CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTAL MEDICINE

GRADUATE STUDIES

We hereby approve the thesis of

Nadia LYOTARD

Candidate for the degree Master of Science

in Dentistry.

Signed: _____
(Chairperson)

_____

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_____

_____

Date: July 7, 2006

EVALUATION OF SHORT-TERM STABILITY WITHOUT RETENTION: A PILOT STUDY

by

NADIA CHRISTIANE LYOTARD

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry

Thesis Advisor: Manish Valiathan, M.D.S., D.D.S., M.S.D.

Department of Orthodontics

School of Dental Medicine

CASE WESTERN RESERVE UNIVERSITY

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Abstract

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Introduction: The purpose of this descriptive study was to evaluate the short-term stability of orthodontic treatment without retention. **Methods:** Thirty consenting patients participated in this study. At the end of active treatment (T_1), the final archwires were removed, leaving the fixed appliances on, and a set of alginate impressions were taken. Four weeks later (T_2), a second set of alginate impressions were taken. A clinical examination performed at T_2 determined if the final archwires were replaced or the fixed appliances removed. Based on the results of this examination, patients were divided into two groups. Group I (n=13) had the fixed appliances removed while group II (n=17) required additional treatment. The ABO-OSG scores as well as the following six variables were measured on plaster casts at

T_1 and T_2: maxillary and mandibular incisor irregularity, overbite, overjet, mandibular intercanine and intermolar widths. These data were analyzed to detect potential changes form T_1 to T_2 and differences between the groups. **Results:** Mandibular incisor irregularity, overjet, and interproximal contacts worsened for the sample as a whole while marginal ridges, occlusal contacts, and total ABO scores improved. No statistically significant changes were found within group I from T_1 to T_2. Mandibular incisor irregularity, overbite, overjet, alignment/rotations, and interproximal contacts worsened within group II from T_1 to T_2 while marginal ridges and occlusal contacts improved during the same time frame. Significant differences were noted in alignment/rotations, interproximal contacts, and mandibular intercanine width between the groups. **Conclusion:** In this sample, allowing one month of settling at the end of active treatment improved the occlusion but negatively impacted dental alignment and interproximal contacts.

DEDICATION

To my parents, Jean and Genevieve, who taught me to have a goal and to never give up until I reach it. Thank you for your endless encouragements, support, and Love.

To my brother Theophile, thanks for your camaraderie and friendship. Your are the best little brother I could wish for. I hope that your life in the United States will be as rich and fulfilling as mine has been these last nine years.

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INTRODUCTION

One of the greatest challenges in orthodontics is to achieve long-term stability. Since the origin of the profession, every orthodontist has experienced the frustration of orthodontic relapse. In an attempt to prevent or minimize relapse, clinicians have developed many philosophies and retention strategies. However, most of these are based on personal experience with little objective data to support them. Sound evidence upon which practitioners can base their retention protocols is now necessary. As a starting point, it is essential to determine if the need for retainers is real and if their use is truly beneficial for all patients.

The purpose of this study is to establish the need for retention by evaluating the short-term relapse without retention. Once the level of need for retention is determined, other studies comparing appliances and protocols may be opened.

REVIEW OF THE LITERATURE

Historical Perspective on Retention

The origins of orthodontics can be traced in medicine as far back as the first millennium. Although malocclusion, impacted and supernumerary teeth were documented in the prehistoric man (Weinberger 1926), the earliest known literature pertaining to the teeth is found in the writings of Hippocrates (460-377 B.C.), founder of Greek medicine. Hippocrates was the first to systematically describe the formation of the teeth, patterns of eruption, function, and different ailments that could affect the dentition. The first reference to an orthodontic treatment was made years later by Aurelius Celsus (25 B.C. - 50 A.D.), a Roman writer. Celsus recommended the daily application of finger pressure to a malposed tooth until it arrived at its correct position. Cajus Plinius, encyclopedic writer contemporary of Celsus, was the first to advocate a mechanical treatment which consisted of filing the teeth to resolve dental irregularities (Weinberger 1926).

Knowledge of the stomatologic system continued to develop over the centuries but much of early dentistry was focused on issues such as toothache, periodontal disease, and premature loss of teeth. It was not until Pierre Fauchard described the precursor of the expansion arch in 1793 (Weinberger 1926) that orthodontics began its evolution to become the specialty as we know it today.

Although the treatment of malocclusion has been advocated for several hundred years, relapse and the use of a retention device was not addressed until the early 1800s. J.M. Alexis Schange was the first to write about the need for a period of stabilization after treatment. According to him, "it would be wrong to think that once the teeth are brought back to normal position, the whole treatment is completed" (Weinberger 1926). He further added that:

> "They must be kept in the place assigned to them, for a long time after treatment, in order that they may acquire the proper firmness, especially if the treatment has progressed for a considerable length of time" (Weinberger 1926).

For this purpose, he used "a rubber band attached to some hooks on the appliance surrounding the molars"

(Weinberger 1926). Strange's appliance is the first officially documented retainer.

In the following years, the difficulty of achieving long-term stability was a challenge for all orthodontists. For Kingsley, who is considered the father of modern orthodontics, it was not difficult to achieve a good occlusion "... but to hold the [dental system] until it becomes permanently settled [was] a much more serious problem" (Kingsley 1880). For him, the success of orthodontics lay in the retainer and he recommended the use of it until reasonable expectation of permanence could be met. His answer to the question "how long would that be?" was "I am an agnostic, I do not know" (Weinberger 1926). This comment reflects the confusion and lack of scientific knowledge that existed about retention.

Although most pioneers in orthodontics had different opinions regarding the means and duration necessary for retention, they all stressed its importance. For Angell, "it [was] of course unnecessary to say that, after the teeth are brought into their proper place, a retaining plate must be made" (Weinberger 1926). Diverse retention devices were used including appliances made of gutta-

percha, bandages surrounding the face to maintain the teeth in contact, as well as vulcanite plates with gold spurs. Angell and Woolworth utilized the appliances used for active treatment as retainers (Weinberger 1926).

When it came to the duration of the retention period, protocols were just as varied. Practitioners all agreed that teeth should be held in position until the supporting tissues had a chance to rearrange and solidify. They just did not agree on how long this process would take. Spalding said that a single night was sufficient while Kingsley recommended three to four months, and others at least a year. Woolworth suggested that his patients monitor the relapse tendency and wear their retainers more often if necessary while Angell recommended that the "plate should be laid aside very gradually, continuing its use at night for a period of many months after treatment [was] brought to a close" (Weinberger 1926).

Another difference in opinion existed regarding the tightness with which teeth should be retained. For Baker, an ideal retainer had to have minimal contact with the enamel of the teeth. This not only improved hygiene and decreased the incidence of rampant decay, but also

provided the freedom that allowed settling of the teeth in a proper occlusion. For others such as Angell, teeth needed to be held immovable after treatment to allow perfect filling of the alveolus around the roots. According to him, if teeth were allowed to move backward and forward, "Nature could not accomplish her work and the teeth could not become firm" (Weinberger 1926). This philosophy was shared by Angle (1907) who thought that allowing some movement would interfere with bone deposition and would result in abnormal alveolar bone formation.

The reigning confusion and poor scientific evidence led to arbitrary retention protocols. This was expressed by Hawley who wrote that the mistake had been to apply a "guessed-at" solution to the unsolved and undetermined problem of the instability of treated malocclusions. He further added that:

> "the length of the period for which any case needs to be retained is admitted to be unknown [and] we have been arbitrarily fixing that time. We apply a fixed retention and at the end of a certain period- one year, two years, or longer as the case may be- we remove the retention" (Hawley 1919).

Normal Physiologic Changes

When attempting to understand the etiology of relapse, it is important to remember that part of the post-treatment changes observed can be attributed to normal physiology. The human dentition is indeed in a dynamic state, constantly changing throughout life. As stated by Horowitz and Hixon:

> "The significant point is that orthodontic therapy may temporarily alter the course of these continuous changes and possibly, for a time, even reverse them; however, following mechanotherapy and the period of retention restraint, developmental maturation process resumes" (Horowitz 1969).

