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SHORT-TERM EFFECTIVENESS OF NIGHT TIME RETAINER WEAR

by

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Submitted in partial fulfillment of the requirements for the degree of

Master of Science in Dentistry

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Abstract

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The purpose of this prospective study was to evaluate a retained and an unretained group one month following the removal of orthodontic appliances. Sixty consenting patients participated in the study. Group I (n = 30) was assigned to nighttime wear of Hawley retainers. Group II (n = 30) was unretained. Six continuous variables (maxillary and mandibular arch length, overbite, overjet, intermolar width, intercanine width) were measured on casts taken at appliance removal and one month later. The American Board of Orthodontics Objective Grading System, which consists of eight categorical measures, was also used to evaluate the casts. Data analysis used paired t-tests and the Wilcoxon sign rank test ($p < 0.05$).

The unretained group showed a statistically significant decrease in mandibular arch length and an increase in overjet, as well as an improvement in vertical marginal ridge positioning and posterior occlusal contacts. This group also had more interproximal spacing after one month. The retained group showed a

significant increase in maxillary arch length and overbite, and a decrease in mandibular arch length and intercanine width. The two groups, when compared, were very different from one another at the end of treatment and post treatment in maxillary and mandibular arch length, overjet, buccolingual inclination, and marginal ridges. Further studies are needed in order to evaluate long-term stability and continued occlusal improvement in both groups.

DEDICATION

This work is dedicated to my family:

My parents, Spencer and Sandra Crew, who have always believed in me even when I did not believe in myself. You have inspired me, supported me, challenged me, and shaped me into the person that I am today.

My brother, Adom, thank you for your friendship, love, and support, and for giving me inspiration.

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INTRODUCTION

The prevention of relapse through the use of retention devices is an issue of great concern to both practitioners and patients alike. Robert Moyers (1973) once defined orthodontic retention as the "holding of teeth following orthodontic treatment in the treated position for the period of time necessary for the maintenance of the result". Most practitioners would agree that a strategy for retention following orthodontic treatment should be considered at the time of diagnosis and treatment planning, and should be planned based on the initial malocclusion and its etiology. The retention strategy, along with the original study models and other diagnostic tools, should be reviewed when the case is ready for debonding. Ideally, a corrected malocclusion should be sustained in a position of stability, health, and function, and the retentive phase of treatment should be geared toward maintaining this correction.

Retention strategies and methods vary significantly among practitioners. However, the protocol used for retention should take into account the original malocclusion, the cause, amount, and method of treatment, the final periodontal condition of teeth, any restorative needs; and growth potential of the patient (Kahl-Nieke et al. 1996). Stabilization and retention after active tooth movement can be characterized in one of three ways (Joondeph, Reidel 2005). Limited retention is typically used following crossbite correction or growth modification; these cases

often require further future orthodontic treatment. Moderate retention typically involves the use of a removable retainer daily for varying numbers of hours in the years following treatment, while permanent or semi-permanent retention is usually reserved for cases in which significant crowding or spacing existed prior to orthodontic intervention.

The Hawley retainer is the most commonly used removable retainer (Wong, Freer 2004). The classic design of the Hawley retainer consists of a palatal or lingual portion of acrylic, retentive clasps, and a labial bow. However, this basic design can be easily modified. Protocols for Hawley retainer wear differ according to clinician preferences; however, most protocols are developed based upon the time needed for reorganization of periodontal and gingival structures following appliance removal (Blake 1998).

Despite the use of retention devices, perhaps the biggest problems faced by orthodontists are relapse and other post-treatment changes. In the early 1900s, Angle, Case, and other practitioners began to take notice of the difficulties they experienced in the achievement of long-term stability (Case 2003). Recent assesments of long-term observation of post-treatment and post-retention results have indicated that relapse occurs in most cases, even those in which retention was continued for a number of years following orthodontics (Little et al. 1981; 1988; 1989). Orthodontic treatment, rendered in conjunction with extractions or non-extraction procedures, along with those cases in which the mandibular intercanine width was carefully maintained, were equally unsuccessful in maintaining satisfactory treatment results

long term. In fact, no variable has been found to be predictive of either stability or relapse (Shields et al. 1985).

Tooth movement can continue throughout life in treated and untreated individuals. As changes in dental relationships following completion of the active phase of treatment are to be expected, and do not necessarily indicate relapse (Shapiro, Kokich 1981), it is the patient and the practitioner who will decide whether the post-treatment change is still acceptable.

REVIEW OF THE LITERATURE

Etiology of Relapse

In examining the etiology of orthodontic relapse, it is important to make a distinction between physiologic recovery and post-treatment relapse. Much has been written regarding the mechanical treatment of malocclusion and methods for retaining teeth following treatment. However, it is important to separate post-treatment changes into those related to administered orthodontics, and those that are related to normal developmental and aging processes. Orthodontic treatment results are potentially unstable and can be divided into two general categories: instability related to changes associated with growth, maturation, and aging of the dentition and occlusion; and the inherent unstable nature of the teeth that compose the occlusion achieved by treatment (Nanda, Nanda 1992).

Facial growth continues throughout adult life. It varies among individuals, and can be quite considerable in some cases (Behrents 1985). Most orthodontic treatment is initiated during the early permanent dentition and is likely to be completed during a time in which the patient is still growing. Late growth of the jaws usually resembles the process and direction of adolescent growth. It is typically of lesser magnitude in females with a clockwise rotation of the mandible, while in males it is of greater magnitude and demonstrates a counterclockwise rotation (Behrents 1989).

Litowitz (1948) stated that cases showing the greatest amount of growth during treatment showed the least amount of post-treatment relapse. Riedel (1960) noted that growth might aid in the correction of orthodontic problems, but that it could also cause relapse in treated cases. Skeletal changes occurring during the retention phase may serve to attenuate, exaggerate, and/or maintain the dentoskeletal relationship (Nanda, Nanda 1992).

In addition to the original pattern of growth exhibited by an orthodontic patient prior to treatment, the original soft tissue environment also plays a significant role in post-treatment relapse. Stability of the orthodontically treated dentition can only be achieved if the forces derived from the orofacial soft tissues, the periodontal and gingival tissues, and the dentition are in harmony and equilibrium with one another. The cheeks and lips play a significant role in orthodontic relapse. Moyers (1973) found abnormal functioning of the mentalis muscle to be one of the major causes of post-treatment incisor relapse. The duration and force of tongue pressure against the lower incisors can also have an effect on orthodontic stability; Hovell (1956) found that, in cases in which the overall space between the jaws was reduced with surgery, incisor relapse was most often related to the rest position of the tongue. Lip seal and pressures within the oral cavity are also important in the equilibrium of tooth position. When the cheek, lip, and/or tongue pressures during speaking, swallowing, or chewing exceed those suggested for successful orthodontic tooth movement, it is likely that some post-treatment relapse back to the original position of

the teeth will occur if the teeth are not retained in the post-treatment position (Ingervall 1988).

Considerable residual forces remain in the tissues of the periodontium after tooth movement; therefore, a stable position of the teeth in the dental arch can be achieved only after the periodontal tissues have been allowed to adapt. Experimental studies have shown that if orthodontic tooth movement is not followed by remodeling of supporting tissues teeth will tend to return to their pre-treatment position (Reitan 1969). The periodontal ligament fibers attach into both cementum and alveolar bone, thus acting as an anchorage system for teeth while bone and cementum are deposited during normal tooth movement (Thilander 2000). Following orthodontic treatment, reorganization of the periodontal ligament occurs over a period of three to four months. However, gingival tissues have a much slower turnover rate than the fibers of the periodontal ligament, and can take up to six months before they are stable (Reitan 1969). Gross gingival changes have been observed after closure of an extraction site or rotation movements. Adjacent to an extraction site, the teeth are approximated, resulting in an accumulation of gingival tissue and enlargement of the interdental papilla. The tissue accumulation is a result of both retraction and compression (McCollum 1980); the gingiva retracts together with the tooth movement. During orthodontic rotation movement, the gingiva rotates to the same degree and in the same direction as the tooth. Extensive rotational movement causes the rotated gingiva to be compressed in the interdental area in the direction of rotation

(Redlich 1999). Therefore, one might expect to see possible reopening of extraction spaces or a return of derotated teeth to their pre-treatment positions.

One of the most commonly proposed reasons for lower incisor relapse has been excessive lower incisor proclination beyond the zone of labiolingual balance. Many studies have examined the effect of maintaining the initial position of the lower incisors as a strategy for increasing post-treatment incisor stability. However, most have eventually shown that, even when lower incisor position is maintained throughout treatment, most patients eventually experience some degree of relapse. A study by Mills and Strahan (2005) showed that, in cases in which lower incisors were advanced as a part of treatment, they ultimately stabilized in a position in between their initial and final positions. Long-term post-retention studies performed at the University of Washington, in which the position of the lower incisor was deliberately maintained, showed success in maintaining satisfactory mandibular anterior alignment to be less than 30 % ten years post-retention, with nearly 20% of the cases showing severe crowding many years out of retention (Little et al. 1981). A similar study at the University of Tennessee found that incisor irregularity increased to half of the pre-treatment value fifteen years after orthodontic treatment (Vaden et al. 1997).

