# Comparison of occlusal contacts with use of Hawley and clear overlay retainers

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After teeth have been orthodontically repositioned, retention devices are used to maintain arch form and minimize the tendency of teeth to shift.[1-4] When teeth do shift, changes that are undesirable are considered "relapse," while changes that are desirable are called "settling." With settling, the number of occlusal contacts (once the fixed appliances are removed) increases, improving the fit of the teeth. The best retention device would be one that allows settling but prevents relapse.

Commonly prescribed retainers include the Hawley, wrap, fixed, clear overlay, and tooth positioners. The designs of these retainers differ, particularly the extent of the retainer-tooth contacts. For example, the Hawley retainer fits against the lingual, and in some cases, the facial surfaces of the teeth, while the clear overlay retainer covers most of the coronal surfaces. Due to these contrasts in retainer design, characteristic differences in tooth position following their use would be anticipated.

The design of the Hawley retainer has remained largely unchanged since its introduction in the early part of this century. The original method of fabrication used lingual and palatal plates made of vulcanized rubber that were accurately adapted to the lingual surfaces of the teeth, and a labial wire with adjustment loops at the canines.[5] Today, acrylic has replaced the rubber.[6]

The clear overlay retainer, as described by Ponitz in 1971, is made of thin (0.025 inch), vacuum-formed thermoplastic material that adapts closely to the lingual, facial, and occlusal surfaces of the teeth.[7] Use of the clear overlay

**Abstract**

Following orthodontic treatment, an increase in the number of occlusal contacts is usually desired during retention. In this study, Hawley and clear overlay orthodontic retainers were compared relative to changes in the number of occlusal contacts. Occlusal contacts were quantified in 30 orthodontic patients at debonding, at retainer delivery, and after 3 months of retention. The paired *t*–test was applied to evaluate longitudinal changes in the number and intensity of contacts. Results show that with the Hawley retainer there was a significant increase in occlusal contacts on posterior teeth and no change on anterior teeth. With the clear overlay retainer there was no significant change in either posterior or anterior contacts during retention. The retentive capacities of the two retainers differ: the Hawley retainer allows relative vertical movement (settling) of the posterior teeth while the clear overlay retainer holds teeth in their debanding position.

**Key Words**

Orthodontic retention • Hawley retainer • Clear overlay retainer • Bite registration • Occlusal contacts

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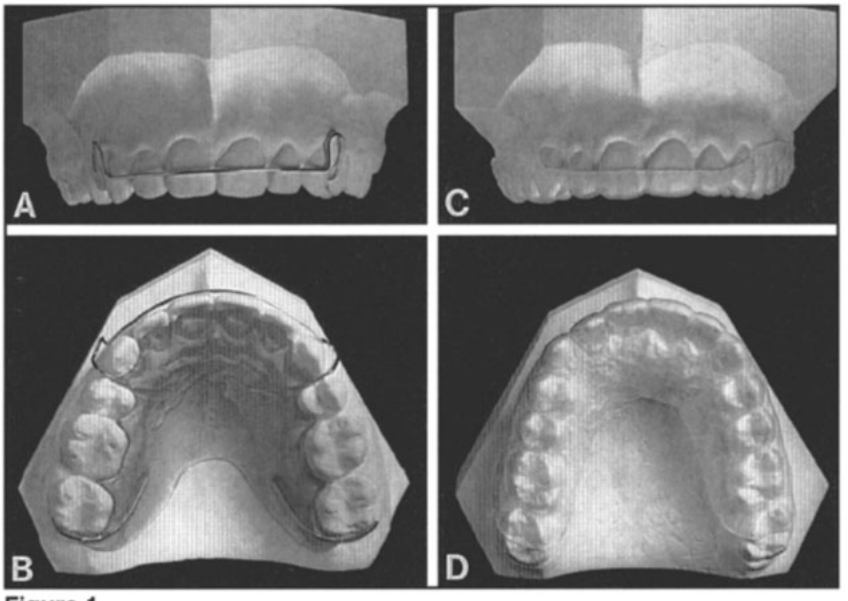