In a longitudinal study of untreated normal occlusions, Sinclair (1983) found that crowding of the lower incisors, area of most frequent post-treatment change, was small but statistically significant from thirteen to twenty years of age. He also noted that mandibular incisor crowding was greater in females. In a study of lower arch crowding in the third decade, Richardson (1998) found similar results but emphasized that changes observed over time were small and difficult to detect clinically as opposed to the ones occurring during adolescence.

Changes in arch length over a forty-five year span were investigated by Bishara (1995) who observed an increase in maxillary and mandibular arch length up to thirteen and eight years of age, respectively. From thirteen to forty-five, there was an average 5 mm decrease in the mandibular arch length of both males and females. This trend was also noted by Sinclair (1983) who observed a decrease in arch length during the transition from primary to permanent dentition and later as well.

Bondevik (1996) analyzed changes in arch width from twenty-three to thirty-four. He found an increase in maxillary and mandibular intermolar width in both sexes. The maxillary intercanine width remained unchanged while the mandibular intercanine width decreased in both males and females. The results of this study may, however, need to be relied on with caution due to the fact that the sample included both treated and untreated subjects. DeKock (1972) observed a somewhat different pattern. He suggested that there was no significant change in arch width in either arch for females between twelve and twenty-six while a slight but statistically significant increase in the width of both arches was noted in males.

Schools of Thought Regarding Orthodontic Stability

In an attempt to understand the causes of relapse, four main schools of thought emerged starting in the late 1880s. For Norman Kingsley (1880), "the occlusion of the teeth was the most potent factor in determining the stability in a new position." The idea that a proper occlusion was the key in long-term stability was shared by many eminent orthodontists such as Edward Angle (1907), Calvin Case (1920), and Milo Hellman (1944) amongst others.

In 1922, Rogers introduced the idea that establishing proper muscle balance was critical, not only in rendering good treatment but also, in maintaining the corrected malocclusion. According to him, the primary etiology of a malocclusion was the absence of functional activity during growth. Rogers saw no sense in correcting a problem without first addressing its cause and developed specific muscle exercises to stimulate the arrested development. These were prescribed as preliminaries to mechanical treatment and, if performed regularly, markedly improved the malocclusion (Rogers 1922). Webster (1948) and Brodie (1938) shared this philosophy.

Lundstrom (1925) formed a third school of thought that considered the apical base as the key to long-term stability. According to him, the alveolar process and the position of the teeth were dependent on the form of the apical base. Only when it was normal, was normal occlusion possible. He vehemently insisted on the fact that a mere expansion of the arch itself would be followed by relapse and that to reach stability, "the orthodontic correction must include also the moving of the whole region surrounding the apical base" (Lundstrom 1925). According to him, there were two possible means of attaining such a result: the first by opening the mid-palatal suture, the second by reconstructing the tissue around the roots of the teeth that have been moved. This concept, which drastically opposed Angle's teachings, was further developed by McCaulay (1944), Strang (1952), and Nance (1947) who emphasized the importance of maintaining the original intercanine and intermolar widths.

In the 1940s, Tweed introduced another theory by advocating that the mandibular incisors must be upright over the basal bone for optimal stability and esthetics. He had been practicing for many years following the philosophy of a full complement of teeth when he decided

to recall most of his patients to evaluate the long-term effects of his treatment. To his stupefaction, he found that only 20% of his recalled patients could be classified as "successes". Tweed noticed that this group of patients showed much more pleasing facial appearances. He carefully examined their mouths and faces and came to the conclusion that

> "failures in treatment were caused by failure to correct all perverted axial inclinations and to establish normal relationship of the teeth to their respective bones" (Tweed 1944).

This conclusion was supported by findings from Brodie and Margolis who respectively found that basal bone cannot be grown and that the normal angular variation of the mandibular incisors to the mandibular plane ranges from 85-93° (Tweed, 1994).

Over the last century, many factors such as treatment modalities, preservation of original mandibular intercanine width, influence of gingival tissues, and the role of third molars were extensively investigated as possible causes for relapse.

Treatment Modalities

The debate of extraction versus non-extraction treatment has been ongoing since Edward Angle (1907)

recommended that orthodontic treatment preserve a full complement of teeth. Researchers have since compared the stability of extraction and non-extraction treatment and the stability of different timing and extraction patterns. Little (1988) examined a sample of twenty-six patients treated non-extraction and revealed an average irregularity index of 6.06 mm at least six years postretention. It is important to note that this sample's irregularity index at the end of treatment ranged from 0.86 mm to 4.15 mm. Glenn and associates (1987) observed a somewhat different pattern in a sample of twenty-eight patients treated non-extraction. Eight years postretention, the irregularity index was 1.2 mm. Only 4% of the patients showed severe relapse with an irregularity index in excess of 6 mm. The overjet, overbite, and intermolar width showed no significant differences between the end of treatment and retention. Similar observations were made by Sadwosky (1994) who noted a maxillary and mandibular irregularity of 1.1 mm and 1.4 mm respectively in a sample of patients evaluated at least five years postretention. The postretention stability of overjet, overbite, and intermolar width was also noted by Dugoni et al. (1995) who analyzed a group

of patients whose only treatment had been a passive lower lingual holding arch. The initial average irregularity of 7.81 mm was corrected by maximizing the use of the leeway space and 76% showed clinically acceptable alignment nine years postretention. The stability of non-extraction treatment combined with palatal expansion was investigated by Moussa et al. (1995) who found 1.5 mm and 1.4 mm of postretention crowding in the maxilla and mandible respectively. Similar results were reported by Azizi and associates (1999) who evaluated long-term stability of mandibular incisors after palatal expansion.

Several studies have looked at the long-term stability of different extraction patterns. Riedel et al. (1998) suggested that extraction of one or two mandibular incisors might provide enough space to relieve crowding while maintaining the initial arch width. Using dental casts and cephalometric radiographs, they evaluated the long-term stability of mandibular incisor extraction. In these cases, the mandibular intercanine width was maintained or constricted during treatment. However, ten years postretention, 29% of patients with one incisor extracted, and 56% of patients with two incisors extracted had unacceptable incisor alignment. Although

the incidence of relapse in this study appeared to be high, Little et al., (1981) observed that 70% of a sample treated with the extraction of four first premolars showed unacceptable incisor irregularity ten years postretention. In a follow-up study, Little et al. (1988) showed that twenty years postretention, only 10% of the patients had acceptable incisor alignment. Although additional studies are necessary to compare the stability of different extraction patterns, it appears that the extraction of one or two incisors, in carefully selected cases, may yield to a more stable result.

With the hope of bringing some unbiased evidence to the extraction non-extraction debate, Paquette et al. (1992) compared skeletal, dental, and soft tissue changes in a sample of class II patients who could be treated with or without extraction equally well. Although several significant differences were apparent after treatment, namely the protrusion of the dentition and the convexity of the profile, the posttreatment changes observed were, on average, identical in both groups. Both intercanine and intermolar width changes were small and consistent with the normal physiology of aging described by Sinclair and Little (1983). Seventy-three percent of the

extraction and 57% of the non-extraction groups showed less than 3.5 mm of incisor irregularity. According to the authors, posttreatment changes were dentoalveolar compensations for a differential maxillomandibular growth pattern. This similarity in postretention change was also observed by Luppanapornlarp and Johnston (1993) who compared the long-term stability of extraction versus non-extraction treatment in "clear-cut" patients. Although the debate is still ongoing, it does not appear that the stability of extraction treatment is superior to non-extraction treatment and vice versa. The important thing is to devise a correct diagnosis so that patients in need of extraction receive appropriate treatment.