Similarly, another widely publicized concept deals with the maintenance of the original mandibular arch form. Some emphasize that it cannot be altered by orthodontic appliance therapy without compromising post-treatment stability (Reidel 1960). However, maintenance of the original intercanine width does not guarantee

stability. Intercanine and intermolar widths tend to decrease during the post-retention period, especially when they are expanded during treatment (Shapiro 1974). A modest amount of intercanine expansion may be maintained successfully in class II division 2 cases than in class I and class II division I cases (Gardner 1976). Ten years of observation of arch width after retention in patients who underwent serial extractions (Little 1990), second premolar extractions (McReynolds, Little 1991), and in cases with initial generalized spacing (Little 1989) found no pre-treatment associations to predict long-term stability.

The orthodontist's goal of treatment is to achieve as near ideal occlusion as possible. It can be assumed that improvement in occlusion contributes to the stability of orthodontically treated cases and may aid in future relapse prevention. The first of Andrews' six keys to occlusion emphasizes the importance of a well-fitting, class I molar relationship in the establishment of a successful orthodontic result (Andrews 1972). In order to maintain a stable overbite correction, a favorable post-treatment incisor relationship is desirable (Houston, Edler 1990). A well-interlocked posterior occlusion helps prevent tooth migration. Kahl-Nieke (1995) examined fifty orthodontic patients, and found that those with an ideal class I molar relationship at the end of treatment usually experienced better incisor alignment and stability over time.

Mandibular incisor size and shape may also play a role in post-treatment relapse. Peck and Peck (2003) hypothesized that the mesiodistal and buccolingual widths of incisors in stable cases were different from those found in unstable cases.

They demonstrated statistically significant differences between the two groups. This led to the development of an index designed to determine the proper incisor dimensions for maintenance of anterior alignment. However, similar studies have found no significant correlation between tooth dimensions and crowding (Puneky et al. 1984; Glynn et al. 1987).

Retainer Designs

After teeth have been orthodontically repositioned, retention devices are used to maintain archform and minimize the tendency for teeth to shift into undesirable positions. When teeth shift into undesirable positions, it is considered relapse, while movement into desirable positions is considered to be settling. When settling occurs, the number of occlusal contacts increases, and the overall fit of the teeth improves. Retainers are typically designed to allow settling while minimizing relapse (Sauget et al. 1997). Commonly used retainers include fixed lingual retainers, tooth positioners, clear overlay retainers, and variations of the traditional Hawley retainer.

Clinicians may choose permanent retainers to retain areas of potential relapse more rigidly, or to reduce dependency on patient compliance. Bonded lingual retainers have been shown to be an effective means of retaining aligned anterior teeth in the post-treatment position in the long term (Stormann, Ehmer 2002). One of two basic designs of lingual bonded retainers are typically used. Rigid mandibular canine-to-canine retainers are attached to the canines only. They are effective in maintaining intercanine width, but are less effective at preventing individual tooth rotation. This type of retainer also tends to show more frequent relapse of those incisors not bonded

to the retainer (Stormann, Ehmer 2002). Customized canine-to-canine retainers are typically attached to six teeth, and are fabricated using flexible 0.0195" or 0.0175" multistranded stainless steel archwire. The flexibility of the multistranded archwire allows for physiologic tooth movement (Blake, Garvey 1998).

Another commonly used retention device is the tooth positioner, a removable appliance made of either soft rubber or plastic that surrounds the crowns of the teeth. This appliance can be either preformed or custom made, and, when worn consistently, can help improve tooth position following removal of orthodontic appliances (Binder 1988). Tooth positioners can also be helpful in re-establishing normal tissue tone and firmness where gingival hyperplasia may have occurred during treatment (Josell 1999).

Clear plastic appliances for retention have gained recent popularity among both patients and clinicians. They are made of durable plastic and have an esthetic value as "invisible" retainers. The Essix type clear overlay retention appliance was first introduced in 1993. The appliance is made of a thin, vacuum formed thermoplastic material that adapts closely to the lingual, facial, and occlusal surfaces of teeth (Sauget et al. 1997). This appliance is a clear plastic device that is retentive without clasps. It has minimal bulk, and does not interfere with speech. Preliminary studies have shown that the Essix retainer is just as effective in controlling post-orthodontic tooth movement as the traditional Hawley type retainer (Lindauer, Shoff 1998). However, this type of retainer typically will not allow full seating of the posterior occlusion, thus eliminating settling following appliance removal (Wang

1997). One study indicated that the clear overlay retainer is less durable and not as long-lasting as the traditional Hawley type retainer (Sheridan et al. 1993). Additionally, there have been a few reports of open bite occurring in some patients wearing clear overlay type retainers, likely caused by full time rather than the nighttime only wear that is recommended by the manufacturer (Sheridan et al. 1993).

The Hawley type retainer is a very commonly used removable retainer. The classic design of the Hawley retainer consists of a palatal or lingual portion of acrylic, retentive clasps, and a labial bow (Sauget et al. 1997). The palatal portion may cover the entire palatal mucosa, or may be fabricated using a horseshoe design, contacting only the lingual portion of the posterior teeth and part of the palatal mucosa. There are often adjustment loops in the canine area and the labial bow contacts either four or six anterior teeth. The palatal acrylic should extend distally to include the second molar, especially in patients who have undergone changes in the transverse dimension.

This basic design can be modified in a variety of different ways. The addition of springs and attachments, along with activation of the labial bow, can allow for limited tooth movement. The clinician may add wires between the canines and first premolars to enhance the retention of the appliance. Additionally, in extraction cases, the basic design may be modified so that retentive clasps do not pass through extraction sites, as this may aggravate the tendency for the spaces to re-open, especially in adult patients (Joondeph, Reidel 2005). A circumferential wire may be incorporated into a maxillary Hawley retainer, as this type of device provides

excellent retention without creating occlusal interferences (Collett 1998). Pontics may be incorporated into the retainer design to enhance esthetics and retain the edentulous areas during the transition from fixed orthodontic appliances to the prosthetic replacement of missing teeth. When implants are a part of the prosthetic treatment plan, the retainer can be modified to avoid tissue impingement during the osseointegration phase.

Spring re-aligners are acrylic appliances that incorporate some of the aspects of tooth positioners and Hawley retainers. This type of appliance, which incorporates acrylic over the labial bow of a Hawley retainer, can be used to help realign malpositioned teeth. It is often designed as a canine to canine passive retainer, or as an active appliance, in areas in which there is great relapse potential (Binder 1988). In many cases, this type of aligner is used on lower teeth only as a canine to canine appliance. However, such an appliance may be quite small and may present an aspiration risk. In order to avoid this risk, the aligner design should be incorporated into a larger Hawley appliance (Joondeph, Reidel 2005).

Retention Protocols in the Literature

Strategies for the retention of a treated orthodontic case are typically discussed at the time of diagnosis and treatment planning, and should take into account the importance of sustaining the corrected malocclusion in a position of stability and a condition of health. However, the optimal period of retention in each orthodontic case is unclear. Few have evaluated post-treatment changes in patients with similar malocclusions but different post-treatment retention strategies. One

investigation looked at sixty treated class II division I cases retrospectively; thirty had been retained for an average of one year following appliance removal, and thirty had not been retained and acted as the control group (Wood 1983). Measurements were obtained from study models and cephalometric radiographs at three different time periods. The two groups were compared with respect to skeletal pattern, overjet, overbite, and interincisal angle. This study found that both the retained and non-retained groups tended to show relapse after the completion of active treatment, with the greatest amount of overbite and overjet relapse found in the retention group. However, the mean initial overbite and overjet in the retained group was larger than that of the control group; this most likely accounted for the greater relapse in the retainer group. In both groups, the relapse in overbite and overjet were associated with the size of these measurements prior to orthodontic treatment, with a tendency for relapse back into a position between the initial and final overbite and overjet. However, the appliances used for retention in this particular study were not standardized within the retention group, nor was the overall duration of retention. The study also did not take into account compliance in retainer wear among the study participants. The importance of retention could have been better examined in this study through the use of matched pairs. However, such an undertaking might be impractical since patients are typically retained following orthodontic treatment.

A similar study examined thirty class II patients who were treated in a single phase with either a functional appliance or headgear, and then assigned to a retention or no retention group and then compared to an untreated control group (Keeling et al.

1998). A significant amount of relapse was found within the retention group versus the untreated controls. This study relied on a very modest sample size and the period of retention was not specified.