Figure 1

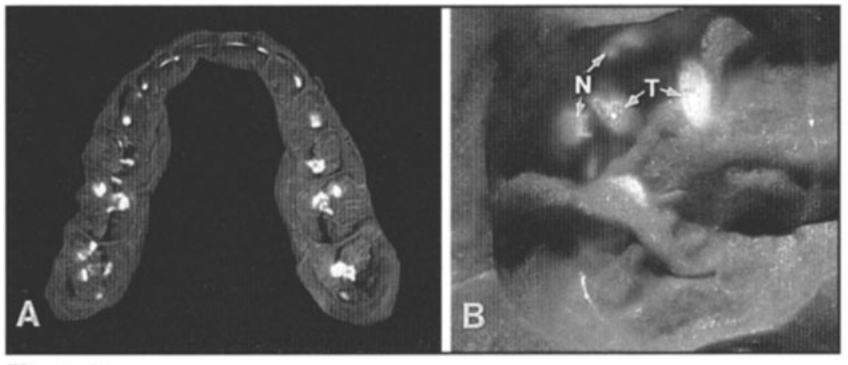


Figure 2

**Figure 1**
**A-B: Maxillary Hawley retainer with the acrylic plate in contact with the palatal tooth surfaces and the labial bow in contact with the anterior teeth.**
**C-D: Clear overlay retainer in contact with palatal, facial and occlusal tooth surfaces.**

**Figure 2**
**A: Vinyl polysiloxane bite registration with backlighting to demonstrate occlusal contacts.**
**B: Higher magnification of first molar contacts in a different registration demonstrating true contacts (T) and near contacts (N).**

retainer has increased since its introduction, but studies on its effects are scarce. In a recent preliminary report, Tibbetts compared Hawley retainers, clear overlay retainers, and tooth positioners by analyzing dental casts at debonding and after a 6-month retention period.[8] The results showed no statistically significant differences in Angle molar classification, overbite, overjet, maxillary or mandibular intercanine width, intermolar width, or arch length.

The aim of the present study was to use changes in occlusal contacts for comparing the retention characteristics of the Hawley and clear overlay retainers. Occlusal contacts between the maxillary and mandibular teeth were statistically compared at debanding, when retainers were delivered, and after 3 months of retention.

## Materials and methods

### Sample characteristics

At the completion of full orthodontic treatment, 30 consecutive patients from the Orthodontic Clinic at the University of the Pacific School of Dentistry were prescribed, alternately, Hawley retainers or clear overlay retainers. Thirteen patients (8 females, 5 males) received maxillary and mandibular Hawley retainers. Two patients (both female) received maxillary Hawley retainers with mandibular fixed lingual retainers. Fifteen patients (9 females, 6 males) received maxillary and mandibular clear overlay retainers. All patients had been in orthodontic treatment for at least 18 months.

The Hawley retainer sample contained 5 patients who had premolar extractions, 8 patients who were treated without extractions, and 2 patients with congenitally missing maxillary lateral incisors. Their mean age was 18 years 8 months (range: 13 years 11 months to 35 years 10 months). The clear overlay retainer sample included 6 patients with premolar extractions, 8 who were treated nonextraction, and 1 with missing maxillary lateral incisors. The mean age was 19 years 6 months (range: 13 years 9 months to 42 years 2 months).

### Retainers

Immediately following removal of the fixed appliances, alginate impressions were made and poured to obtain models of the maxillary and mandibular arches. One week later the retainers were delivered. At delivery, the Hawley appliances were adjusted so the labial bow made uniform, passive contact with each anterior tooth (Figure 1). The mandibular incisors were in light contact with the acrylic, lingual to the maxillary incisors, when the posterior teeth were in maximum intercuspation. The clear overlay retainers were fabricated from 0.025 inch thermoplastic (Tru–Tain; Rochester, Minn) vacuum-heat adapted to dry models. The facial surfaces of the retainers were trimmed to cover the incisal one-third of the incisors and to extend 3 mm beyond the gingival margin posteriorly (Figure 1). Occlusal coverage extended distally to cover approximately the mesial half of the maxillary and mandibular second molars.