McReynolds and Little (1991) tested the concept that serial extraction decreases the need for retention by lessening the development of mandibular incisor crowding. They studied patients who had undergone serial extraction of mandibular second premolars followed by orthodontic treatment and compared them to patients for whom second premolars were extracted in the permanent dentition. No statistically significant difference in incisor irregularity or intercanine width was found between the two groups at least ten years postretention. Little et

al. (1990) came to the same conclusion comparing postretention changes in patients who were treated with serial extraction versus late extraction of first premolars. They reported that 73% of the patients showed unsatisfactory postretention alignment. Haruki and Little (1998) noted a somewhat different result when comparing extraction of four first bicuspids during the mixed versus permanent dentition. They reported a significant difference in the mandibular irregularity index between the groups at least ten years postretention and suggested that this difference may be due to the anterior alignment immediately following extraction instead of allowing physiologic drift to occur after serial extraction.

The Mandibular Transverse Dimension

Non-extraction therapy inevitably results in widening the arches in order to resolve the crowding. This revives a heated controversy about the stability of mandibular canine dimension. Indeed, there are some who maintain that arch form is determined at an early age and cannot, thereafter, be altered in a stable fashion. Others argue

> "…that a crowded or otherwise deformed arch [does] not represent its true size or form and that both might be altered by treatment and be

> expected to be stable if normal function were established" (Walter 1953).

In 1953, Walter attempted to resolve this controversy by studying the casts of thirty-four patients before treatment, at the end of treatment, and an average two and one half years postretention. He found that 95% of maxillary and mandibular arch widths were permanently increased by a mean of 3.3 mm and 2.45 mm respectively. Walter, therefore, concluded that the statement that dental arches cannot be permanently widened is incorrect. His study, however, started with one hundred and two subjects who did all have complete records at each of the three time points. It is unclear if his conclusion was or was not based on the whole sample. Furthermore, he did not discuss any statistical analysis that might have been used and reported no standard deviation or range for the increase in arch widths that he observed. In 1962, obviously not convinced by his previous results, Walter narrowed down his focus on the study of intercanine and intermolar widths in one hundred subjects. All patients were treated with edgewise appliances and fifty of them underwent extraction. Initial, final, as well as postretention records were available for all patients and

the average postretention period was two years and nine months. He reported that 62% of extraction and non-extraction patients had an average 2 mm and 1.4 mm increase in intercanine width respectively. These results confirmed his previous findings but again, no standard deviation, range, or use of a statistical analysis was reported.

Also questioning the stability of expansion and frustrated that orthodontists followed "the beaten path of expansion and mechanical retention," Strang (1946) attempted to determine what caused permanent stability. He began to study cases that could be called successful for having been stable after years of freedom from mechanical support. He found that the most significant factor was that the initial and final intercanine and intermolar widths showed little, if any, variation. Strang attributed this to the position of mandibular canines and first molars as the key to harmonious muscular forces. He believed that balanced muscular forces were preserved by maintaining the position of these specific teeth. Strang later tested his hypothesis in clinical practice for "several years" by shaping the archwires to preserve the initial arch width. No

retention was provided at the end of treatment and patients were recalled every six weeks for observation. The stability he observed led him to conclude that muscular balance was inherent and unalterable in every individual and that treatment should be aimed at preserving it. Strang's view, although based solely on his observations and clinical experience, is shared by many. Housley (2003) studied twenty-nine patients treated non-extraction with expanding mandibular lingual arches and fixed edgewise appliances. He reported an average 1.52 mm increase in mandibular intercanine width during treatment followed by a 0.80 mm decrease six years postretention and concluded that the only way to maintain an increase in the canine transverse dimension is fixed retention. Some could rightfully dispute his conclusion by arguing that a positive overall change at least six years postretention does actually support the concept of a stable increased mandibular canine dimension.

In an effort to sort the confusion resulting from the variability of these different studies, Burke et al. (1998) conducted a meta-analysis in an attempt to reach a general conclusion on the alleged unalterable intercanine width. Twenty-six studies, comprising a total of 1,233

patients, met the inclusion criteria. The sample was divided according to the original malocclusion but the results showed that all groups, regardless of treatment modality or initial malocclusion, expanded during treatment and constricted after. The net change ranged from -0.59 mm to 0.46 mm. Because this net change was found to be close to zero in 1,233 subjects, the authors concluded that maintenance of the original intercanine width in orthodontic treatment is necessary.

Influence of Gingival Tissues

As the structures supporting the teeth, alveolar bone, periodontal as well as gingival fibers seemingly have an important role in the stability of orthodontically treated teeth. In 1984, Sharp et al. examined for a relationship between root resorption and loss of crestal alveolar bone with relapse. Their hypothesis was that the subcrestal periodontium provides stability for the tooth in opposition to the forces responsible for relapse, and a reduction in its surface area would result in an increased tendency for relapse. The examination of thirty-six patients, divided in two groups based on whether they showed 2 mm or more crowding at least ten years postretention, revealed that root

resorption as well as crestal alveolar bone loss was significantly higher in the group showing the most relapse. Although these findings are interesting, the small sample size and the fact that no end of treatment records were available to determine the quality of the finishes calls for further investigation before reaching definite conclusions. Reitan (1959) approached the question from a different perspective when he evaluated the histologic changes associated with the orthodontic rotation of teeth in dogs. Eleven teeth were rotated fifty to seventy degrees over an eight to twelve week period and retained from fifteen to two hundred and thirty-two days. This experiment showed that the fibers of the periodontal ligament in the apical two-thirds of the roots were completely rearranged after one hundred and forty-seven days. The fibers associated with the coronal one-third of the roots and the gingival fibers, however, showed only partial rearrangement after two hundred and thirty-two days of retention. Reitan concluded that the transection of the marginal region's stretched fibers can help in reaching occlusal stability and recommended it in cases of extreme rotation. In the early 1970s, Edwards (1988) invented the circumferential

supracrestal fiberotomy (CSF) procedure that he later tested in a study of three hundred and twenty consecutively treated patients. They were recalled two to three years postretention and a difference of 2.03 mm mean relapse in mandibular incisor crowding was noted between the CSF and control groups. However, eight to ten years later, this difference was only 1.36 mm. Edwards also noted that, although some relapse was observed in the CSF group, severe relapse defined as an irregularity index in excess of 6 mm, was seemingly eliminated. The major drawback of this study is the use of Little's irregularity index which may not be adequate to detect rotations since a tooth can be rotated without breaking contact with the adjacent teeth. Ahrens et al. (1981) also evaluated the efficiency of CSF in a sample of twelve patients who were evaluated thirty days after the procedure was performed. They devised an intelligent way to report angular measurements that revealed a clinically significant difference of 5.57° of mean relapse between the surgerized and control groups. These results are however weakened by the very small sample size and short observation period. Using the dental casts of twenty-three patients, eleven having undergone CSF and twelve

used as controls, Tanner et al. (2000) also evaluated the role of CSF in preventing rotational relapse. He found a mean difference of 2.8 mm in mandibular incisor crowding between the groups. Again, this result should be relied on with caution due to the small sample size, short observation period during which Hawley retainers were worn full time, and the use of Little's irregularity index to measure rotational relapse. Although most studies detect a significant improvement in retention following CSF, their shortcomings call for further research.

The Role of Third Molars

The effect of third molars on late mandibular incisor crowding has been a provocative subject for many years. Dewey (1931) commented that

> "in some cases the mandibular third molar will become impacted due to the lack of space, in others it creates space for eruption by causing the anterior teeth to crowd."

Vego (1961) compared a group of twenty-five untreated subjects which had bilateral agenesis of the third molars with a group of forty untreated cases having all molars present. He noted a statistically significant difference of 0.8 mm in arch perimeter after five years

of observation and concluded that mandibular third molars exert a force on approximating teeth which results in crowding. Although statistically significant, this difference in arch perimeter is probably not clinically relevant. Moreover, the samples were not matched, the initial crowding was more severe in the group with third molars present, and the third molars were congenitally missing which suggests that the subjects may differ genetically in other important aspects. Similarly, Lindqvist and Thilander (1982) found that the crowding on the side of the mouth where a third molar was extracted was slightly less than on the contra-lateral side where the third molar was retained. The mean difference (0.16 mm) was, however, even smaller than the one reported by Vego (1961) and the three-year observation period may have been too short to detect a significant difference. Opposing these findings, Ades et al. (1990) reported no connection between third molar presence or position and late mandibular incisor crowding. These findings are supported by Harradine et al. (1998) who studied seventy-seven subjects who either had the third molars extracted or not. The 0.3 mm difference found after five years was neither statistically nor clinically significant.

