orthodontic treatment. Low CRE scores represent a better occlusion. High CRE scores represent more imperfections in the dentition. If the CRE score decreases, it shows an improvement in occlusion. If the CRE score increases, it shows that more teeth have moved out of proper position and might indicate relapse. Some studies have used the CRE to observe the changes in tooth movement from debond to different specified recall dates.[7,12] One study found that the overall CRE score improved during the retention period.[12] These authors found that the CRE variable of alignment/rotation worsened during the retention period. Marginal ridges, buccolingual inclinations, occlusal contacts, overjet, and occlusal relationships all improved. This study also used the peer assessment rating to assess initial case irregularity.[13] They found that the peer assessment rating or initial case irregularity was not a good indicator of future settling during retention.

The literature has shown that teeth move after the orthodontic appliances are removed. We need to further understand the types of tooth movement after fixed orthodontic treatment. The purpose of this study was to quantify the differences in tooth movement, from the debond date to 1 year postdebond, among 3 retention protocols using the CRE. The sample was also separated into groups of extraction and nonextraction therapy, along with low and high case complexities, using the discrepancy index to determine whether there were any differences in tooth movement among these groups. The discrepancy index quantifies many different aspects of malocclusion and assigns point totals based on severity. For example, crowding greater than 7 mm will receive 7 points, and crowding of 3.5 mm will receive 2 points.[14]

MATERIAL AND METHODS

Records were evaluated from patients treated at the University of Oklahoma graduate orthodontic clinic between 2002 and 2010 to find equal numbers of patients for each retention protocol group. The subjects were selected based on availability of the records and also to be equally divided among retention protocol groups and type of treatment. This study was approved by the institutional review board.

The 90 patients were divided into 3 retention groups: upper Hawley/lower Hawley, upper Hawley/lower bonded canine to canine, and upper Essix/lower bonded canine to canine. Each group included 15 extraction and 15 nonextraction subjects for a total of 30 in each of the 3 groups. Of the 90 patients in the sample, 45 had extractions and 45 did not. The different retention groups were compared according to the 8 variables of the CRE at debond and the 1-year recall. The subjects were also separated into extraction and nonextraction groups, and groups with low (10-20) and high (>20) discrepancy index scores. The patients were instructed to wear the removable retainer full time for 6 months and then only at night thereafter.

The patient records needed for this study were pretreatment study models and cephalometric radiographs, debond study models and panoramic radiographs, and 1-year posttreatment models and panoramic radiographs.

The exclusion criteria for this study included patients with cleft lip and palate or other craniofacial syndromes, incomplete records, multiple missing teeth, continued habits that cause malocclusion, scores less than 10 on the discrepancy index, and implants or dental prosthetic bridges.

The sample included 49 female (54.5%) and 41 male (45.5%) subjects. Of the 90 patients, there were 77 whites (85%), 3 Asians (3%), 6 Hispanics (8%), and 4 blacks (4%). The average age was 15.2 years, with a range of 11.1 to 34.8 years. The average length of treatment time was 24.7 months (SD, 2.1 years) with a range of 16 to 35 months. The average length of retention time was 12.3 months (SD, 1 year) with a range of 8 to 18 months.

All subjects were evaluated with the ABO discrepancy index. This analysis quantifies the complexity of orthodontic treatment for each patient.[14] Of the 90 patients, 57 had a discrepancy index score in the range of 10 to 20. There were 33 who scored 20 and over. All subjects analyzed in this study were board-qualifying cases with regard to case complexity measured by the discrepancy index. The upper Hawley/lower Hawley group had 19 Angle Class I, 8 Class II, and 3 Class III subjects. The upper Hawley/lower bonded group had 7 Class I, 18 Class II, and 2 Class III patients. The upper Essix/lower bonded group had 13 Class I, 14 Class II, and 3 Class III subjects. The upper Hawley/lower Hawley group had the most Class I patients. The upper Hawley/lower bonded group had the most Class II subjects.

Table I. CRE scores for the 90 subjects at debond (T1) and recall (T2)

Variable	*Average at T1*	*Average at T2*	P *value*
Alignment/rotation	7.43	8.46	0.0028*
Marginal ridges	4.28	2.99	<0.0001*
Buccolingual inclination	2.57	2.99	0.0080*
Overjet	4.00	2.62	<0.0001*
Occlusal contacts	4.89	2.57	<0.0001*
Occlusal relationship	3.08	3.48	0.1337
Interproximal contacts	1.47	0.57	<0.0001*
Root angulation	2.03	1.67	<0.0001*
CRE total	29.80	25.21	<0.0001*

*Statistically significant.