Patients receiving Hawley retainers were instructed to wear them full-time, except during meals. Those prescribed clear overlay retainers were instructed to wear their retainers full-time for the first three days (except during meals), and nightly thereafter.

### Bite registrations

Vinyl polysiloxane impression material (Regisil PB; Caulk–Dentsply, Milford, Del) was used to record the occlusal contacts. Patients were seated upright in a dental chair and the registration material was applied over the occlusal surfaces of the mandibular teeth. The patient was told to bite firmly in maximum intercuspation (see pre-

**Table 1**
**Hawley retainer group. Means and standard deviations of occlusal contacts at debonding, retainer delivery, and after 3 months retention. Statistical comparison by paired *t*-test**

| | T1 | | T2 | | T3 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | P (T1-T2) | P (T2-T3) | P (T1-T3) |
| Total contacts | 34.33 | 10.45 | 40.40 | 9.79 | 45.73 | 11.76 | NS | NS | <0.01 |
| True | 15.60 | 5.82 | 17.87 | 4.91 | 20.20 | 6.39 | NS | NS | <0.05 |
| Near | 18.73 | 6.95 | 22.53 | 7.24 | 25.53 | 7.95 | NS | NS | <0.05 |
| Anterior contacts | 9.07 | 4.83 | 9.60 | 4.36 | 9.80 | 3.88 | NS | NS | NS |
| True | 4.67 | 3.27 | 3.80 | 2.86 | 3.80 | 2.46 | NS | NS | NS |
| Near | 4.40 | 2.32 | 5.80 | 2.88 | 6.00 | 2.73 | NS | NS | NS |
| Posterior contacts | 25.27 | 8.49 | 30.80 | 8.91 | 35.93 | 11.57 | NS | NS | <0.01 |
| True | 10.93 | 3.99 | 14.07 | 3.95 | 16.40 | 5.64 | <0.05 | NS | <0.01 |
| Near | 14.33 | 6.48 | 16.73 | 6.96 | 19.53 | 7.83 | NS | NS | NS |

vious studies.[9-13]) A second bite registration was made within 15 minutes to test the reproducibility. The two bite registrations were examined on a light box and contacts (appearing as transparencies in the material, see Figure 2) were compared. If a subjective difference in the pattern of contacts was observed, another registration was made. In no case was a fourth registration needed. To objectively analyze the bite registrations, each was labelled with a randomized identification code and the registrations intermixed.

For analysis of the occlusal contacts, individual registrations accumulated from multiple patients were selected at random. Occlusal contacts were evaluated and classified as either true or near contacts (Figure 2). True contacts perforated the impression material; near contacts appeared as thin translucencies and were counted only if they were 0.20 mm or less as measured with an Iwanson caliper. Observing from the maxillary side, the locations of the contacts were assigned by tooth and then grouped as either anterior (incisors and canines) or posterior (premolars, first molars, and second molars). All registrations were evaluated and measured by the same individual.

**Error of method**

The registrations were made within 30 minutes of debanding (T1), at the time of retainer delivery (T2), and three months later (T3). All registrations were made in the afternoon by the same clinician (ES). To test the measurement accuracy, 10 bite registrations were selected at random and the near contacts measured. The same registrations were remeasured on a different day. The standard measurement error (Sx) was calculated using Dahlberg's formula[14]: $Sx = \sqrt{\frac{\sum D^2}{2N}}$ where D is the difference between duplicated measurements and n is the number of double measurements. To determine the reliability of the registration technique, pairs of bite registrations taken at the same sitting were compared. Dahlberg's formula was applied to determine the standard error between the two bite registrations.

## Results

**Method error**

The standard measurement error (Sx) from repeated thickness measurements of the same bite registration was 0.014 mm. Comparison of measurements between paired records made on the same day showed an error of 0.018 mm. Thus the variation found in repeated registrations approximated the limits of the measurement technique.