Because the optimal duration of retention for most orthodontically treated cases is indeterminate, wide variation in retention protocols exist. As noted previously, reorganization of the periodontal ligament occurs over a period of three to four months following orthodontic treatment, gingival tissues may take up to six months to achieve stability, and supracrestal fibers may take up to a year (Reitan 1969). Blake and Garvey (1998) cited such biological evidence as a primary reason for recommending full-time use of Hawley retainers for three to six months following fixed appliance removal, followed by nighttime only wear for the next eighteen months. A similar rationale was likely used in the development of maxillary Hawley retention strategy developed by Destang and Kerr (2003). They performed a study in which patients followed two different Hawley retainer protocols for the first year following orthodontic appliance removal. One group followed a six month regimen using removable maxillary Hawleys for three months full time and three months at night only. The second group followed a regimen of six months full time and six months at night only. The results of this study showed maxillary incisor alignment, as determined by Little's Irregularity Index, to relapse 50% in the first group but only 23% in the second group. However, this particular investigation did not take into account the original malocclusion of each patient, and did not stratify the results based upon the characteristics of the initial or final occlusion. The authors also failed

to examine outcomes other than irregularity, such as changes in overbite or overjet, during the specified time period. Patients were not questioned about their compliance to the prescribed wear schedule during the retention period. Additionally, the sample size of each group was very small, with only twenty patients in the first group and eighteen patients in the second group, making it difficult to generalize the conclusions.

One of the newer types of removable appliances is the overlay retainer. The Raintree Essix Company has popularized this device as an inexpensive retainer that can be quickly fabricated in the orthodontic office. One of the first studies designed to compare the retention of Essix appliances to that of conventional Hawley retainers was performed in 1993 by Lindauer and Shoff. This investigation examined two separate retention groups; one of which was assigned to wear an Essix overlay type retainer according to the manufacturer's instructions—the mandibular retainer was to be worn full-time and the maxillary retainer worn part-time for the first four weeks, and then both retainers at nighttime only thereafter. The second group was assigned to Hawley retainers; these retainers were worn full-time for the first three months, and only at night for the next three months. The results of this study showed no significant difference in incisor irregularity, overbite, or overjet at the end of six months between the two groups. One weakness of this study was a failure to look at the patients at different times during the six-month interval to determine at what point the majority of the relapse for each group occurred. Similar to other previously mentioned studies, this study also had a very small sample size (thirty patients total),

and did not attempt to stratify patients based on the initial or final occlusal characteristics of the patients in each group. One of the major differences noted in the literature between Hawley type and thermoplastic retainers is the facilitation of post-treatment settling of the occlusion. Hawley type retainers have been found to increase the number of occlusal contacts in the initial period following appliance removal better than their thermoplastic counterparts (Sauget et al. 1997). The Lindauer and Shoff study (1993) did not include measures of occlusal contacts, nor did it evaluate the maintenance of posterior occlusal corrections.

The current literature provides many empirical recommendations on retainer types and retention time in the context of long-term and post-retention relapse, while the question of the extent to which relapses occur during the retention phase has been largely ignored. One particular study examined 132 patients treated by a single practitioner at different points throughout the retention and post-retention phase, with the goal of determining at what point during the retention period relapse occurred and with which retention appliances (Lang et al. 2002). Patients were assigned to one of five retention groups: maxillary Hawley and a lower bonded canine to canine retainer; maxillary Hawley along with maxillary and mandibular bonded canine to canine retainers; maxillary and mandibular Hawley retainers; maxillary and mandibular bonded canine to canine retainers; and other unspecified retainers. The practitioner recommended full-time wear of all removable appliances for an unspecified period of time. In addition to the measures used in previous retention studies, this study also measured intercanine and intermolar width at three different

times, the effect of gender, and the original malocclusion and Angle class on post-treatment stability.

As expected based on previous examinations, more adverse change in irregularity and intercanine width was seen in the removable versus the fixed retainer groups. Interestingly, intermolar width was found to be more stable in the removable than the fixed appliance group. Additionally, the study found males to had more relapse than females. This study had a very large sample size, which is desirable but not always feasible in retention studies, thus allowing comparisons to be made between this study and many others found in the literature. Following data analysis, the authors concluded that the post-treatment changes in the total study group were largely independent of Angle class. As a result, they did not include this sub-grouping in the results, and pooled all of the data without first examining the groups individually.

The prospective randomized study is considered the "gold standard" in research. However, few truly randomized studies examining the effects of different retainer protocols have been performed to date. Stormann and Ehmer (2002) recognized that they were using fixed retainers very frequently in their practice, and randomized 103 patients to one of three fixed retention groups: a fixed retainer bonded only to each of the mandibular canines; a fixed retainer fabricated from an 0.0195 mm braided stainless steel wire bonded to all six mandibular anterior teeth; and a similar retainer fabricated from 0.0125 braided wire bonded to the same six teeth. This study is one of the few that examined incisor relapse along with bond

failure, patient discomfort, and periodontal and oral hygiene problems associated with the retainers. Their results showed that, even among different types of bonded retainers, long-term stability varies, with the 0.0195 mm retainer showing the least amount of incisor relapse and the least number of bond failures during a twenty-four month examination period. It was also noted that plaque index scores and bleeding on probing worsened in most of the patients during the twenty-four month time period, although none of the retainers had to be removed during this time period due to this occurrence. No mention was made as to the extent of periodontal disease based upon a periodontal evaluation of bone height or probing depths in any of the involved patients.

There is a significant lack of evidence available in the literature regarding optimal duration and type of retention for post-treatment stability. Most retention protocols followed by the clinician are largely dependant upon personal preference. A commonly cited advantage of fixed retainers over removable retainers is the elimination of the need for patient compliance (Zachrisson 1986; 1997). Some clinicians prefer removable appliances because, despite the fact that they can be lost or broken, replacement is less time consuming than with broken or debonded fixed retainers (Collett 1998). Issuing two removable retainers and delegating responsibility to the patient is also a cost-effective means of managing retention; unlike with fixed retainers, there is no question as to whom retainer maintenance "belongs" long after the removal of orthodontic appliance (Sheridan 2005). Retention patterns often show little, if any, consistency among clinicians in different regions of

a country. A study performed by Wong and Freer (2004) surveyed seven hundred Australian orthodontists for information regarding their retention protocols. An analysis of the results showed that the majority of the clinicians used maxillary thermoplastic retainers and mandibular bonded 3-3 retainers fabricated from 0.0175 inch multistrand stainless steel wire. The orthodontists commonly recommended a "regular retention period" of two years, and defined "permanent retention" as lifetime. Many of the practitioners had changed their retention protocols within the past five years prior to the survey. This further emphasizes that retention strategies vary significantly between clinicians, and are based largely on convenience and practitioner preferences.

HYPOTHESIS

There are no differences in maxillary and mandibular arch length, overbite, overjet, intercanine width, intermolar width, and the American Board of Orthodontics Objective Grading System scores between a retained group and an unretained group after one month. If rejected, there would be a difference between the two groups in these measures after one month.

MATERIALS AND METHODS

Study Population

The Case Western Reserve University Institutional Review Board (IRB) approved the study. The study group consisted of patients selected from the Case Western Reserve University Department of Orthodontics treated by orthodontic residents under the supervision of practicing orthodontic faculty. The criteria for inclusion in the sample included completion of routine straightwire orthodontic treatment in the Case Western Reserve University Department of Orthodontics; completion of an informed consent document by the subject and his or her Guardian; and eligibility for removal of appliances during the time period August 2005 to August 2006.

Thirty subjects were assigned to the retention group. A set of dental impressions using Jeltrate Plus™ (Masel Enterprises, Bristol, PA) was taken of each participant prior to the removal of orthodontic appliances. These impressions were sent to a professional orthodontic laboratory (American Orthodontic Laborotory, Cleveland, OH) where a set of Hawley retainers were fabricated. The Hawley retainers used in this study had a labial bow, bilateral adjustment loops between the canines and premolars, a C-clasp on each of the most mesial premolars, and an occlusal rest on each of the first molars.

On the day that fixed appliances were removed, the Hawley retainers were delivered and a set of alginate impressions were taken and poured in plaster. Each subect was instructed to wear the Hawley retainer every night for the first month following appliance removal. After one month, the subjects returned to the orthodontic clinic, at which time a second set of alginate impressions were taken. Patients were asked to fill out a post-treatment survey after one month. This survey consisted of questions regarding the number of hours the retainers were worn each day, and reasons, if any, why they did not wear the retainers as prescribed.

The control group was obtained from a sample used in a previous study (Lyotard 2006). This sample included thirty subjects treated by residents in the Case Western Reserve University Department of Orthodontics for whom orthodontic wires were removed for one month prior to removal of orthodontic appliances. Impressions were taken at the time of final wire removal, and again one month later.

The control group consisted of fourteen females (47%) and sixteen males (53%), while the retention group consisted of twenty-three (77%) females and seven (33%) males. At the start of treatment, twenty-four (80%) of the subjects in the control group were under the age of 15, compared to twenty-five (84%) in the retention group.