All patients were measured according to the ABO's CRE. The following aspects of occlusion were measured: alignment/rotation, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts, and root angulation.[11]

Statistical analysis

To test for error of measurement, 10 subjects were selected at random and rescored with the CRE. This score was compared with the original score, and the difference of each variable was calculated. Dahlberg's formula,[15] $S^2 = \sum d^2/2n$, was used to calculate the error of the measurements.

Software (version 9.2; SAS, Cary, NC) was used for the statistical analysis. Paired *t* tests were used to compare the paired sample means. Analysis of variance tests were used to compare the means for more than 2 groups. A 2-sided 0.05 alpha level was used to define statistical significance.

RESULTS

Overall differences of the 90 subjects in CRE scores from debond to the 1-year recall for alignment/rotation, marginal ridges, buccolingual inclination, overjet, occlusal contacts, interproximal contacts, root angulation, and total CRE score proved to be statistically significant. The difference from debond to the recall for occlusal relationship showed statistical insignificance. The variables that improved in occlusion were marginal ridges, overjet, occlusal contacts, interproximal contacts, root angulation, and CRE total. The variables that worsened were alignment/rotation, buccolingual inclination, and occlusal relationship. The total CRE score improved from 29.8 to 25.2 points. This was an improvement of 4.6 points from debond to the 1-year recall (Table I).

Table II shows the comparison of variables among the different retention groups. There were statistical

Table II. Comparison of variables among the different retention groups

Variable	*Retention group*	*Mean of difference (T2-T1)*	P *value*
Alignment/rotation	Upper Hawley/lower Hawley	1.87	0.1323
	Upper Hawley/lower bonded 3-3	0.23	
	Upper Essix/lower bonded 3-3	0.97	
Marginal ridges	Upper Hawley/lower Hawley	−2.23	0.0182*
	Upper Hawley/lower bonded 3-3	−1.13	
	Upper Essix/lower bonded 3-3	−0.50	
Buccolingual inclination	Upper Hawley/lower Hawley	0.83	0.1450
	Upper Hawley/lower bonded 3-3	0.33	
	Upper Essix/lower bonded 3-3	0.10	
Overjet	Upper Hawley/lower Hawley	−1.13	0.5437
	Upper Hawley/lower bonded 3-3	−1.87	
	Upper Essix/lower bonded 3-3	−1.13	
Occlusal contacts	Upper Hawley/lower Hawley	−2.13	0.8190
	Upper Hawley/lower bonded 3-3	−2.67	
	Upper Essix/lower bonded 3-3	−2.17	
Occlusal relationship	Upper Hawley/lower Hawley	0.43	0.9846
	Upper Hawley/lower bonded 3-3	0.33	
	Upper Essix/lower bonded 3-3	0.43	
Interproximal contacts	Upper Hawley/lower Hawley	−1.60	0.0162*
	Upper Hawley/lower bonded 3-3	−1.00	
	Upper Essix/lower bonded 3-3	−0.10	
Root angulation	Upper Hawley/lower Hawley	−0.57	0.1740
	Upper Hawley/lower bonded 3-3	−0.37	
	Upper Essix/lower bonded 3-3	−0.17	
Total CRE	Upper Hawley/lower Hawley	−4.57	0.2784
	Upper Hawley/lower bonded 3-3	−6.53	
	Upper Essix/lower bonded 3-3	−2.67	

T2, Recall; *T1*, debond; *3-3*, canine to canine.
*Statistically significant.

Table III. CRE scores at debond (T1) and recall (T2) for the 3 retention groups

Retention group	*Variable*	*Average at T1*	*Average at T2*	P *value*	*Power*
UH/LH	Alignment/ rotation	7.57	9.43	0.0036*	0.94
	Marginal ridges	5.20	2.97	0.0002*	0.98
	Buccolingual inclination	2.50	3.33	0.0072*	0.99
	Overjet	4.07	2.93	0.0640	0.39
	Occlusal contacts	5.47	3.33	0.0245*	0.39
	Occlusal relationship	2.57	3.00	0.3227	0.14
	Interproximal contacts	2.40	0.80	0.0048*	0.74
	Root angulation	2.23	1.67	0.0034*	1.00
	CRE total	31.93	27.37	0.0350*	0.44
UH/LB	Alignment/ rotation	6.90	7.13	0.6835	0.08
	Marginal ridges	3.87	2.73	0.0072*	0.95
	Buccolingual inclination	2.60	2.93	0.1940	0.65
	Overjet	4.37	2.50	0.0020*	0.78
	Occlusal contacts	4.83	2.17	<0.0001*	1.00
	Occlusal relationship	2.57	2.90	0.4704	0.12
	Interproximal contacts	1.40	0.40	0.0029*	0.89
	Root angulation	1.83	1.47	0.0190*	0.99
	CRE total	28.53	22.00	0.0004*	0.96
UE/LB	Alignment/ rotation	7.83	8.80	0.0893	0.44
	Marginal ridges	3.77	3.27	0.1731	0.36
	Buccolingual inclination	2.60	2.70	0.7031	0.08
	Overjet	3.57	2.43	0.0248*	0.63
	Occlusal contacts	4.37	2.20	0.0013*	0.78
	Occlusal relationship	4.10	4.53	0.3931	0.15
	Interproximal contacts	0.60	0.50	0.5407	0.16
	Root angulation	2.03	1.87	0.1694	0.99
	CRE total	28.93	26.27	0.0484*	0.68