**Occlusal contacts at debanding (T1)**

Bite registrations made for both retainer groups indicate a wide variation between individuals with regard to the number of total occlusal contacts. The Hawley retainers had a mean of 34.3 occlusal contacts (± 10.45 standard deviation) and the clear overlay retainers had a mean of 31.8 (±11.8; see Tables 1, 2). Comparing the Hawley and clear overlay retainer groups at debanding, there were no statistically significant differences between the mean number of total contacts, true contacts, near contacts, or anterior/posterior contacts (Table 3).

**Table 2**
**Clear overlay retainer group. Means and standard deviations of occlusal contacts at debonding, retainer delivery, and after 3 months retention. Statistical comparison by paired *t*-test**

| | T1 | | T2 | | T3 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | P (T1-T2) | P (T2-T3) | P (T1-T3) |
| Total contacts | 31.80 | 11.78 | 35.67 | 13.00 | 36.67 | 13.65 | NS | NS | NS |
| True | 14.00 | 6.46 | 16.13 | 7.54 | 15.00 | 6.59 | NS | NS | NS |
| Near | 17.80 | 7.49 | 19.53 | 7.92 | 21.67 | 9.31 | NS | NS | NS |
| Anterior contacts | 8.13 | 3.93 | 7.93 | 3.33 | 8.73 | 3.15 | NS | NS | NS |
| True | 3.13 | 2.33 | 3.33 | 2.58 | 3.13 | 2.29 | NS | NS | NS |
| Near | 5.00 | 3.57 | 4.60 | 2.80 | 5.60 | 3.25 | NS | NS | NS |
| Posterior contacts | 23.67 | 11.34 | 27.73 | 12.27 | 27.93 | 12.14 | NS | NS | NS |
| True | 10.13 | 6.32 | 12.80 | 7.63 | 11.93 | 6.11 | NS | NS | NS |
| Near | 13.53 | 6.65 | 14.93 | 7.03 | 16.00 | 7.89 | NS | NS | NS |

**Occlusal contacts at retainer delivery (T2)**

At the time of retainer delivery, T2, there were no significant differences between the two retainer groups in the average number of each classification of occlusal contacts (Tables 1, 2). Within each retainer group there were no significant changes between T1 and T2 except for an increase in posterior true contacts in the Hawley group (T1: 10.9 ± 4.0; T2: 14.1 ± 4.0, $P<0.05$).

**Occlusal contacts after 3 months retention (T3)**

At T3 The mean number of posterior true contacts (Hawley: 16.4; clear overlay: 11.9) and the mean number of total true contacts (Hawley: 20.2; clear overlay: 15.1) were significantly different between the retainer groups ($P<0.05$; see Tables 1 and 2). Neither sample showed a significant within–group change between T2 and T3.

In the Hawley group, between T1 and T3, significant increases were found in the average number of total contacts, the mean number of total true contacts, near contacts, posterior contacts, and posterior true contacts (Table 1). The average number of posterior near contacts approached statistical significance ($P=0.06$). There were no differences in anterior contacts.

The clear overlay group displayed no significant differences in any category between T1 and T3 (Table 2) .

**Comparison of changes between groups**

No significant changes occurred between the two retainer groups from T1 to T2 in any of the occlusal contact categories (Table 3, Figure 3).

From T2 to T3 the number of total contacts and posterior contacts increased significantly more in the Hawley group than the clear overlay group (Table 3, Figure 3). There was a small reduction in the number of true posterior contacts with the clear overlay retainers. Most of the decrease occurred at the first molars and to a lesser extent at the first premolars. The mean changes in anterior contacts were not significant.

From T1 to T3, the occlusal contact changes in the Hawley group compared with the clear overlay group showed a similar pattern to that found from T2 to T3 (Table 3, Figure 3).