Main Outcomes

The outcomes of interest in this study were post-orthodontic relapse and settling. These outcomes were determined using a composite score derived from the American Board of Orthodontics Objective Grading System, as well as individual outcomes of interest defined as the change from the end of treatment to one month following the end of treatment. Post-treatment orthodontic instability is often characterized by progressive crowding of the mandibular incisors following the removal of orthodontic appliances. Mandibular incisor irregularity is often the precursor to maxillary crowding, deepening of the overbite, and generalized deterioration of the treated case (Little 1975). This study examined post-orthodontic instability using variables similar to those used by Little et al. (1981).

Model Analysis

Plaster models were measured at two time periods. The first time period was immediately following appliance removal (T1), and the second was one month following removal of orthodontic appliances (T2). Digital dial calipers (Electronic Digital Calipers, China) with fine tips measuring to the one-hundredth millimeter were used to measure the following variables:

1. Maxillary and mandibular crowding: Measured as the arch perimeter between the mesial surfaces of the first molars minus the sum of the mesiodistal crown diameters of the incisors, canines, and premolars. The measurement values were recorded in millimeters. Negative values indicated crowding, and positive values indicated spacing.

2. Overbite: The vertical overlap or open bite of the anterior teeth, recorded in relation to the coverage of the lower incisors or the

degree of open bite (Richmond et al. 1992). The measurement values were measured in millimeters.

3. Overjet: the mean horizontal overlap of the upper and lower central incisors (Richmond et al. 1992).

4. Intercanine width: the distance between the cusp tips or estimated cusp tips in cases of wear facets.

5. Intermolar width: the distance between the mesiobuccal cusp tips of the maxillary molars, and the distobuccal cusp tips of the mandibular molars (Kahl-Nieke et al. 1995)

The American Board of Orthodontics Objective Grading System (ABO-OGS) is an index used for the evaluation of orthodontic outcomes. The index consists of eight categorical variables for scoring dental casts and panoramic radiographs, as well as a total composite score of the eight variables. The variables include:

1. Alignment: an assessment of tooth alignment

2. Marginal Ridges: used to assess the proper vertical positioning of the posterior teeth

3. Buccolingual inclination: used to asses the buccolingual angulation of the posterior teeth

4. Occlusal relationship: measures the position of the buccal cusps of the maxillary canines, premolars, and molars; these cusps should align within 1mm of the interproximal embrasures of the mandibular posterior teeth

5. Occlusal contacts: used to asses the posterior occlusion

6. Overjet: measures the transverse relationship of the posterior teeth, and the anteroposterior relationship of the anterior teeth

7. Interproximal Contacts: used to determine whether all spaces have been closed

8. Total score: a composite of all measures

When grading orthodontic casts for presentation to the American Board of Orthodontics, one additional measurement, root angulation, is also included in the composite score. However, this study evaluated only the seven model measures and the total score; the measurement for root parallelism was excluded, as panoramic radiographs were not routinely taken in the orthodontic clinic following appliance removal.

Statistical Analysis

Data collection was organized using the Microsoft Office® Excel® 2003 software program. Statistical analysis was performed through the use of both the Excel and Minitab v. 14.0 software programs. For the continuous measures, standard descriptive statistics were computed for each variable assessed at the pre-treatment, end of treatment, and one month post-treatment periods, and paired t-tests were used to compare the mean differences in each time interval. For the categorical ABO-OGS measurements, the Wilcoxon sign rank test was used, and the median and the range of variability (minimum and maximum) were reported. Both the continuous and categorical measures were tested at a significance level of $p < 0.05$.

Reliability

Measurements were obtained consecutively on each subject's casts. For each variable, end of treatment and one month post-treatment measurements were considered for one subject before going on to the next variable. Measuring sequentially, in this way, enhanced the identification of homologous landmarks, and

increased the repeatability of the measurements (Vaden et al. 1997). In order to reduce examiner bias, ten sets of casts were measured in random order at three different time periods one month apart. Interclass correlation was calculated for the continuous variables, and ranged from 0.88-0.96. Each set of models was measured twice for the categorical ABO-OGS measurements. Weighted Kappa statistics were used to assess intra-examiner agreement, and ranged from 0.78-0.97.

MANUSCRIPT FOR PUBLICATION

SHORT-TERM EFFECTIVENESS OF NIGHT TIME RETAINER WEAR

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Abstract

The purpose of this prospective study was to evaluate a retained and an unretained group one month following the removal of orthodontic appliances. 60 consenting patients participated in the study. Group I (n=30) was assigned to nighttime wear of Hawley retainers. Group II (n=30) was unretained. ABO-OGS scores and six continuous variables (maxillary and mandibular arch length, overbite, overjet, intermolar width, intercanine width) were measured on casts taken at appliance removal (T1), and one month later (T2). Data analyses used paired t-tests and the Wilcoxon sign rank test ($p<0.05$). The unretained group showed a statistically significant decrease in mandibular arch length and an increase in overjet, as well as an improvement in vertical marginal ridge positioning and posterior occlusal contacts. This group also experienced more interproximal spacing from T1-T2. The retained group showed a significant increase in maxillary arch length and overbite, and a decrease in mandibular arch length and intercanine width from T1-T2. The two groups, when compared, were different from each other at T1 and T2 in maxillary and mandibular arch length, overjet, buccolingual inclination, and marginal ridges. Further studies are needed in order to evaluate both short and long term stability and continued occlusal improvement in both groups.

The prevention of relapse through the use of retention devices is an issue of great concern to both practitioners and patients alike. Robert Moyers once defined orthodontic retention as the "holding of teeth following orthodontic treatment in the treated position for the period of time necessary for the maintenance of the result[1].

Retention strategies and methods vary significantly among practitioners, and have been broadly classified into three categories. Limited retention is typically used following crossbite correction or growth modification; these cases often require further future orthodontic treatment. Moderate retention typically involves the use of a removable retainer for varying numbers of hours in the years following treatment, while permanent or semi-permanent retention is usually reserved for cases in which significant crowding or spacing existed prior to orthodontic intervention.

The Hawley retainer is perhaps the most commonly used removable retainer[2]. The classic design of the Hawley retainer consists of a palatal or lingual portion of acrylic, retentive clasps, and a labial bow; however, this basic design can be easily modified. Protocols for Hawley retainer wear are based upon the time needed for reorganization of periodontal and gingival structures following appliance removal[3], the ease of fabrication, and clinician preferences.

Despite the use of retention devices, perhaps the biggest problem faced by orthodontists is the occurrence of relapse and other post-treatment changes. From the early 1900's, Angle, Case, and other practitioners began to notice some of the difficulties that they were experiencing in the achievement of long term stability[4]. Studies on the assessment of long-term observations of post-treatment and post-retention results have indicated that relapse occurs in most cases, even those in which retention was continued

for a number of years following orthodontics[5]. Despite assessment of different variables, the scientific basis for retention devices and protocols remains poor and highly subjective to practitioner preferences.

Orthodontists now realize that tooth movement may continue throughout life in treated and untreated individuals[6]. As changes in dental relationships after completion of the active phase of treatment are to be expected and do not necessarily indicate relapse[7], it would be optimal to develop a retention protocol that allows for favorable post treatment changes while minimizing those changes that are undesirable. The purpose of this study was to examine the behavior of a retained group and an unretained group one month following the removal of orthodontic appliances.

MATERIAL AND METHODS:

The study included sixty consenting patients who completed treatment in the Case Western Reserve University Department of Orthodontics. Thirty patients nearing the end of their fixed appliance treatment were selected for the retention group. A set of impressions using Jeltrate Plus impression material (Masel Enterprises, Bristol, PA) was taken from each participant one visit prior to the removal of orthodontic appliances. These impressions were sent to a professional orthodontic laboratory (American Orthodontic Laborotory, Cleveland, OH) where a set of Hawley retainers were fabricated. The Hawley retainers used in this study had a labial bow, bilateral adjustment loops between the canines and premolars, a C-clasp on each of the most mesial premolars, and an occlusal rest on each of the mandibular first molars. The acrylic was scalloped along the cemento-enamel junction of the teeth. Patients were instructed to wear the retainers at night starting on the day that appliances were removed.

The unretained group included thirty patients in whom orthodontic wires were removed for one month prior to removal of orthodontic appliances. The patients returned after one month, and impressions were taken to assess changes. If they were deemed to be stable or to have improved, appliances were removed. If changes were undesirable, further treatment was rendered.

Model Analysis

Models were taken prior to orthodontic treatment (T0), immediately following the removal of orthodontic appliances or final archwires (T1), and again one month later (T2). Digital dial calipers (Electronic Digital Calipers, China) with fine tips measuring to the 100^{th} of a millimeter were used to measure six continuous variables: maxillary and mandibular arch length, overbite, overjet, intercanine width, and intermolar width.

The American Board of Orthodontics Objective Grading System (ABO-OGS) is an index used for the evaluation of orthodontic outcomes[8]. According to this index, a higher individual score is considered to be less acceptable than a lower individual score. The variables are alignment, marginal ridges, buccolingual inclination, occlusal relationship, occlusal contacts, overjet, interproximal contacts, and total score. One additional measurement, root angulation, is also included in the composite score. However, in this study the measurement for root parallelism was excluded, as panoramic radiographs were routinely taken in the orthodontic clinic at the time of appliance removal (T1), but were not routinely taken a month later (T2).