UH/LH, Upper Hawley/lower Hawley; *UH/LB*, upper Hawley/lower bonded; *UE/LB*, upper Essix/lower bonded.
*Statistically significant.

differences for marginal ridges, occlusal contacts, and interproximal contacts among the different retention groups. There was no statistical difference between the retention groups for alignment/rotation, buccolingual inclination, overjet, occlusal relationship, and root angulation. There was no statistical change from debond to the recall for the total CRE score among the 3 retention groups.

At debond, the alignment/rotation variable was the largest contributor to the overall CRE score at 25%. The interproximal contact variable contributed the least at 5% of the overall CRE score. At the recall, the alignment/rotation variable was the largest contributor to the overall CRE score at 34%. The interproximal contact variable contributed the least at 2% of the overall CRE score.

The variables of each retention group were compared at debond and recall (Table III). All 3 groups improved in total CRE scores. The upper Hawley/lower bonded retainer group demonstrated the greatest improvement in occlusion with 5 variables that showed statistical improvement in the occlusion. The upper Hawley/lower Hawley group had 4 variables that had statistical improvements, but 2 variables showed statistical worsening. The upper Essix/lower bonded retainer had 2 variables that showed statistically significant improvements. This group showed the least improvement among the 3 retention protocols (Fig).

The mean differences for extraction or nonextraction from debond and recall were all statistically insignificant except for interproximal contacts (Table IV). The variables were compared according to the discrepancy index score. In the low discrepancy index group (10-20), the mean values at debond were significantly different from those at the recall for marginal ridges, buccolingual inclination, overjet, occlusal contacts, interproximal contacts, root angulation, and total. In the high discrepancy index group (>20), the mean values at debond were significantly different from those at recall for alignment/rotation, marginal ridges, occlusal contacts, occlusal relationship, and interproximal contacts (Table V). The low discrepancy index group had 30 Angle Class I, 19 Class II, and 8 Class II subjects. The high discrepancy group had 9 Class I, 21 Class II, and 8 Class III subjects.

DISCUSSION

All patients in this sample were in the nighttime removable retainer wear phase of retention. No patients were still wearing the retainers 24 hours a day when the recall records were taken. The patients' exact levels of compliance for retainer wear were not recorded, and they were selected based on the availability of their records and the type of retention protocol. Evaluating the compliance of the patients or the breaking or malfunctioning of the appliances, which could have altered the movement of the teeth during retention the phase, was outside of the scope of this study.

Some variables showed increases in CRE scores; these were interpreted to be unfavorable tooth movements. The variables that became worse or showed signs of relapse were alignment/rotation (statistically significant), buccolingual inclination (statistically significant), and occlusal relationship (no statistical significance). The alignment/rotation variable showed the greatest worsening, with over 1 full point of change. Occlusal