Although these studies report conflicting data, they all report very small differences between groups with and without third molars. This tends to indicate that the decision to extract should be based on the possible development of pathosis and the long-term periodontal status rather than on the fear of late mandibular incisor crowding.

After more than a century of practicing orthodontics, the specialty is still faced with the challenge of long-term stability. In an attempt to maintain treatment results, orthodontists have developed numerous types of retainers. Although these appliances have been used for many years, the literature regarding the different retention protocols is scarce. Only a few studies, with inconclusive results, have compared different retainers and the recommendations regarding retention time range from none (Strang 1949) to permanent (Housley et al. 2003). This lack of evidence forces clinicians to base their retention protocols on cost, ease of fabrication, and personal preference, which sounds just as arbitrary as it was at the end of the nineteenth century.

Evaluation of short-term stability without retention: A pilot study

Authors: Nadia Lyotard, DMD[a]

Mark Hans, DDS, MSD[b]

Suchitra Nelson, MS, PhD[c]

Manish Valiathan, MDS, DDS, MSD[d]

a- Resident, Department of Orthodontics, Case Western Reserve University, Cleveland, Ohio

b- Professor and Chair, Department of Orthodontics, Case Western Reserve University in Cleveland, Ohio

c- Associate Professor, Department of Community Dentistry, Case Western Reserve University in Cleveland, Ohio

d- Assistant Professor, Department of Orthodontics, Case Western Reserve University in Cleveland, Ohio

Corresponding author:

Manish Valiathan MDS, DDS, MSD
Case Western Reserve University
School of Dental Medicine
Department of Orthodontics
10900 Euclid Ave.
Cleveland, OH 44106
Tel (216) 368-6810
Fax (216) 368-6310
Email: mxv13@case.edu

Abstract

Introduction: The purpose of this descriptive study was to evaluate the short-term stability of orthodontic treatment without retention. **Methods**: Thirty consenting patients participated in this study. At the end of active treatment (T_1), the final archwires were removed, leaving the fixed appliances on, and a set of alginate impressions were taken. Four weeks later (T_2), a second set of alginate impressions were taken. A clinical examination performed at T_2 determined if the final archwires were replaced or the fixed appliances removed. Based on the results of this examination, patients were divided into two groups. Group I (n=13) had the fixed appliances removed while group II (n=17) required additional treatment. The ABO-OSG scores as well as the following six variables were measured on plaster casts at T_1 and T_2: maxillary and mandibular incisor irregularity, overbite, overjet, mandibular intercanine and intermolar widths. These data were analyzed to detect potential changes form T_1 to T_2 and differences between the groups. **Results**: Mandibular incisor irregularity, overjet, and interproximal contacts worsened for the sample as a whole while marginal ridges, occlusal contacts, and total ABO scores improved. No statistically significant changes were found within group I from T_1 to T_2. Mandibular incisor irregularity, overbite, overjet, alignment/rotations, and interproximal contacts worsened within group II from T_1 to T_2 while marginal ridges and occlusal contacts improved during the same time frame. Significant differences were noted in alignment/rotations, interproximal contacts, and mandibular intercanine width between the groups. **Conclusion**: In this sample, allowing one month of settling at the end of active treatment improved the occlusion but negatively impacted dental alignment and interproximal contacts.

INTRODUCTION

One of the greatest challenges in orthodontics is to predictably achieve long-term stability. In an attempt to prevent relapse, clinicians have developed varied philosophies, strategies, and appliances. Most are, however, based on clinical experience that has led to strong convictions but little empirical evidence. As a starting point in the investigation of this clinically relevant area, it is essential to determine if retention is in fact beneficial to all patients. An extensive review of the literature did not reveal a study that has attempted to answer this fundamental question.

Although the first reference to orthodontic treatment was made as early as the beginning of the first millennium by Celsus, relapse and the use of a retention device were not addressed until the early 1800s[1]. J.M. Alexis Schange was the first to write about the need for a period of stabilization after treatment and used "a rubber band attached to some hooks on the appliance surrounding the molars"[1] as a retention device. Shange's appliance is the first officially documented retainer.

Although most pioneers agreed on the need for retention, they had vastly different opinions regarding the appliance that should be used. The actual protocols for retention varied just as much. Spalding[1] said that a single night was sufficient while Kingsley[2] recommended three to four months, and others at least a year[1]. Hawley[3] clearly expressed this nearly one hundred years ago when he wrote that the mistake had been to apply a "guessed-at" solution to the unsolved and undetermined problem of the instability of treated malocclusions. In an attempt to understand the

causes of relapse, four main schools of thought emerged starting in the late 1880s. For Kingsley[2], "the occlusion of the teeth was the most potent factor in determining the stability in a new position". In 1922, Rogers[4] introduced the idea that establishing proper muscle balance was critical in maintaining the corrected malocclusion. Lundstrom[5] formed a third school of thought that considered the apical base as the key to long-term stability and Tweed[6] introduced the theory advocating that mandibular incisors must be upright over the basal bone for optimal stability and esthetics.

Over the last century, many factors such as treatment modalities[7-9], preservation of original mandibular intercanine width[10,11], continued growth[12], influence of gingival tissues[13,14], and role of third molars[15,16] have been extensively investigated as predictors for relapse. However, no single predicting factor has been identified. In an attempt to maintain treatment results, orthodontists have developed numerous types of retainers with differing regimens. A few studies have attempted to compare different retainers and protocols ranging from no retention[17] to permanent retention[18] but data on the different retention devices and protocols are still inadequate.

The lack of real evidence has led orthodontists to develop retention protocols based on ease of fabrication, costs and perhaps, perceived ability to maintain the results they have strived for during the course of treatment. The purpose of the study is to investigate the need for retainers by evaluating the short-term relapse without

retention. Once the need for retention is better understood, future studies may investigate different protocols and appliances.

PATIENTS AND METHODS

Sample selection

All patients treated with fixed edgewise appliances nearing the end of their orthodontic treatment at Case Western Reserve University (CWRU) were requested to participate in the study. The recruitment of participants lasted from August 2005 to December 2005. Thirty-six out of fifty-six potential participants consented to the study. Four patients, eager to get their braces off, withdrew from the study and two were still in active treatment when data collection for this stage of the study ended. The final sample consisted of thirty patients. The procedures and protocol for the study have been approved by the Institutional Review Board at Case Western Reserve University.

When the end of treatment was approved by the faculty member overseeing the case (T_1), the final archwires were removed, leaving the fixed appliances on, and a set of alginate impressions were taken. Four weeks later (T_2), a second set of alginate impressions were taken. The patient was evaluated by the faculty member and a decision was made whether additional treatment was required or the braces would come off. For patients who had braces removed, thermoform retainers were delivered. If negative changes were detected during the clinical exam, additional treatment was rendered prior to appliance removal. Two groups were thus formed based on the results of the clinical examination performed at T_2.

Measurements

All data were collected by a single operator (N.L.). The following six measurements were made with a digital caliper to the nearest hundredth of a millimeter on plaster models at T_0 (pre-treatment), T_1 (post-treatment), and T_2 (four-week recall):

1. Maxillary crowding: the difference between space available (from first molar to first molar) and space necessary (sum of the mesio-distal dimension of each tooth anterior to the first molar).
2. Mandibular crowding: the difference between space available (from first molar to first molar) and space necessary (sum of the mesio-distal dimension of each tooth anterior to the first molar).
3. Overbite: the vertical overlap of maxillary and mandibular incisors.
4. Overjet: distance form the facial surface of mandibular central incisors to the facial of maxillary central incisors.
5. Mandibular intercanine width: distance between cusp tips.
6. Mandibular intermolar width: distance between the mesio-buccal cusp tips.