Statistical Analysis

Data collection was organized using the Microsoft Office® Excel® 2003 software program. Statistical analysis was performed through the use of Excel; SPSS® v. 15.0 for Windows®, and Minitab v. 14.0 software programs. For the continuous measures, standard descriptive statistics were computed for each variable (tables I and II), and paired t-tests were used to compare the mean differences from T1-T2 (table III). For the categorical ABO-OGS measurements, the Wilcoxon sign rank test was used, and the median and the range of variability (minimum and maximum) were reported (table IV). Both the continuous and categorical measures were tested at a significance level of $p<0.05$.

Reliability

In order to assess reliability, ten sets of casts were measured in random order at three different time periods one month apart. Interclass correlation was calculated for the continuous variables, and ranged from 0.88-0.96. Each set of models was measured twice for the categorical ABO-OGS measurements. Weighted Kappa statistics were used to assess intra-examiner agreement, and ranged from 0.78-0.97.

Results

The retained group consisted of twenty five females and five males. The mean age at the start of treatment was twelve years, and the average treatment time was twenty five months. The unretained group consisted of seventeen males and thirteen females. The mean age at the start of treatment was 13.6 years, and the average treatment time was twenty seven months.

In the unretained group, there was a statistically significant increase in interproximal spacing and overjet from T1-T2. There was also a decrease in mandibular

arch length. This group experienced a statistically significant improvement in the vertical positioning of the marginal ridges; in the number of posterior occlusal contacts; and in the total ABO score.

The retained group showed a statistically significant increase in maxillary arch length and overbite from T1-T2. There was also a decrease in mandibular arch length and intercanine width. For the categorical measures, the retained group showed a statistically significant improvement in the total ABO score.

Looking at the retained group versus the unretained group showed that the two groups were similar at T0. However, they were different from each other at T1 in maxillary arch length, mandibular arch length, overbite, marginal ridges, and buccolingual inclination of the posterior teeth. The two groups also behaved differently from one another at T2 in the same categories.

Discussion

Both groups showed a statistically significant decrease in mandibular arch length after one month, with almost twice as much relapse occurring in the unretained group. Immediately following the removal of orthodontic appliances, teeth are out of equilibrium with the cheek, lip, and tongue pressures that oppose them. The PDL and adjacent gingival structures can take up to six months before reorganization occurs[9]; therefore, it may be important to hold teeth in their corrected positions at least part time in order to facilitate remodeling. The unretained group may have experienced a greater decrease in arch length because they did not benefit from any form of stabilization following appliance removal, allowing the teeth to relapse back towards their pretreatment positions.

The unretained group also experienced a statistically significant increase in overjet. The increase in overjet appears to be associated with the decrease in mandibular arch length and the increase in maxillary arch length that were also observed in this group. The Hawley retainer used in this study included a labial bow which was adjusted so that it passively contacted the labial surfaces of the maxillary and mandibular incisors and canines. This pressure most likely contributed to the maintenance of the corrected overjet in the retained group; even though patients were instructed to wear the retainers only part time, placing them back into the mouth at night may have corrected any increase in overjet that occurred during normal function. Little reported that post treatment, overjet tended to settle somewhere between the pretreatment and end of treatment positions[5]. The subjects in the current study followed these previously reported overjet trends, however further studies are needed to determine whether the patients will continue in this pattern over a longer time period.

The retained group showed a statistically significant increase in overbite between T1 and T2. This may have been a result of the occlusal rests on the mandibular first molars; such an occlusal interference may have contributed to a deepening of the overbite during retainer wear. Previous studies have shown overbite to continue to increase in the post-treatment period until most of the overbite correction achieved with treatment has relapsed[9,10,11]. However, because the time period in the current study was limited to one month, we do not know whether the patients in this study would follow a similar pattern over time.

The retained group also experienced an increase in maxillary arch length and a decrease in mandibular arch length; however, these findings were less than in the

unretained group. Previous studies have shown that incisor relapse often occurs despite the presence of retainers[5,12], a phenomenon that was similarly illustrated in the current study. Studies examining the effectiveness of nighttime Hawley retainer wear have also shown similar results, with an increase in mandibular crowding and maxillary spacing seen in these patients after six months[11, 13]. However, most other retention studies began with full time wear of retainers starting from the day that orthodontic appliances were removed. The part time wear schedule in the current study may have allowed for excessive tooth movement when the retainers were not being worn.

The intercanine width also showed a statistically significant decrease from T1-T2 in the retained group. This may have occurred for a number of reasons. An observation of the intercanine widths at T0 and T1 shows that a mean increase in this measure occurred during treatment. However, previous literature has shown a decrease in the intercanine width to occur even when the initial intercanine width is maintained during orthodontic treatment[5]. According to the principles of normal growth and development, the mandibular anterior segment exhibits a physiologic distal and lingual drifting of the dentition as the mandible continues to grow forward[14]. If the patients were still experiencing mandibular growth at the time that appliances were removed, this decrease in the intercanine width, along with the decrease in mandibular arch length, may have occurred due to normal growth. The unretained group also experienced a decrease in the intercanine width from T1-T2; however, the mean decrease was found to be less than in the retained group. This may have occurred because the majority of the patients in the unretained group were males who may not have experienced the degree of mandibular growth at the end of treatment that the majority female retained group had. Further

studies observing the trends in the intercanine width are needed to see whether the intercanine width in the unretained group follows that of the retained group over time.

Evaluating the groups according to the ABO-OGS criterion showed that the unretained group improved significantly in occlusal measures after one month, with significant changes exhibited in the marginal ridge and posterior occlusal contact categories. The retained group also showed improvement in these categories; however, the acrylic on the palatal and lingual surfaces of the retainers may have prohibited more settling from occurring. The American Board of Orthodontics states that measures of posterior occlusion are important in the development of an outcomes index because the achievement of a proper occlusion is a crucial factor in holding teeth in their corrected positions[7]. It is likely that proper intercuspation is an important factor in retention, and it is desirable to attain as many posterior contacts as possible to evenly distribute the amount of strain placed on the structures of the periodontium.

A surprising finding was that the control and retainer groups were very different from one another at the end of treatment and one month later in the categories of maxillary and mandibular arch length and overbite, as well as buccolingual inclination of the posterior teeth and the vertical positioning of the marginal ridges. This may have been due to the fact that the study was carried out in a clinical setting with residents treating the patients under the auspices of clinical faculty members. The results may have been different if the cases had been treated by a single practitioner. Many of the patients in the retained group were treated by first and second year residents, while patients in the unretained group were seen mainly by third year residents. This may have introduced some proficiency bias into the study. Additionally, treatment time in the

unretained group was longer on average than in the retained group; the patients in the unretained group may have been more difficult cases at baseline, and therefore took longer to treat. One limitation of the current study is that ABO measurements were not performed at baseline in order to compare the severity of cases in each group. Such an evaluation may have allowed for a better comparison between the subjects in the study. Another limitation was the small sample size of only sixty patients. In order to report the obtained results at an alpha level equal to 0.05 and a power of 80 percent, 137 subjects would have been needed in each group, for a total sample of 274 patients. A larger group may have allowed for more accurate comparisons to be made between the retained and unretained groups.

Retention studies are often met with many obstacles as they attempt to make comparisons and draw conclusions that will add to the orthodontic literature. Many of the opinions that are currently held about retention come from the studies performed by Little and colleagues at the University of Washington. These studies concluded that the only way to ensure continued satisfactory alignment post treatment is through the use of fixed or removable retainers for life; however, as with any study, there were limiting factors. Other retention studies have been performed since Little's work, and all have experienced similar problems in obtaining a satisfactory sample. It is often difficult to obtain an adequate sample of patients in whom pretreatment, end of treatment, and post treatment records have been kept, and in order to come to conclusions about the efficacy of retainers it is important to have good longitudinal records. Additionally, it is difficult to find patients with a similar amount of incisor irregularity and a similar occlusion at the end of treatment so that valid comparisons can be made post treatment. These were just

two of the problems experienced in collecting a sample for the current study. However, until there is truly a scientific basis for decisions regarding retention, all of the current retention literature can be utilized by practitioners as they attempt to formulate their own retention protocols.

Conclusions:

The retained and unretained groups behaved quite differently from one another in a number of categories. The Hawley retainers used in the retained group held the alignment of the anterior teeth, but also allowed for some settling of the posterior occlusion. The patients in the unretained group experienced more incisor relapse, but also had a better posterior occlusion after a month than the retained group did. Further studies are needed in order to evaluate the long term stability and the continued occlusal improvement in both groups over a longer period of time.