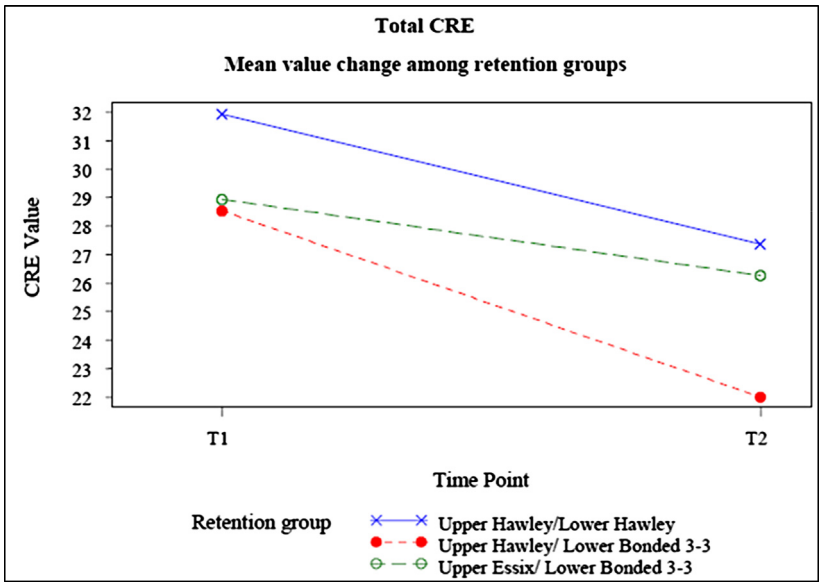

Fig. Overall CRE changes for the retention groups from debond to recall.

Table IV. Difference of CRE scores for the extraction and nonextraction groups

Variable	*Extraction/ nonextraction*	*Difference of means*	P *value*
Alignment/rotation	Extraction	1.31	0.3875
	Nonextraction	0.73	
Marginal ridges	Extraction	−1.31	0.9314
	Nonextraction	−1.27	
Buccolingual inclination	Extraction	0.51	0.5708
	Nonextraction	0.33	
Overjet	Extraction	−1.38	1.0000
	Nonextraction	−1.38	
Occlusal contacts	Extraction	−2.49	0.6652
	Nonextraction	−2.16	
Occlusal relationship	Extraction	0.04	0.1800
	Nonextraction	0.76	
Interproximal contacts	Extraction	−1.33	0.0455*
	Nonextraction	−0.47	
Root angulation	Extraction	−0.38	0.8994
	Nonextraction	−0.36	
CRE total	Extraction	−5.20	0.5372
	Nonextraction	−3.98	

*Statistically significant.

relationships showed the least change among all the variables. The difference was statistically insignificant and can be interpreted to mean that there was no real change in occlusal relationships. This can be interpreted to mean that the anterior and posterior positions of the teeth will not improve during the settling phase.

Marginal ridges, overjet, occlusal contacts, interproximal contacts, and root angulation improved, showing lower CRE scores 1 year after the debond date. A clinician can expect these settling changes and consider them in the decision to remove the orthodontic appliances. Occlusal contacts showed the greatest improvement in CRE score by more than 2 full points. The improvement of occlusal contacts coincides with previous studies.[8-10] A clinician can expect improvement in occlusal contacts over a year of settling and possibly not use as much occlusal equilibration of cusp tips on the day of debond.

This study showed that overall a more favorable stable occlusion existed 1 year after the debond date. The average CRE score for this sample went from 29.8 at debond down to 25.2 at 1 year after the appliances were removed. This is a total overall improvement of 4.6 points on the CRE. To achieve board certification, a case should score below 27 on the CRE. On average, these cases would have failed to meet the board certification standards on the day of debond. After 1 year of settling and retainer wear, on average, these cases could possibly pass the phase III examination. When a doctor plans to present a case for ABO phase III certification, it would be better to wait and let the occlusion settle to obtain lower CRE scores. These results were different from those in a study by Greco et al.[7] They found that the overall CRE score worsened after a certain retention period. The results from this study more closely coincide with the results obtained from a study cited previously.[13] They found that the overall CRE score improved after a retention period and agreed that alignment worsened from the date of debond to

Table V. CRE scores at debond (T1) and recall (T2) for the high and low discrepancy index (DI) groups

DI group	Variable	Pairs (n)	Average at T1	Average at T2	P value
Low, 10-20	Alignment/ rotation	57	7.60	8.26	0.1122
	Marginal ridges	57	4.65	3.18	<0.0001*
	Buccolingual inclination	57	2.39	2.79	0.0263*
	Overjet	57	4.37	2.65	<0.0001*
	Occlusal contacts	57	5.14	2.25	<0.0001*
	Occlusal relationship	57	3.21	3.09	0.6613
	Interproximal contacts	57	1.28	0.56	0.0028*
	Root angulation	57	1.88	1.44	0.0002*
	CRE total	57	30.61	24.16	<0.0001*
High, >20	Alignment/ rotation	33	7.15	8.79	0.0055*
	Marginal ridges	33	3.64	2.67	0.0294*
	Buccolingual inclination	33	2.88	3.33	0.1378
	Overjet	33	3.36	2.58	0.0993
	Occlusal contacts	33	4.45	3.12	0.0146*
	Occlusal relationship	33	2.85	4.15	0.0146*
	Interproximal contacts	33	1.79	0.58	0.0095*
	Root angulation	33	2.30	2.06	0.1032
	CRE total	33	28.39	27.03	0.3932

*Statistically significant.

the 1-year retention time. They also agreed that overjet, occlusal contacts, and marginal ridges all improved during the retention period.