In addition, the American Board of Orthodontics' Objective Grading System (ABO-OGS) was used to score the plaster models both at T_1 and T_2 to detect potential changes in the posterior occlusion. Since the ABO-OGS is an index which evaluates orthodontic outcome, the casts at T_0 were not scored. In order to blind the operator to the time frame being evaluated, casts were numbered 1 through 60 in no particular

order. Using a table of random numbers, they were then randomly selected to be scored with the gauge provided by the American Board of Orthodontics (ABO).

A change of either 0.5mm or 1 point over four weeks for the continuous and categorical data respectively was deemed clinically significant.

Data analysis

Data from the 130 plaster casts were entered into the statistical program Minitab, Release 14. In order to detect potential changes between T_1 and T_2, both for the sample as a whole and for the two groups, paired t-tests and Wilcoxon signed rank tests were performed for the six continuous variables and the ABO scores respectively. To test for differences between the groups, unpaired t-tests and Wilcoxon rank sum tests were used for the continuous and categorical data respectively.

Intra-examiner reliability was determined by computing t-tests as well as Wilcoxon signed rank tests with the data of ten randomly selected casts at least two weeks after the first round of data collection. Significance for all statistical tests was predetermined at $P < 0.05$.

RESULTS

The final sample consisted of fourteen males and sixteen females with an average of 15.2 +/- 2.9 years and 16.4 +/- 1.5 years of age respectively. Twenty of the participants were Caucasians, five African-Americans, three Hispanics, and two had other ethnic backgrounds. Six individuals had extractions and five had a rapid palatal expander prior to fixed treatment.

Subjective clinical exams performed at the recall appointment revealed that thirteen patients showed no change or an improvement in their occlusion after four weeks without archwires. Their appliances were therefore removed At T2 and thermoplastic retainers were delivered. Seventeen patients required additional treatment prior to the removal of appliances and retainer fabrication. The average additional treatment lasted 62 days. Therefore, Group I consisted of the thirteen individuals who had their braces removed and Group II had seventeen individuals who required additional treatment.

Table I consists of the differences in ABO scores between the time final archwires were removed and the recall appointment four weeks later. Four patients showed no change in total score while nine exhibited relapse and seventeen improved overall.

Table II outlines the changes of the six continuous variables between the time the archwires were removed and the recall visit four weeks later. The difference in mandibular crowding and overjet were found to be statistically significant.

Table III outlines the change in ABO scores between the time the archwires were removed and the recall visit four weeks later. Marginal ridges, occlusal and interproximal contacts as well as the total score showed a statistically significant difference.

Tables IV and V illustrate the results for the two groups. There was no change within group I from T_1 to T_2. Within group II, mandibular crowding, overbite, overjet, alignment/rotations, and interproximal contacts all showed a significant worsening

during the observation period while marginal ridges and occlusal contacts showed a trend towards improvement. Differences between the changes for the two groups show significant differences in intercanine width, alignment/rotations, and interproximal contacts.

There was no statistical difference between the measurements done initially and the ones made at least two weeks later on the ten randomly selected casts.

DISCUSSION

Comparison of these findings with other studies is difficult because there is no previous work published that prospectively evaluates short-term stability without retention. The results of this exploratory study however show several potentially important trends occurring immediately after orthodontic treatment.

It is interesting to note that seven out of the eight categorical variables recorded show a marked overall improvement over time (Table I). Marginal ridges and bucco-lingual inclination scores exhibit the most stability with twenty-five out of thirty patients with a score that did not change or improved in these two categories. Also, if one takes a closer look at the scores for each individual, one notices that every patient exhibits some change in at least one variable. These findings remind us that the human dentition is a dynamic entity and suggest that orthodontic stability may very well be a myth.

The analysis of the continuous variables (Table II) reveals that only mandibular crowding and overjet show a statistically significant change over four weeks which concur with the current knowledge provided by the literature[19,20]. The

current increase in mandibular incisor irregularity and overjet, although statistically significant, were for the most part small, averaging 0.40 mm and 0.36 mm respectively. Such differences may not be clinically relevant. It is however important to remember that the use of mean values masks the important distinction between crowding recurring and spaces reopening. The range indeed reveals clinically significant changes from –2.07 mm to 1.4 mm, suggesting that some patients experienced greater relapse than others over a short period of time.

Surprisingly, the variable exhibiting the least amount of change is the mandibular intercanine width. This finding contradicts the results of most studies[10,11] that evaluated the stability of the mandibular canine dimension and concluded that a significant decrease was to be expected regardless of treatment modalities. Although it is possible that the four week observation interval was too short for this small sample size to allow significant changes in the intercanine dimension, this finding may reopen the debate on "the fallacy of denture expansion" considering that no known attempt was made to maintain the pre-treatment mandibular intercanine width in any of the thirty subjects.

The analysis of the ABO-OSG's scores (Table III) reveal statistically significant changes in marginal ridges and number of occlusal as well as interproximal contacts. These findings make sense and an experienced orthodontist will probably concur that the forces of mastication will help achieve a better interdigitation. Clinical experience also tells us that when spacing is present in the initial malocclusion, it has a strong tendency to recur, hence the increase in the

interproximal contacts score. Contradicting the results of the descriptive analysis, the ABO-OSG revealed no significant changes in either the alignment/rotations or overjet scores. A possible explanation may be that the changes occurring over a four week interval were too small to be detected by the categorical scale of the ABO-OSG. This apparent lack of sensitivity from the ABO-OSG leads one to believe that the actual variations between T_1 and T_2 may have been underestimated.

The analysis of the two groups reveals several important facts (Tables IV and V). No significant change was noted for any variable within group I from T_1 to T_2. This finding supports the clinical decision to remove braces at the recall appointment for these thirteen individuals. Further supporting the treatment decision that was made at T_2, seven significant differences were found within group II. Both mandibular incisor irregularity and the alignment/rotations component of the ABO-OSG indicated significant relapse. The interproximal contacts score increased showing a reappearance of spaces. This relapse of incisor alignment is consistent with previous findings[8,9]. The combined worsening in incisor irregularity and interproximal contacts provide a possible explanation for the fourth and fifth significant differences within group II, namely the increase in overbite and overjet from T_1 to T_2. The ABO scores for marginal ridges and occlusal contacts showed a significant improvement over four weeks. This is consistent with clinical experience that suggests that masticatory forces have a positive influence on the interdigitation of the posterior dentition.

Interestingly, the only significant differences between the two groups are the differences in the change in alignment/rotations, interproximal contacts, and

intercanine width. Since most orthodontists do not measure intercanine width intra-orally, this suggests that, although a comprehensive clinical examination was performed at the recall appointment, the state of the incisors was key in deciding whether additional treatment was necessary.

CONCLUSION

The results of this study reinforce the idea that the human dentition is a dynamic entity constantly undergoing changes. The analysis of both continuous and categorical data reveals that allowing one month of post-treatment settling improves the several areas clinicians evaluate carefully prior to removal of braces but negatively impacts dental alignment and interproximal contacts. Perhaps, clinicians should develop retention strategies and protocols which prevent negatives changes to occur while allowing the favorable aspects of this dynamic state to take place.

REFERENCES

1. Weinberger BW. Orthodontics: a historical review of its origin and evolution. St.Louis: Mosby; 1926.

2. Kingsley N. Treatise on Oral Deformities. New York: Appleton and Company, 1880

3. Hawley CA. A removable retainer. Dent Cosmos. 1919;61(6):449-55.

4. Rogers AP. Making facial muscles our allies in treatment and retention. Dent Cosmos. 1922;64(7):711-30.

5. Lundstrom A. Malocclusion of the teeth regarded as a problem in connection with the apical base. Int J Orthod Oral Surg.1925;11(7):591-602.