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TABLE I.—Retained Group Descriptive Statistics

Variable	n	mean	st. dev	min	median	max
Maxillary Crowding (T0)	30	-0.562	6.66	-27.75	-0.685	12.59
Maxillary Crowding (T1)	30	0.877	0.806	0	0.705	3.06
Maxillary Crowding (T2)	30	1.001	0.829	0	0.785	3.06
Mandibular Crowding (T0)	30	-1.689	3.26	-11.88	-0.755	2.2
Mandibular Crowding (T1)	30	0.456	0.774	-0.77	0.365	3.06
Mandibular Crowding (T2)	30	0.251	0.882	-1.07	0.115	2.71
Overbite (T0)	30	3.824	1.419	0	4.015	7.4
Overbite (T1)	30	2.6213	0.5331	1.69	2.64	3.55
Overbite (T2)	30	2.911	0.696	1.69	2.885	4.32
Overjet (T0)	30	3.764	1.818	1.34	3.33	9.26
Overjet (T1)	30	2.608	0.725	1.16	2.495	4.14
Overjet (T2)	30	2.779	0.727	1.2	2.67	4.25
Intercanine (T0)	30	26.122	2.055	22.16	25.91	30.82
Intercanine (T1)	30	26.981	1.338	24.16	25.91	30.82
Intercanine (T2)	30	26.68	1.447	23.37	26.7	30.17
Intermolar (T0)	30	43.919	2.978	37.76	43.115	49.6
Intermolar (T1)	30	45.136	3.006	37.59	45.25	50.75
Intermolar (T2)	30	44.953	2.73	37.75	44.53	49.66

TABLE II.—Unretained Group Descriptive Statistics

Variable	n	mean	st. dev	min	median	max
Maxillary Crowding (T0)	30	0.121	3.191	-5.92	0.23	9.16
Maxillary Crowding (T1)	30	0.0787	0.837	-1.39	0.23	1.47
Maxillary Crowding (T2)	30	0.393	1.006	-1.5	0.19	2.7
Mandibular Crowding (T0)	30	-0.391	2.402	-4.37	-0.955	6.1
Mandibular Crowding (T1)	30	0.00433	0.682	-0.98	-0.05	1.51
Mandibular Crowding (T2)	30	-0.394	0.813	-2.07	-0.325	1.4
Overbite (T0)	30	3.529	1.341	0	3.535	5.74
Overbite (T1)	30	2.054	0.714	0.64	1.94	3.25
Overbite (T2)	30	2.22	0.706	1.16	2.11	3.67
Overjet (T0)	30	4.169	1.528	2.35	3.76	8.83
Overjet (T1)	30	2.691	0.846	1.18	2.615	4.4
Overjet (T2)	30	3.052	0.768	1.28	2.995	4.62
Intercanine (T0)	30	26.347	2.788	20.44	25.79	34.39
Intercanine (T1)	30	26.323	1.898	22.64	26.25	30.84
Intercanine (T2)	30	26.293	1.761	22.99	26.505	29.77
Intermolar (T0)	30	45.296	3.289	38.09	44.855	54.07
Intermolar (T1)	30	44.687	2.134	41.05	44.535	49.59
Intermolar (T2)	30	44.498	1.904	40.85	44.195	47.62

TABLE III.-- Results of paired t-tests for continuous data

Continuous Measures (Mean, Standard Deviation)				
Control Group				
	Time			p-values
Variable	**T0**	**T1**	**T2**	**T1-T2**
Maxillary Crowding	0.121±3.191	0.079±0.837	0.393±1.006	0.136
Mandibular Crowding	-0.391±2.402	0.004±0.682	-0.398±0.922	0.025
Overbite	3.529±1.341	2.054±0.714	2.220±0.706	0.149
Overjet	4.169±1.528	2.691±0.846	3.052±0.768	0.010
Intercanine Width	26.347±2.788	26.323±1.898	26.293±1.761	0.794
Intermolar Width	45.296±3.289	44.687±2.134	44.498±1.904	0.243
Retainer Group				
	Time			p-values
Variable	**T0**	**T1**	**T2**	**T1-T2**
Maxillary Crowding	-0.562±6.66	0.877±0.806	1.001±0.829	0.042
Mandibular Crowding	-1.689±3.260	0.456±0.774	0.251±0.882	0.038
Overbite	3.824±1.419	2.621±0.533	2.911±0.696	0.001
Overjet	3.764±1.818	2.608±0.725	2.779±0.727	0.201
Intercanine Width	26.122±2.055	26.981±1.338	26.680±1.477	0.002
Intermolar Width	43.919±2.978	45.136±3.006	44.953±2.730	0.177
Controls vs. Retainers				
	p-values			
Variable	**T0**	**T1**	**T2**	**T1-T2**
Maxillary Crowding	0.614	0.000	0.013	0.377
Mandibular Crowding	0.085	0.020	0.005	0.322
Overbite	0.412	0.001	0.000	0.371
Overjet	0.355	0.682	0.163	0.310
Intercanine Width	0.723	0.126	0.356	0.062
Intermolar Width	0.507	0.457	0.978	0.978

TABLE IV. Wilcoxon Sign Rank Results for Continuous Data

ABO Measures (median, minimum, and maximum values)				
Control				
Variables	**T1**	**T2**	**T2-T1**	**p-value**
Alignment	3 (0,8)	4 (0,11)	1 (-5,5)	0.171
Marginal Ridges	5 (1,11)	4 (1,8)	-1 (-4,1)	0.001
Buccolingual Inclination	4 (0,9)	4 (0,9)	0 (-4,2)	0.398
Overjet	3 (0,7)	2.5 (0,7)	-1 (-5,3)	0.409
Occlusal Contacts	5.5 (1,18)	5 (0,14)	-2 (-12,9)	0.008
Occlusal Relationship	2 (0,15)	2 (0,14)	0 (-4,3)	0.427
Interproximal Contacts	0 (0,2)	0 (0,4)	0 (-1,3)	0.019
Total Score	27 (13,43)	22 (12,51)	-1.5 (-12,8)	0.017
Retainer				
Variables	**T1**	**T2**	**T2-T1**	**p-value**
Alignment	4 (0,12)	4 (1,9)	0 (-3,3)	0.778
Marginal Ridges	3 (0,10)	3 (0,9)	0 (-2,2)	0.135
Buccolingual Inclination	0 (0,4)	0 (0,4)	0 (-1,1)	0.625
Overjet	3 (0, 15)	3 (0,10)	0 (-7,2)	0.849
Occlusal Contacts	6.5 (0,17)	6 (1,16)	-1 (-3,4)	0.103
Occlusal Relationship	3 (0,11)	2 (0,13)	0 (-4,2)	0.070
Interproximal Contacts	0 (0,3)	0 (0,1)	0 (-2,1)	0.273
Total Score	21 (10,15)	20.5 (9,44)	-2.5 (-11,6)	0.033
Controls vs. Retainers (p-values)				
Variables	**T1**	**T2**	**T2-T1**	
Alignment	0.160	0.674	0.349	
Marginal Ridges	0.000	0.006	0.132	
Buccolingual Inclination	0.000	0.000	0.510	
Overjet	0.887	0.389	0.587	
Occlusal Contacts	0.917	0.155	0.096	
Occlusal Relationship	0.940	0.587	0.595	
Interproximal Contacts	0.225	0.065	0.007	
Total Score	0.061	0.135	0.672	

APPENDIX 1: RAW DATA

The following is a legend to be used for Tables 1-4 in Appendix 1:

Continuous Variables:

Mx Cr 1: Maxillary arch length at T1
Mx Cr 2: Maxillary arch length at T2
Md Cr 1: Mandibular arch length at T1
Md Cr 2: Mandibular arch length at T2
OB 1: Overbite at T1
OB 2: Overbite at T2
OJ 1: Overjet at T1
OJ 2: Overjet at T2
Intcan 1: Intercanine width at T1
Intcan 2: Intercanine width at T2
Intmol 1: Intermolar width at T1
Intmol 2: Intermolar width at T2

Categorical Variables:

AR: Alignment and Rotations
MR: Marginal Ridges
BI: Buccolingual Inclination
OJ: Overjet
OC: Occlusal Contacts
OR: Occlusal Relationship
IC: Interproximal Contacts
T1: Total score at T1
T2: Total score at T2