## Discussion

Results from this study show statistically significant differences in the number of occlusal contacts between Hawley and clear overlay retainers. After 3 months of retention with the Hawley retainers, there was a statistically significant increase in the number of total contacts ($P<0.01$). In contrast, over the same time period with the clear overlay retainers, there was no change in the number of occlusal contacts.

We believe these results are reliable due to a minimal number of confounders. The two samples matched favorably for size, age, gender, and numbers of cases with teeth extracted or missing. With regard to the methods, the bite technique for recording occlusal contacts was highly reproducible. In addition, the method has been validated in several previous investigations.[9-12,15] Finally, because diurnal variation in occlusal contacts has been reported,[16] the bite registrations were made only during the afternoon.

The number of occlusal contacts at debonding in both retainer samples was similar to that reported by Radolsky and Sadowsky.[10] The mean

**Table 3**
**Comparison of changes in occlusal contacts between Hawley and clear overlay retention groups. Statistical comparison by paired *t*-test**

| Contact Changes | T1-T2 Hawley Mean | Hawley S.D. | Overlay Mean | Overlay S.D. | P | T2-T3 Hawley Mean | Hawley S.D. | Overlay Mean | Overlay S.D. | Pp | T1-T3 Hawley Mean | Hawley S.D. | Overlay Mean | Overlay S.D. | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 6.07 | 5.22 | 3.87 | 4.75 | *NS* | 5.33 | 4.03 | 1.00 | 6.16 | *<0.05* | 11.40 | 4.58 | 4.87 | 6.35 | *<0.01* |
| True | 2.27 | 3.15 | 2.73 | 3.71 | *NS* | 2.33 | 4.15 | -1.07 | 3.24 | *<0.05* | 4.60 | 3.98 | 1.67 | 3.35 | *<0.05* |
| Near | 3.80 | 3.63 | 1.13 | 4.31 | *NS* | 3.00 | 3.44 | 2.07 | 5.59 | *NS* | 6.80 | 4.59 | 3.20 | 5.25 | *NS* |
| Anterior | 0.53 | 3.23 | -0.20 | 1.86 | *NS* | 0.20 | 3.63 | 0.80 | 2.57 | *NS* | 0.73 | 3.37 | 0.60 | 2.64 | *NS* |
| True | -0.87 | 2.47 | 0.07 | 1.87 | *NS* | 0.00 | 1.96 | -0.20 | 1.82 | *NS* | -0.87 | 2.82 | -0.13 | 2.06 | *NS* |
| Near | 1.40 | 2.85 | -0.27 | 2.63 | *NS* | 0.20 | 3.05 | 1.00 | 2.24 | *NS* | 1.60 | 2.80 | 0.73 | 2.69 | *NS* |
| Posterior | 5.53 | 3.36 | 4.07 | 4.51 | *NS* | 5.13 | 4.87 | 0.20 | 5.53 | *<0.05* | 10.66 | 5.45 | 4.27 | 5.05 | *<0.01* |
| True | 3.13 | 2.50 | 2.67 | 2.97 | *NS* | 2.33 | 3.37 | -0.87 | 3.54 | *<0.05* | 5.46 | 3.72 | 1.80 | 3.34 | *<0.01* |
| Near | 2.40 | 1.84 | 1.40 | 4.03 | *NS* | 2.80 | 4.35 | 1.07 | 5.65 | *NS* | 5.20 | 4.66 | 2.47 | 3.89 | *NS* |
| 2nd molars | 2.07 | 2.22 | 1.60 | 2.69 | *NS* | 1.26 | 2.71 | 0.27 | 2.76 | *NS* | 3.33 | 3.22 | 1.87 | 2.75 | *NS* |
| True | 1.00 | 1.60 | 1.07 | 1.71 | *NS* | 0.93 | 1.91 | -0.13 | 1.55 | *NS* | 1.93 | 2.63 | 0.94 | 1.57 | *NS* |
| Near | 1.07 | 1.33 | 0.53 | 2.20 | *NS* | 0.33 | 3.11 | 0.40 | 2.38 | *NS* | 1.40 | 3.16 | 0.93 | 2.63 | *NS* |
| 1st molars | 2.40 | 1.24 | 1.40 | 1.84 | *NS* | 1.27 | 1.75 | -0.60 | 1.80 | *<0.01* | 3.67 | 2.02 | 0.80 | 1.78 | *<0.001* |
| True | 1.00 | 1.39 | 1.00 | 1.31 | *NS* | 1.00 | 2.04 | -0.67 | 2.32 | *<0.05* | 2.00 | 2.17 | 0.33 | 1.59 | *<0.05* |
| Near | 1.40 | 1.40 | 0.40 | 1.35 | *NS* | 0.27 | 2.58 | 0.07 | 2.40 | *NS* | 1.67 | 2.66 | 0.47 | 2.26 | *NS* |
| 2nd premolars | 0.93 | 1.53 | 0.40 | 1.30 | *NS* | 1.53 | 1.13 | 0.67 | 2.16 | *NS* | 2.47 | 1.77 | 1.07 | 2.58 | *NS* |
| True | 0.80 | 1.01 | 0.13 | 1.25 | *NS* | 0.20 | 1.08 | -0.06 | 0.70 | *NS* | 1.00 | 1.20 | 0.07 | 1.22 | *<0.05* |
| Near | 0.13 | 1.73 | 0.27 | 0.88 | *NS* | 1.33 | 1.76 | 0.73 | 2.15 | *NS* | 1.47 | 1.96 | 1.00 | 2.14 | *NS* |
| 1st premolars | 0.00 | 1.56 | 1.22 | 2.11 | *NS* | 1.80 | 1.99 | -0.33 | 1.00 | *<0.01* | 1.80 | 1.87 | 0.89 | 1.96 | *NS* |
| True | 0.60 | 0.70 | 0.33 | 0.71 | *NS* | 0.00 | 1.33 | 0.23 | 1.39 | *NS* | 0.60 | 1.17 | 0.56 | 1.13 | *NS* |
| Near | -0.60 | 1.78 | 0.89 | 2.32 | *NS* | 1.80 | 2.30 | -0.56 | 2.19 | *<0.05* | 1.20 | 1.62 | 0.33 | 1.50 | *NS* |