6. Tweed C. Indications for the extraction of teeth in orthodontic procedure. Am J Orthod. 1944;30(8):405-28.

7. Glenn G, Sinclair P, Alexander R. Non-extraction orthodontic therapy: Post-treatment dental and skeletal stability. Am J Orthod Dentofacial Orthop. 1987;92:321-28.

8. Little R, Riedel R, Engst D. Serial extraction of first premolars-postretention evaluation of stability and relapse. Angle Orthod. 1990;60:255-62.

9. Riedel R, Little R, Bui T. Mandibular incisor extraction- postretention evaluation of stability and relapse. Angle Orthod. 1998;62:103-68.

10. Burke SP, Silveira AM, Goldsmith LJ, Yancey JM, Van Stewart A, Scarfe WC. A meta-analysis of mandibular intercanine width in treatment and postretention. Angle Orthod. 1998;68:53-60.

11. Housley JA, Nanda RS, Currier GF, McCune DE. Stability of transverse expansion in the mandibular arch. Am J Orthod Dentofacial Orthop. 2003;124:288-93.

12. Baum AT. Orthodontic treatment and the maturing face. Angle Orthod. 1966;36(2):121-35.

13. Ahrens D, Shapira Y, Kuftinec M. An approach to rotational relapse. Am J Orthod. 1981;80:83-91.

14. Edwards J. A long-term prospective evaluation of the circumferential supracrestal fiberotomy in alleviating orthodontic relapse. Am J Orthod Dentofacial Orthop. 1988;93:380-87.

15. Ades A, Joondeph D, Little R, Chapko M. A long-term study of the relationship of third molars to changes in the mandibular dental arch. Am J Orthod Dentofacial Orthop. 1990;97:323-35.

16. Harradine N, Pearson M, Toth B. The effect of extraction of third molars on late lower incisor crowding: A randomized controlled trial. Br J Orthod 1998;25:117-122.

17. Strang RHW. Highlights of Sixty-four Years in Orthodontics. Angle Orthod. 1974;44:101-12.

18. Parker WS. Retention – retainers may be forever. Am J Orthod. 1989;95:505-13.

19. Little R, Wallen T, Riedel R. Stability and relapse of mandibular anterior alignment-first premolar extraction cases treated by traditional edgewise orthodontics. Am J Orthod. 1981;80:349-65.

20. Little R, Riedel R, Artun J. An evaluation of changes in the mandibular anterior alignment from 10 to 20 years postretention. Am J Orthod. 1988;93:423-28.

Table I - Raw ABO Scores for Participants at T_1 and T_2

Cast Number	Alignment Rotations (T_2-T_1)	Marginal Ridges (T_2-T_1)	Buccolingual Inclination (T_2-T_1)	Overjet (T_2-T_1)	Occlusal Contacts (T_2-T_1)	Occlusal Relationships (T_2-T_1)	Interproximal Contacts (T_2-T_1)	Total (T_2-T_1)
1	1	-1	-1	1	0	-1	1	0
* 2	-1	-3	0	-3	-2	2	-1	-8
3	1	1	0	-1	0	-2	1	0
4	1	-2	0	-1	4	-1	0	1
5	5	-2	1	-3	-3	0	0	-2
* 6	-1	1	-2	-1	-5	0	0	-8
* 7	0	-1	0	3	-3	0	1	0
* 8	-1	-1	0	2	9	-1	0	8
9	3	-1	-1	-2	4	-2	2	3
10	1	-1	0	-1	-8	1	1	-7
* 11	-1	0	-1	-3	-4	-4	1	-12
12	1	1	0	0	-2	1	0	1
13	-3	-1	0	-3	-6	0	1	-12
14	2	-2	0	-2	-3	0	0	-5
* 15	-5	-1	2	-1	0	0	0	-5
* 16	1	-1	0	2	2	0	0	4
17	5	0	-4	2	-9	3	0	-3
18	2	0	0	1	0	-2	1	2
19	4	-1	-1	0	-3	0	0	-1
* 20	0	-3	0	2	1	0	0	0
* 21	5	0	1	-5	-1	-1	0	-1
* 22	-3	1	-1	-1	-1	0	0	-5
* 23	-3	0	-1	2	-2	1	0	-3
24	2	0	1	3	-2	-1	3	6
* 25	2	-2	0	1	-12	0	-1	-12
26	-1	1	-2	1	1	0	1	1
27	-2	0	0	-2	-8	1	3	-8
28	2	-4	0	-1	-4	-1	1	-7
* 29	0	-1	2	1	0	1	-1	2
30	2	-1	0	-2	-3	0	0	-4

(*) Patients who had their braces removed at the recall appointment

Table II - Analysis of Continuous Variables for Participants at T_1 and T_2

	Mean (mm)	SD	P-value
Mx crowding T_1	0.078	0.84	
Mx crowding T_2	0.393	1.01	
T_2-T_1	0.315	1.12	0.136
Md crowding T_1	0.004	0.68	
Md crowding T_2	-0.394	0.81	
T_2-T_1	-0.398	0.92	* 0.025
Overbite T_1	2.054	0.71	
Overbite T_2	2.220	0.71	
T_2-T_1	0.166	0.61	0.149
Overjet T_1	2.691	0.85	
Overjet T_2	3.051	0.77	
T_2-T_1	0.360	0.72	* 0.010
Md intercanine width T_1	26.323	1.90	
Md intercanine width T_2	26.293	1.76	
T_2-T_1	-0.029	0.62	0.794
Md intermolar width T_1	44.687	2.13	
Md intermolar width T_2	44.498	1.90	
T_2-T_1	-0.189	0.87	0.243

(*) Statistically significant at $P < 0.05$

Table III - Analysis of ABO Scores for Participants at T_1 and T_2

	Median	Range	P-value
Alignment/Rotations T_1	3	8	
Alignment/Rotations T_2	4	11	
T_2-T_1	1	10	0.175
Marginal Ridges T_1	5	10	
Marginal Ridges T_2	4	7	
T_2-T_1	-1	5	* 0.004
Buccolingual Inclination T_1	4	9	
Buccolingual Inclination T_2	4	9	
T_2-T_1	0	6	0.379
Overjet T_1	3	7	
Overjet T_2	2.5	7	
T_2-T_1	-1	8	0.412
Occlusal Contacts T_1	5.5	17	
Occlusal Contacts T_2	5	14	
T_2-T_1	-2	21	* 0.012
Occlusal relation T_1	2	15	
Occlusal relation T_2	2	14	
T_2-T_1	0	7	0.435
Interproximal contacts T_1	0	2	
Interproximal contacts T_2	0	4	
T_2-T_1	0	4	* 0.023
Total Score T_1	27	30	
Total Score T_2	22	39	
T_2-T_1	-1.5	20	* 0.021

(*) Statistically significant at $P < 0.05$

Table IV - Analysis of Continuous Variables for Group I and Group II

Variable	Group I			Group II			I/II
	Mean (mm)	SD	P-value	Mean (mm)	SD	P-value	P-value
Mx Crowding T_1	-0.044	0.96		0.172	0.75		0.509
Mx Crowding T_2	0.235	0.68		0.514	1.21		0.430
T_2-T_1	0.279	0.88	0.275	0.342	1.30	0.296	0.877
Md Crowding T_1	-0.014	0.53		0.018	0.79		0.896
Md Crowding T_2	-0.115	0.74		-0.608	0.82		0.096
T_2-T_1	-0.101	0.67	0.599	-0.626	1.04	* 0.024	0.105
Overbite T_1	2.282	0.67		1.880	0.72		0.126
Overbite T_2	2.285	0.70		2.170	0.73		0.663
T_2-T_1	0.004	0.70	0.984	0.290	0.53	* 0.039	0.231
Overjet T_1	2.958	0.81		2.488	0.84		0.132
Overjet T_2	3.062	0.74		3.044	0.81		0.952
T_2-T_1	0.104	0.70	0.604	0.556	0.68	* 0.004	0.088
Md Intercanine Width T_1	26.746	1.94		25.999	1.86		0.297
Md Intercanine Width T_2	26.443	2.05		26.179	1.56		0.703
T_2-T_1	-0.303	0.60	0.091	0.179	0.56	0.207	* 0.033
Md Intermolar Width T_1	44.635	2.12		44.726	2.21		0.910
Md Intermolar Width T_2	44.538	1.93		44.468	1.94		0.923
T_2-T_1	-0.0977	0.57	0.549	-0.259	1.05	0.326	0.597