TABLE 1.-- Raw Retained Continuous Data

	Mx Cr 1	Mx Cr 2	Md Cr 1	Md Cr 2	OB 1	OB 2	OJ 1	OJ 2	Intcan1	Intcan 2	Intmol 1	Intmol 2
1	2.08	2.08	0.61	0.61	2.5	2.5	2.5	2.5	27.23	27.17	46.32	44.53
2	1.92	1.92	1.1	1.95	2.84	3.16	2.34	2.85	27.48	26.77	39.72	39.72
3	0.55	0.55	0.92	0.92	1.87	1.87	2.2	2.21	26.83	27.14	42.66	43.78
4	0	0.57	0	-0.78	2.93	2.88	2.51	2.64	26.65	26.08	45.25	44.53
5	0.92	1.96	0.83	0.22	1.73	1.73	1.23	1.96	27.48	27.38	49.49	49.3
6	0.41	0.82	3.06	2.71	3.27	2.67	2.49	2.79	26.95	26.65	45.9	45.9
7	1.17	2.15	-0.3	-0.66	3.14	4.12	1.96	2.13	25.58	24.66	45.78	44.49
8	0	0	-0.77	-0.77	2.77	2.89	1.5	2	27.63	26.1	45.25	45.39
9	0.69	0.45	0	0	2.35	2.67	2.28	3.05	27.9	27.72	44.02	43.59
10	0	0	0	0	1.96	2.75	2.98	3.49	24.28	23.37	41.73	41.58
11	0.64	0.64	0.52	0.52	2.7	3.24	2.79	3.96	27.97	27.33	46.42	47.21
12	0.4	0.4	0.18	0.6	2.27	2.27	3.41	3.05	25.97	25.37	46.24	46.1
13	0.16	0.16	0.65	0.65	2.01	2.12	4.07	2.13	25.45	25.93	43.41	44.18
14	0.82	0.82	-0.19	-0.19	2.53	3.25	2.25	2.66	26.99	26.51	44.67	44.31
15	0.75	0.75	0.26	0.26	2.79	4.32	4.14	4.25	27.69	27.44	44.37	44.29
16	3.06	3.06	0.65	0.65	3.03	3.03	2.62	2.2	25.44	25.44	37.59	37.75
17	0.99	0.83	0.28	0.16	3.08	4.22	2.04	3.77	27.27	27.88	43.03	43
18	1.69	1.69	-0.59	-0.59	3.07	3.39	2.34	2.53	27.13	27.12	45.61	45.59
19	0.54	0.54	1.84	1.84	2.05	2.04	2.91	2.91	30.14	30.17	47.25	47.93
20	0	0	0.08	-0.05	2.09	2.54	2.18	2.33	26.09	26.05	43.54	43.5
21	1.39	1.67	1.36	1.36	3.44	3.5	3.6	1.75	26.12	25.56	50.75	49.45
22	0.37	0.37	0.45	0.45	2.17	2.65	3.3	3.42	26.66	26.06	45.56	45.06
23	0	0.84	-0.41	-0.68	2.58	3.25	2.69	3.78	26.16	26.14	43.35	43.17
24	0.72	0.72	0.93	-1.07	2.51	3.01	3.62	3.96	27.88	27.82	42.2	43.07
25	1.99	1.99	-0.21	-0.21	1.69	1.69	1.16	1.2	24.16	24.16	45.17	45.17
26	2.11	2.11	0.61	-0.03	3.47	3.47	3.3	3.32	27.54	26.86	49.14	48.33
27	0	0	1.24	0.07	3.19	3.29	2.46	2.99	29.96	29.38	46.79	46.07
28	1.69	1.69	0.59	0.59	3.55	3.78	2.37	2.38	26.93	26.13	42.72	43.25
29	0	0	0	-1	2.75	2.71	2.38	2.47	28.73	29.27	50.38	48.68
30	1.26	1.26	0	0	2.31	2.32	2.61	2.68	27.15	26.75	49.77	49.66

TABLE 2.-- Raw Retainer ABO Data

ID	AR	MR	BI	OJ	OC	OR	IC	T1	AR	MR	BI	OJ	OC	OR	IC	T2
1	3	3	3	4	7	5	0	25	4	3	2	4	7	5	0	25
2	6	2	4	9	7	2	0	30	3	4	4	9	5	2	1	28
3	4	4	0	7	7	8	0	30	1	4	0	7	6	4	0	22
4	4	5	0	3	8	0	0	20	3	5	0	1	7	0	1	17
5	0	2	0	3	4	1	0	10	1	2	0	5	5	1	1	15
6	8	2	0	8	0	0	3	21	6	1	0	8	4	0	1	20
7	4	3	0	4	6	3	0	20	3	3	0	2	3	2	0	13
8	4	3	1	2	6	5	0	21	6	1	0	2	4	5	0	18
9	4	0	0	6	3	2	1	16	4	0	0	4	2	2	0	12
10	3	0	0	2	2	8	0	15	5	0	0	3	5	8	0	21
11	3	3	0	8	8	4	0	26	3	2	0	8	7	4	0	24
12	3	2	4	2	12	11	0	34	3	2	4	2	10	13	0	34
13	5	1	0	0	6	3	0	15	8	0	0	2	7	3	0	20
14	6	4	0	4	5	0	0	19	6	4	0	4	9	0	0	23
15	6	0	1	10	6	0	0	23	7	1	1	10	6	0	0	25
16	1	3	2	2	12	0	0	20	1	3	2	1	12	0	0	19
17	3	4	4	2	17	0	0	30	4	3	4	2	14	0	0	27
18	7	5	0	9	11	0	1	33	5	5	0	9	10	0	0	29
19	2	6	1	7	9	6	0	31	5	4	1	7	7	2	0	26
20	1	4	2	3	6	4	0	20	3	2	1	3	6	2	0	17
21	12	10	1	15	13	3	1	55	9	9	2	8	16	0	0	44
22	4	3	1	1	5	5	1	20	6	2	1	3	3	5	0	20
23	6	6	1	4	4	5	0	26	7	5	1	3	2	4	0	22
24	2	3	0	2	8	4	0	19	3	4	0	1	7	4	0	19
25	5	3	0	2	8	7	1	26	5	3	0	2	6	7	0	23
26	5	3	4	1	7	3	1	24	4	4	4	0	4	2	1	19
27	5	3	0	0	5	0	0	13	4	3	0	2	6	0	0	15
28	7	3	0	2	12	0	2	26	8	3	0	1	9	0	1	22
29	2	2	3	1	5	1	0	14	3	3	3	1	4	1	0	15
30	6	3	0	0	2	0	1	12	4	1	0	2	1	0	1	9

TABLE 3.-- Raw Continuous Unretained Data

ID	Mx Cr 1	Mx Cr 2	Md Cr 1	Md Cr 2	OB 1	OB 2	OJ 1	OJ 2	Intcan 1	Intcan 2	Intmol 1	Intmol 2
1	0.62	1.91	-0.52	-0.12	2.24	1.35	2.37	2.19	25.85	26.82	46.15	45.71
2	1.3	2.17	0.81	0.2	2.25	2.95	2.59	3.22	28.35	28.04	44.14	44.21
3	0.31	0.34	-0.59	-0.59	2.18	1.85	2.45	3.65	27.53	26.86	44.68	45.37
4	-1.35	-1.5	-0.86	-0.28	1.62	2.6	2.2	3.74	26.29	26.75	43.01	42.78
5	-0.4	-0.02	-0.93	-1.97	2.61	3.15	2.18	2.64	23.8	24.3	43	43.27
6	0.48	0.23	0.28	-1.12	1.93	3.02	3.39	2.98	25.41	24.88	45.15	44.89
7	-1.07	0.31	-0.32	-1.13	1.43	1.59	2.64	3.26	27.63	27.42	45.08	44.5
8	0.01	0.12	-0.54	-1.27	3.08	2.82	4.36	4.46	27.44	28.17	45.57	45.71
9	-0.21	2.7	0.3	-1.21	1.95	2.28	2.38	3	25.99	26.47	46.35	47.62
10	-1.02	0.87	0.16	-1.22	1.81	1.52	2.72	3.31	27.46	27.03	46.46	46.36
11	-0.1	-0.5	-0.69	-0.24	3.13	2.25	2.67	2.8	28.71	29.07	44.57	45.25
12	0.97	-0.71	1.24	-0.37	3.25	3.64	4.4	4.62	22.64	23.04	44.01	43.02
13	1.47	0.17	0.79	-0.16	0.75	1.88	1.41	3.21	28.74	28.4	42.8	43.24
14	0.37	-0.25	0.13	-0.97	1.94	2.34	4.06	3.54	27.96	27.81	49.59	45.81
15	-1.23	0.07	-0.14	-0.1	3.11	3.67	3.28	4.24	27.03	26.77	43.36	44.07
16	-0.66	-0.07	-0.58	0.28	1.56	1.92	1.93	2.15	23.29	22.99	41.05	40.85
17	0.23	0.46	1.11	-2.07	0.64	1.61	1.22	2.66	25.36	26.02	43.18	43.24
18	1.07	0.69	-0.53	-0.39	1.09	1.16	1.18	1.28	27.22	26.39	42.52	41.98
19	-0.66	-0.95	0.54	-0.78	1.38	2.11	2.69	3.51	23.28	24.51	43.83	43.81
20	-0.14	0.19	-0.02	-0.44	2.79	1.96	3.59	3.73	25.5	25.85	44.71	44.18
21	-0.69	0.27	0.72	1	2.87	1.65	4.32	2.47	30.84	29.77	47.49	47.45
22	-1.39	-0.37	-0.05	-0.2	1.78	2.55	2.92	2.94	26.67	25.79	41.17	41.03
23	1.29	0.83	0.02	0.81	2.44	2.33	1.88	2.65	26.57	26.59	46.13	45.81
24	0.61	2.37	1.51	1.4	1.77	2.35	2.25	1.69	24.58	24.63	44.5	44.03
25	1.38	-0.38	0.81	0.75	2	1.82	2.77	2.99	25.33	24.89	48.38	47.01
26	0.23	0.16	-0.39	-0.11	1.66	1.52	3.04	3.68	24.1	24.53	42.67	42.31
27	0.27	1.87	-0.98	-0.94	1.94	2.11	2.67	2.84	28.86	28.94	48.12	47.59
28	-0.24	1.36	-0.62	0.27	1.92	1.84	2.53	3.38	26.12	26.54	47.27	47.31
29	0.25	0.19	-0.48	-0.03	1.29	1.18	2.11	1.91	24.93	23.53	43.46	44.03
30	0.66	-0.73	-0.05	-0.82	3.21	3.58	2.54	2.81	26.21	26	42.21	42.5