number of total contacts in their study was 36.6 (17.1 near contacts, 19.1 actual contacts), while this study recorded 34.3 ± 10.5 total contacts (18.7 ± 7.0 near contacts, 15.6 ± 5.8 true contacts) for the Hawley retainer group and 31.8 ± 11.8 total contacts (14.0 ± 6.5 near, 17.8 ± 7.5 true) in the clear overlay retainer group. The increase in contacts observed in the Hawley retainer group agrees with the findings of Durbin and Sadowsky,[9] who compared Hawley retainers with tooth positioners. With the Hawley retainer they found the total number of contacts increased significantly during the first 3 months of retention, with most of the increase associated with posterior contacts. From these results it is apparent that with a Hawley retainer, the posterior teeth settle after the bands are removed. Razdolsky and Sadowsky[10] described minimal migration of the contacts toward the central groove. No attempt was made in this study to characterize the location, or alteration of location, of contacts on individual teeth.

From appliance removal to retainer delivery, any alteration in occlusal contacts in both samples should be similar. Both showed a small increase in the number of posterior contacts from T1 to T2, with a greater increase in the Hawley retainer group. This difference cannot be explained. Several possibilities can be proposed to account for the differences between retainer groups from T1 to T3. First, no attempt was made to adjust the overlay retainers to optimal occlusal contact. With up to 0.05 inches of retainer material between the teeth, initial contact at closure was between the more posterior teeth. This contact may have loaded the molars more than the anterior teeth and have prevented further eruption or settling, or possibly intruded the molars.[17,18] However, the differential occlusal loading when the retainers were worn at night would have been counteracted during the day when the retainers were not worn. Alternately,

**Figure 3**
**Comparison of Hawley and clear overlay retainers. The mean change and standard deviation are shown for total tooth contacts (A), posterior tooth contacts (B), and anterior tooth contacts (C) between debonding and retainer delivery (T1–T2), retainer delivery and three months retention (T2–T3), and from debonding to three months retention (T1–T3).**
***p<0.05; **p<0.01**

if the mandibular condyles had been distracted to produce a more uniform distribution of occlusal contact with the retainers in place,[19,20] there should have been an increase in posterior contacts when the overlay retainers were removed and the condyle assumed its normal position. The data shows the opposite occurred.