(*) Statistically significant at $P < 0.05$

Table V - Analysis of ABO scores for Group I and Group II

	Group I			Group II			I/II
Variable	**Median**	**Range**	**P-value**	**Median**	**Range**	**P-value**	**P-value**
Alignment/Rotations T_1	4	8		3	5		0.250
Alignment/Rotations T_2	4	6		4	10		0.315
T_2-T_1	-1	10	0.386	2	8	* 0.019	* 0.015
Marginal Ridges T_1	5	9		5	9		0.851
Marginal Ridges T_2	4	7		4	7		0.834
T_2-T_1	-1	4	0.053	-1	5	* 0.036	0.884
Buccolingual Inclination T_1	5	7		4	9		0.802
Buccolingual Inclination T_2	5	9		4	9		0.950
T_2-T_1	0	4	1.000	0	5	0.205	0.645
Overjet T_1	3	6		4	6		0.616
Overjet T_2	2	7		3	7		0.967
T_2-T_1	1	8	0.944	-1	6	0.182	0.391
Occlusal Contacts T_1	5	11		9	17		0.572
Occlusal Contacts T_2	4	13		5	14		0.706
T_2-T_1	4	13	0.168	-3	13	* 0.038	0.451
Occlusal relation T_1	2	15		2	10		0.983
Occlusal relation T_2	2	14		2	8		0.754
T_2-T_1	0	6	1.000	0	5	0.398	0.558
Interproximal contacts T_1	0	2		0	1		0.586
Interproximal contacts T_2	0	1		1	4		0.060
T_2-T_1	0	2	0.787	1	3	* 0.006	* 0.011
Total Score T_1	26	30		28	24		0.884
Total Score T_2	21	39		24	19		0.094
T_2-T_1	-3	20	0.099	-1	18	0.084	0.691

(*) Statistically significant at $P < 0.05$

APPENDIX 1

Raw Data

TABLE 1.--General Data for Participants

ID	MxCr0 (mm)	MxCr1 (mm)	MxCr2 (mm)	MdCr0 (mm)	MdCr1 (mm)	MdCr2 (mm)	OB0 (mm)	OB1 (mm)	OB2 (mm)
1	5.25	0.62	1.91	2.19	-0.52	-0.12	3.46	2.24	1.35
2	-2.69	1.3	2.17	-0.04	0.81	0.2	5.07	2.25	2.95
3	0.28	0.31	0.34	3.04	-0.59	-0.59	2.79	2.18	1.85
4	-4.48	-1.35	-1.5	-1.95	-0.86	-0.28	4.06	1.62	2.6
5	-1.67	-0.4	-0.02	-2.2	-0.93	-1.97	5.74	2.61	3.15
6	-0.86	0.48	0.23	-0.2	0.28	-1.12	4.33	1.93	3.02
7	0.97	-1.07	0.31	2.19	-0.32	-1.13	1.81	1.43	1.59
8	1.51	0.01	0.12	-1.39	-0.54	-1.27	4.57	3.08	2.82
9	9.16	-0.21	2.7	5.13	0.3	-1.21	3.25	1.95	2.28
10	0.18	-1.02	0.87	-2.11	0.16	-1.22	4	1.81	1.52
11	-2.16	-0.1	-0.5	-1.33	-0.69	-0.24	0	3.13	2.25
12	-5.92	0.97	-0.71	-4.37	1.24	-0.37	5.33	3.25	3.64
13	1.07	1.47	0.17	-1.1	0.79	-0.16	3.37	0.75	1.88
14	-3.25	0.37	-0.25	-4.23	0.13	-0.97	3.61	1.94	2.34
15	-2.14	-1.23	0.07	-1.73	-0.14	-0.1	4.85	3.11	3.67
16	1.07	-0.66	-0.07	0.26	-0.58	0.28	3.19	1.56	1.92
17	0.33	0.23	0.46	-0.39	1.11	-2.07	4.77	0.64	1.61
18	2	1.07	0.69	-1.78	-0.53	-0.39	1.32	1.09	1.16
19	0.95	-0.66	-0.95	-3.11	0.54	-0.78	3.02	1.38	2.11
20	-1.19	-0.14	0.19	0.21	-0.02	-0.44	2.16	2.79	1.96
21	-5.17	-0.69	0.27	-1.92	0.72	1	3.05	2.87	1.65
22	-2.63	-1.39	-0.37	0.14	-0.05	-0.2	1.84	1.78	2.55
23	0.18	1.29	0.83	-2.62	0.02	0.81	4.97	2.44	2.33
24	3.37	0.61	2.37	2.04	1.51	1.4	4.19	1.77	2.35
25	5.06	1.38	-0.38	-0.45	0.81	0.75	4.51	2	1.82
26	2.02	0.23	0.16	0.79	-0.39	-0.11	2.26	1.66	1.52
27	-1.51	0.27	1.87	-0.99	-0.98	-0.94	2.03	1.94	2.11
28	2.54	-0.24	1.36	6.1	-0.62	0.27	4.33	1.92	1.84
29	1.7	0.25	0.19	-0.92	-0.48	-0.03	3.14	1.29	1.18
30	-0.33	0.66	-0.73	-1	-0.05	-0.82	4.85	3.21	3.58

TABLE 1.--General Data for Participants (continued)

ID	OJ0 (mm)	OJ1 (mm)	OJ2 (mm)	Intcan0	Intcan1	Intcan2	Intmol0	Intmol1	Intmol2	U1FH0	U1FH1
1	2.46	2.37	2.19	28.24	25.85	26.82	48.14	46.15	45.71	112	109
2	3.76	2.59	3.22	24.83	28.35	28.04	42.55	44.14	44.21	113	122
3	3.39	2.45	3.65	30.86	27.53	26.86	49.5	44.68	45.37	105	116
4	2.38	2.2	3.74	25.94	26.29	26.75	41.41	43.01	42.78	116	116
5	2.45	2.18	2.64	23.11	23.8	24.3	43.93	43	43.27	96	108
6	4.98	3.39	2.98	25.04	25.41	24.88	45.2	45.15	44.89	107	115
7	5.13	2.64	3.26	26.13	27.63	27.42	45.52	45.08	44.5	108	109
8	6.73	4.36	4.46	28.67	27.44	28.17	44.91	45.57	45.71	128	114
9	5.71	2.38	3	30.79	25.99	26.47	48.42	46.35	47.62	131	128
10	5.93	2.72	3.31	24.88	27.46	27.03	44.37	46.46	46.36	122	113
11	2.35	2.67	2.8	29.45	28.71	29.07	45.67	44.57	45.25	112	114
12	4.97	4.4	4.62	23.52	22.64	23.04	38.09	44.01	43.02	111	120
13	3.1	1.41	3.21	26.44	28.74	28.4	41.71	42.8	43.24	118	119
14	5.07	4.06	3.54	27.62	27.96	27.81	48.35	49.59	45.81	106	115
15	3.58	3.28	4.24	20.44	27.03	26.77	45.34	43.36	44.07	105	112
16	4.79	1.93	2.15	24.22	23.29	22.99	40.95	41.05	40.85	109	112
17	3.07	1.22	2.66	23.82	25.36	26.02	44.26	43.18	43.24	100	114
18	4.58	1.18	1.28	27.18	27.22	26.39	42.96	42.52	41.98	120	112
19	4.13	2.69	3.51	25.59	23.28	24.51	44.1	43.83	43.81	135	127
20	5.78	3.59	3.73	25.64	25.5	25.85	44.8	44.71	44.18	103	112
21	3.76	4.32	2.47	34.39	30.84	29.77	54.07	47.49	47.45	139	113
22	3.71	2.92	2.94	25.33	26.67	25.79	42.98	41.17	41.03	109	101
23	3.2	1.88	2.65	26.74	26.57	26.59	43.65	46.13	45.81	109	107
24	2.78	2.25	1.69	24.78	24.58	24.63	47.08	44.5	44.03	104	104
25	3.78	2.77	2.99	24.5	25.33	24.89	49.98	48.38	47.01	117	127
26	5.98	3.04	3.68	25.15	24.1	24.53	45.68	42.67	42.31	115	116
27	8.83	2.67	2.84	28.37	28.86	28.94	50.48	48.12	47.59	128	109
28	3.24	2.53	3.38	28.8	26.12	26.54	47.95	47.27	47.31	116	117
29	3.03	2.11	1.91	23.31	24.93	23.53	43.49	43.46	44.03	112	118
30	2.41	2.54	2.81	26.64	26.21	26	43.34	42.21	42.5	90	109