TABLE 4.-- Raw Unretained ABO Data

ID	AR	MR	BI	OJ	OC	OR	IC	T1	AR	MR	BI	OJ	OC	OR	IC	T2
1	3	3	7	1	4	3	0	21	4	2	6	2	4	2	1	21
2	5	11	2	3	6	1	2	30	4	8	2	0	4	3	1	22
3	6	4	1	5	5	10	0	31	7	5	1	4	5	8	1	31
4	3	3	4	4	3	3	0	20	4	1	4	3	7	2	0	21
5	2	10	6	3	3	4	0	28	7	8	7	0	0	4	0	26
6	2	3	2	3	13	6	0	29	1	4	0	2	8	6	0	21
7	6	6	2	2	3	0	0	19	6	5	2	5	0	0	1	19
8	6	7	8	4	3	15	0	43	5	6	8	6	12	14	0	51
9	2	4	4	2	1	4	0	17	5	3	3	0	5	2	2	20
10	3	4	4	7	12	1	0	31	4	3	4	6	4	2	1	24
11	5	7	7	5	9	7	0	40	4	7	6	2	5	3	1	28
12	2	5	2	4	9	1	0	23	3	6	2	4	7	2	0	24
13	6	5	2	5	13	3	0	34	3	4	2	2	7	3	1	22
14	2	6	9	4	8	4	0	33	4	4	9	2	5	4	0	28
15	5	5	7	3	4	2	0	26	0	4	9	2	4	2	0	21
16	1	3	5	0	5	2	0	16	2	2	5	2	7	2	0	20
17	6	5	7	5	10	1	0	34	11	5	3	7	1	4	0	31
18	2	1	0	4	10	2	1	20	4	1	0	5	10	0	2	22
19	2	8	2	2	5	0	0	19	6	7	1	2	2	0	0	18
20	3	4	1	1	5	5	0	19	3	1	1	3	6	5	0	19
21	0	4	1	5	2	1	0	13	5	4	2	0	1	0	0	12
22	8	4	5	1	5	1	0	24	5	5	4	0	4	1	0	19
23	4	2	7	3	4	0	0	20	1	2	6	5	2	1	0	17
24	1	6	4	3	11	3	0	28	3	6	5	6	9	2	3	34
25	3	7	5	6	12	1	1	35	5	5	5	7	0	1	0	23
26	5	4	8	3	1	1	0	22	4	5	6	4	2	1	1	23
27	3	2	3	2	11	1	1	23	1	2	3	0	3	2	4	15
28	2	7	8	5	18	1	0	41	4	3	8	4	14	0	1	34
29	4	5	4	5	13	2	1	34	4	4	6	6	13	3	0	36
30	4	7	7	2	9	1	0	30	6	6	7	0	6	1	0	26

APPENDIX 2: DATA TABLES

The following is a legend to be used for Tables 5 and 6 in Appendix 2:

Continuous Variables:

Mx AL: Maxillary arch length
Md AL: Mandibular arch length
OB: Overbite
OJ: Overjet
IC: Intercanine width
IM: Intermolar width

T1: End of treatment
T2: One month post-treatment
T1-T2: Difference between T1 and T2

Categorical Variables:

AR: Alignment and Rotations
MR: Marginal Ridges
BI: Buccolingual Inclination
OJ: Overjet
OC: Occlusal Contacts
OR: Occlusal Relationship
IC: Interproximal Contacts
Total: Total Score

TABLE 5.-- Continuous Data

Unretained				
	T1 (mean)	**T2 (mean)**		**T1-T2 (p-values)**
Variable				
Mx AL	0.79	0.393		0.136
Md AL	0.004	-0.398		0.025
OB	2.054	2.22		0.149
OJ	2.691	3.052		0.011
IC	26.323	26.293		0.794
IM	44.687	44.498		0.243
Retained				
Variable	**T1 (mean)**	**T2 (mean)**		**T1-T2 (p-values)**
Mx AL	0.877	1.001		0.042
Md AL	0.456	0.251		0.038
OB	2.621	2.911		0.001
OJ	2.608	2.779		0.201
IC	26.981	26.68		0.002
IM	45.136	44.953		0.177
Unretained vs. Retained (p-values)				
Variable	**T1**	**T2**		**T1-T2**
Mx AL	0	0.013		0.377
Md AL	0.02	0.005		0.322
OB	0.001	0		0.371
OJ	0.682	0.163		0.311
IC	0.126	0.356		0.062
IM	0.457	0.978		0.978

Table 6.-- ABO Measures (median, minimum, maximum)

Unretained					
Variables	**T1**		**T2**		**T1-T2 (p-values)**
AL	3 (0,8)		4 (0,11)		0.171
MR	5 (1,11)		4 (1,8)		0.001
BI	4 (0,9)		4 (0,9)		0.398
OJ	3 (0,7)		2.5 (0,7)		0.409
OC	5.5 (1,18)		5 (0,14)		0.008
OR	2 (0,15)		0 (0,4)		0.427
IC	0 (0,2)		0 (0,4)		0.019
Total	27 (13,43)		22 (12, 51)		0.017
Retained					
Variables	**T1**		**T2**		**T1-T2 (p-values)**
AL	4 (0,12)		4 (1,9)		0.778
MR	3 (0,10)		3 (0,9)		0.135
BI	0 (0,4)		0 (0,4)		0.625
OJ	3 (0,15)		3 (0,10)		0.849
OC	6.5 (0,17)		6 (1,16)		0.103
OR	3 (0,11)		2 (0,13)		0.007
IC	0 (0,3)		0 (0,1)		0.273
Total	21 (10,15)		20.5 (9,44)		0.033
Unretained vs. Retained (p-values)					
Variables	**T1**		**T2**		**T1-T2**
AL	0.16		0.674		0.349
MR	0		0.006		0.132
BI	0		0		0.511
OJ	0.887		0.389		0.587
OC	0.917		0.155		0.096
OR	0.944		0.587		0.595
IC	0.225		0.065		0.007
Total	0.061		0.135		0.672

APPENDIX 3: IRB APPROVAL

Case Western Reserve University
Institutional Review Board
NOTICE OF APPROVAL

Responsible Investigator: **Manish Valiathan**
Department: **Dental Clinic Ortho**
IRB Protocol #: **20041010**
Title: ***A Prospective Randomized Clinical Study of Retention Protocols***
Co-Investigator: **Alika L Crew**

Approval Date: **February 14, 2006**
Continuing Review Deadline: **January 30, 2007**
Expiration Date: **February 13, 2007**

The Institutional Review Board (IRB) has APPROVED the above continuing review protocol through the expedited review process.

It has been determined that this study involves minimal risk, and that the following vulnerable populations will be involved: minors.

As an investigator of human subjects, your responsibilities include the following (see full description of responsibilities at our website):

1. Report all adverse events and unanticipated problems involving human subjects to the IRB Office, located in the Office of Research Compliance (ORC), within three (3) business days of your knowledge of the occurrence.
2. Provide the IRB with a complete Continuing Review form (available at the CWRU IRB Web Pages, or from the ORC) by the continuing review deadline noted above, and when the study is terminated.
3. Discontinue all work pertaining to this protocol if a continuing review approval is not finalized by the expiration date noted above.
4. Submit all proposed changes to the protocol to the IRB, and receive approval from the IRB, before implementation of the change.
5. Keep all research data and original consent documents in your possession for at least three (3) years after the study is terminated.

Please use the attached consent form for your study.

If you wish to amend it, please submit an addendum – wait for IRB approval – prior toimplementation.

If you have to place your consent on letterhead, please make certain that you will use only the text on the stamped document.

Questions? Please visit our website: http://ora.ra.cwru.edu/orc_humansubjects_CWRU_IRB.asp

OR
contact our administrative office…
Isabel Sanchez, IRB Administrator
216.368.6993
Maureen Dore-Arshenovitz, IRB Assistant
216.368.6925
Fax: 216.368.3737

CASE Institutional Review Board
Office of Research Compliance
Sears Building 657
Cleveland, OH 44106-7230

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