Because the second molars were only partially covered by the overlay retainers, they may have erupted more relative to the more mesial teeth. The second molars would then become an occlusal stop when the retainers were removed. However, this explanation is unlikely because the second molars did not show an increase in occlusal contacts.

It is most likely that the overlay retainers reverse the settling occurring between T1 and T2 because the retainers are fabricated on casts taken at T1. This hypothesis is consistent with data from the clear overlay group showing a slight reduction in posterior contacts from T2 to T3, but no difference in the number of contacts at T3 compared to T1.

The Hawley retainer, on the other hand, may encourage posterior tooth eruption. Since the Hawley retainers were worn full time, the anterior bite plane and labial wire may have held the anterior teeth, allowing the posterior teeth to extrude. This suggestion is supported by data showing no change in the anterior contacts in the Hawley group, while the posterior contacts increased. Assuming some tooth settling had occured during the day in the clear overlay retainer patients, it is likely that had the bite registrations been made in the morning, differences between the two retainer groups would have been even greater.

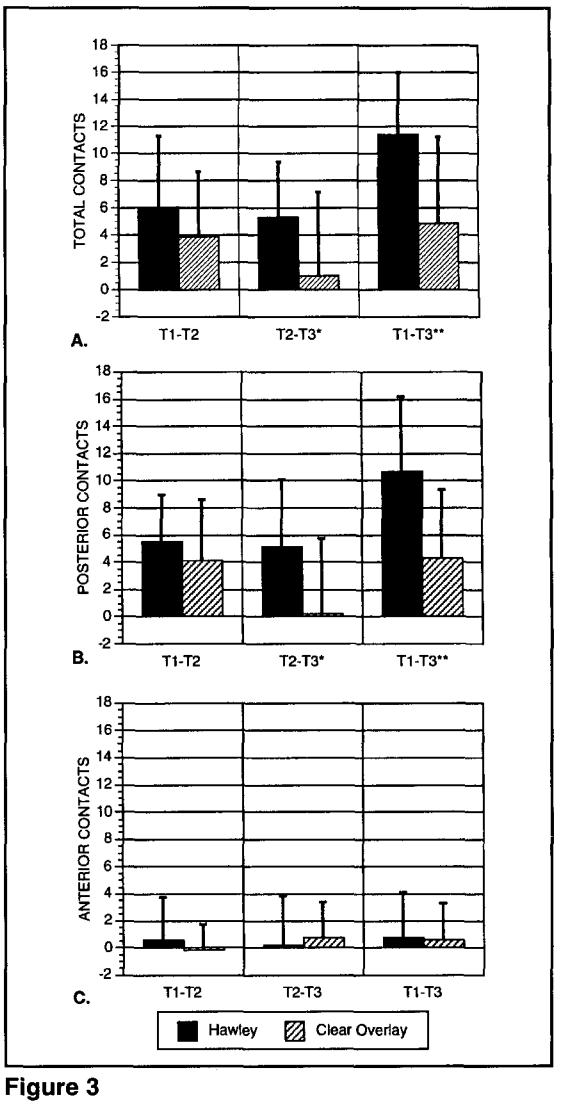


**Figure 3**

Based on previous studies, additional increases in occlusal contacts during retention should be

expected over time, particularly as daily retainer wear is reduced.[10,21] In the present study, greater increases would be anticipated in the clear overlay patient group if retainer use were to be discontinued. Areas for future investigation include comparisons of changes in occlusal contacts with other types of removable as well as fixed retainers, and long-term follow-up on changes occuring over an extended retention period. Ultimately, it would be of interest to establish whether the differences in occlusal contact patterns after 3 months retention will result in differing tendencies toward settling or relapse at extended retention and postretention intervals.