There were differences with the 2 types of retention protocols. The upper Hawley/lower Hawley group showed similar results to the overall sample. The alignment/rotation, buccolingual inclination, and occlusal relationship variables all showed signs of worsening. The upper Hawley/lower Hawley group showed the greatest regression in the alignment/rotation variable, with a difference of 2.86 points. This could be because the mandibular incisors relapsed from poor compliance in wearing the removable retainers.

The upper Hawley/lower bonded retainer group had 5 variables that showed statistical improvements in the occlusion and the greatest statistical overall improvement compared with the other types of retention. The variables that worsened in the upper Hawley/lower bonded retainer group were alignment/rotation, buccolingual inclination, and occlusal relationship; they were statistically insignificant. This can be interpreted to mean that there was actually no change in these variables.

The upper Essix/lower bonded retainer had the least improvement among the 3 retention protocols. Six of the 8 changes in variables were statistically insignificant, meaning no real change. The upper Essix/lower bonded retainer had only 2 variables that showed statistically significant improvements (overjet and occlusal contacts). This could be because there is full occlusal coverage with this retention, and it did not allow the teeth to interdigitate. This information agrees with previous data. Sauget et al[11] found no significant changes in the clear overlay retainer with regard to settling during retention.

The overall improvement in CRE score was greatest in the upper Hawley/lower bonded retainer at 6.53 points. The overall improvement in the upper Hawley/lower Hawley was 4.56 points. The overall CRE improvement for the upper Essix/lower bonded was 2.67 points. The upper Hawley/lower bonded retainer was the best retention protocol for improving the CRE score during the time period of 1 year after the date of debond.

The change in variables between extraction vs nonextraction showed no statistical difference for any variable, except for interproximal contacts. This analysis was done without considering the retention groups (Table IV).

The discrepancy index quantifies the complexity of treatment. The patients were divided into 2 groups according to discrepancy index scores. One group had a score from 10 to 20, and the other group scored greater than 20. The group with scores greater than 20 should be considered the more difficult treatment group. The CRE scores at debond for the low and high discrepancy index groups were 30.61 and 28.39, respectively. The low group, with less complexity, actually had a worse finish at debond. At the recall, the low and high discrepancy groups finished with CRE scores of 24.16 and 27.03, respectively. The low group had a CRE score improvement of 6.45, whereas the high group had an improvement of 1.36. The difference in improvement between the low and high groups was statistically significant. The low group had a worse CRE score than the high group at debond but finished with a better CRE score at the 1-year retention date (Table V).

The deterioration of the occlusal relationship in the high discrepancy index group was significantly different from the change in occlusal relationship in the low group. The occlusal relationship for the high group deteriorated 1.3 points and showed statistical significance. The low group actually improved by 0.12 points, but this was not statistically significant. This difference might be because the initial full-step Class II and Class III patients had higher discrepancy index scores, and the settling of those teeth relapsed back to the initial occlusal classification. Fifty-two percent of the low group of subjects

were Angle Class I, and 63% of the high group were Angle Class II.

Continuing studies are needed on the topic of settling and tooth movement after the appliances have been removed. A study could be completed to determine which teeth are responsible for the changes in the variables of the CRE. This would give the clinician a better idea about what to expect from tooth movement during retention. It is still necessary to study the differences in settling among the Angle classifications. Also, a study could be completed by separating the groups into subjects with high and low mandibular plane angles. Another study could include an additional group of retention protocol that consists of maxillary and mandibular fixed retainers.

CONCLUSIONS

1. All CRE variables but one (occlusal relationship) changed significantly during the retention period. The alignment/rotation and buccolingual inclination variables worsened significantly. Marginal ridge, overjet, occlusal contacts, interproximal contacts, root angulation, and CRE total all improved significantly.
2. The upper Hawley/lower bonded retainer showed the greatest CRE improvement from debond to the 1-year recall, but this improvement was not statistically different from the changes in the other 2 retention protocols.
3. The upper Essix/lower bonded retainer group showed the least improvement in CRE scores during the retention phase.
4. There were no statistically significant differences between the extraction and nonextraction subjects with respect to changes in the CRE variables.
5. Initial case complexity was the most significant factor in determining improvement of the occlusion with settling. The more difficult and complex the treatment, the less likely it was that settling would produce significant improvement.

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