## Conclusion

This study demonstrates that significantly more occlusal contacts appear during the first 3 months of retention with use of the Hawley retainer, whereas little change is found with the clear overlay retainer. These findings suggest that Hawley retainers should be prescribed if one of the objectives of retention is to allow for relative vertical tooth eruption (tooth settling), particularly of posterior teeth. Conversely, if the desired occlusion is established before retainer fabrication, for example with a positioner, the clear overlay retainers should function well to maintain the occlusal contact pattern.

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## References


1. Reitan K. Principles of retention and avoidance of posttreatment relapse. Am J Orthod 1969;55:776–790.
2. Little RM. Stability and relapse of dental arch alignment. In Nanda R and Burstone, CJ (eds): Retention and stability in orthodontics. Philadelphia: Saunders; 1993:97–106.
3. Sadowsky C. Long–term stability following orthodontic therapy. In Nanda R and Burstone CJ (eds): Retention and stability in orthodontics. Philadelphia: Saunders; 1993:107–113.
4. Joondeph DR, Riedel RA. Retention and relapse. In Graber TM, Vanarsdall RL (eds): Orthodontics–Current principles and techniques. St. Louis: Mosby–Year Book; 1994:908–950.
5. Hawley CA. A removable retainer. Int J Orthod 1919;5:291–8.
6. Nikolai RJ, Horner KD, Blackwell DA, Carr RJ. On the design of looped orthodontic retainer wires. Angle Orthod 1991;61:211–220.
7. Ponitz RJ. Invisible retainers. Am J Orthod 1971;59:266–272.
8. Tibbets JR. The effectiveness of three orthodontic retention systems: A short term clinical study (Abstract). Am J Orthod Dentofac Orthop 1994; 106:671.
9. Durbin DS, Sadowsky C. Changes in tooth contacts following orthodontic treatment. Am J Orthod Dentofac Orthop 1986;90:375–382.
10. Razdolsky Y, Sadowsky C. Occlusal contacts following orthodontic treatment: a follow–up study. Angle Orthod 1989;59:181–5.
11. Haydar B, Ciger S, Saatçi P. Occlusal contact changes after the active phase of orthodontic treatment. Am J Orthod Dentofac Orthop 1992; 102:22–8.
12. Lindner JP. Centric occlusion contact in subjects with Angle's Class I and Class II molar relationships. 1973; Master's Thesis, Marquette University.
13. Ziebert GJ, Donegan SJ. Tooth contacts and stability before and after occlusal adjustment. J Prosth Dent 1979;42:276–281.
14. Dahlberg G. Statistical methods for medical and biological students. London: George Allen and Unwin Ltd, 1940:122–132.
15. Riise C. A clinical study of the number of occlusal tooth contacts in the intercuspal position at light and hard pressure in adults. J Oral Rehab 1982;9:469–477.
16. Berry DC, Singh BP. Daily variations in occlusal contacts. J Prosth Dent 1983;50:386–391.
17. Brown DT, Gaudet EL, Phillips C. Changes in vertical tooth position and face height related to long term anterior repositioning splint therapy. J Craniomandib Pract 1994;12:19–22.
18. Ramfjord SP, Blankenship JR. Increased occlusal vertical dimension in adult monkeys. J Prosth Dent 1981;45:74–83.
19. Hylander WL. An experimental analysis of temporomandibular joint reaction force in macaques. Am J Phys Antrop 1979;51:433–456.
20. Hatcher DC, Faulkner MG, Hay A. Development of mechanical and mathematical models to study temporomandibular joint loading. J Prosth Dent 1986;55:377 384.
21. Gazit E, Lieberman MA. Occlusal contacts following orthodontic treatment measured by a photoocclusion technique. Angle Orthod 1985;55:316-320.