TABLE 1.-- General Data for Participants (continued)

ID	IMPA0	IMPA1	Age	Race	Sex	RPE	#Ext	Last Adj
1	94	97	1	0	0	1	0	0
2	87	99	1	0	1	0	0	1
3	92	94	1	0	1	0	0	4
4	92	104	1	3	0	0	0	0
5	91	102	1	0	0	0	0	1
6	111	103	1	0	0	0	0	0
7	97	90	1	2	1	0	0	4
8	95	95	1	0	1	0	0	4
9	98	108	1	1	1	0	0	0
10	96	94	1	3	0	0	1	1
11	78	77	1	0	0	0	2	4
12	89	96	1	0	0	1	0	0
13	111	110	1	0	0	1	0	0
14	86	94	1	0	0	1	0	0
15	87	89	1	0	0	0	0	4
16	99	103	1	0	1	0	0	4
17	90	104	0	0	1	0	0	1
18	96	91	1	1	0	0	4	0
19	100	99	1	0	1	0	0	4
20	116	100	1	0	1	0	0	0
21	116	97	1	1	1	0	4	1
22	92	87	1	3	1	0	4	0
23	88	86	1	3	0	0	0	1
24	83	83	1	2	1	0	0	0
25	99	94	1	0	0	0	0	0
26	94	95	1	0	1	0	0	4
27	102	108	1	3	0	0	2	1
28	85	90	1	0	0	1	0	0
29	75	77	1	0	0	0	0	1
30	86	94	1	0	1	0	0	0

TABLE 2.-- General Data for Non-participants

ID	MxCr0 (mm)	MxCr1 (mm)	MdCr0 (mm)	MdCr1 (mm)	OB0 (mm)	OB1 (mm)	OJ0 (mm)	OJ1 (mm)	Intcan0	Intcan1
1	-3.27	-0.65	-3.17	-0.43	5.28	1.49	3.7	2.51	28.48	28.52
2	-1.34	-0.71	-2.27	-0.34	4.77	2.35	5.03	2.77	23.18	27.94
3	-0.78	0.33	-0.23	-0.57	5.31	2.25	3.61	2.1	25.01	25.02
4	-0.36	0.1	0.51	-0.32	3.56	1	3.74	2.82	30.03	30.47
5	-9.85	0.64	-4.06	0.41	3.86	3.42	2.53	3.58	26.56	25.3
6	-4.31	-0.96	-2.26	-0.2	2.8	1.73	2.19	2.47	26.87	27.81
7	-0.51	2.72	0.67	0	3.58	1.82	4.86	2.39	26.61	26.49
8	1.08	-0.9	-1.42	-0.63	4.39	1.14	2.46	2.5	25.07	25.26
9	1.45	-0.61	-4.96	0.72	3.89	0.82	4.17	2.23	26.24	27.32
10	-1.92	-0.76	-1.16	0.28	4.4	2.62	5.05	2.82	28.63	27.08
11	0.01	0.02	-2.36	0.04	0.69	0.77	2.32	2.38	24.95	25.7
12	-0.52	2.56	-2.67	0.54	4.1	1.49	2.77	2.4	26.07	28.58
13	-1.43	0.37	-0.08	0.31	2	2.36	3.4	2.5	27.22	27.26
14	-2.31	0.38	-1.98	0.31	3.74	2.1	4.6	3.43	25.93	25.78
15	-1.17	0.38	-1.1	-0.22	3.82	2.16	3.83	2.71	26.81	27.33
16	-0.31	0.24	1.79	-0.06	3.66	2.15	5.37	2.39	24.05	27.16
17	-8.54	-1.47	0.83	-0.08	2.78	1.44	3.36	2.47	20.66	18.91
18	-2	0.19	-1.02	0.5	3.73	1.97	3.52	2.68	24.26	25.1
19	2.04	-0.26	1.32	-0.22	2.73	1.25	1.84	1.99	28.2	25.63
20	-3.25	0.49	-1.23	-0.05	2.95	1.02	3.21	2.57	28.87	29.13

TABLE 2.-- General Data for Non-participants (continued)

ID	Intcan0	Intcan1	Intmol0	Intmol1	U1-FH0	U1-FH1	IMPA0	IMPA1	Age	Race	Sex	RPE	Ext	# Ext	Last Adj
1	28.48	28.52	47.24	45.23	109	113	90	102	1	0	1	0	0	0	0
2	23.18	27.94	40.73	44.85	105	112	89	102	1	0	0	1	0	0	0
3	25.01	25.02	44.4	44.01	99	109	94	104	1	0	1	0	0	0	0
4	30.03	30.47	51.92	48.32	106	122	88	97	1	0	0	0	0	0	1
5	26.56	25.3	40.94	42.22	116	131	88	96	1	0	1	0	0	0	0
6	26.87	27.81	48.03	44.65	112	112	87	92	1	0	1	0	1	4	0
7	26.61	26.49	41.7	43.3	112	104	93	105	1	0	1	0	0	0	1
8	25.07	25.26	41.79	43.16	106	106	92	99	1	0	1	0	0	0	0
9	26.24	27.32	48.36	47.09	114	119	95	117	1	0	0	0	0	0	0
10	28.63	27.08	45.33	46.09	111	120	116	109	1	0	0	1	0	0	1
11	24.95	25.7	44.08	43.46	124	123	89	97	1	0	1	0	0	0	0
12	26.07	28.58	46.3	47.15	112	122	95	99	1	2	0	0	0	0	0
13	27.22	27.26	44.21	42.13	114	114	97	96	1	0	1	0	0	0	0
14	25.93	25.78	41.79	45.43	124	118	100	102	1	0	0	1	0	0	0
15	26.81	27.33	44.69	46.82	98	113	104	105	1	0	0	0	0	0	1
16	24.05	27.16	41.03	43.13	121	120	107	113	1	0	1	1	0	0	1
17	20.66	18.91	44.47	44.49	120	113	82	86	1	3	1	0	1	2	4
18	24.26	25.1	39.7	40.3	117	111	102	98	1	0	1	0	0	0	0
19	28.2	25.63	45.22	45.5	118	111	68	80	1	0	1	1	0	0	4
20	28.87	29.13	44.12	43.53	122	126	95	102	1	0	1	0	0	0	0

TABLE 3.-- ABO Scores for Participants

ID	AR	MR	BLI	OJ	OC	OR	IPC	Total T1	AR	MR	BLI	OJ	OC	OR	IPC	Total 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

TABLE 4.-- ABO Scores for Non-participants

ID	AR	MR	BLI	OJ	OC	OR	IPC	Total Score
1	3	3	4	3	5	4	0	22
2	2	7	2	4	5	7	0	27
3	0	6	5	1	5	2	0	19
4	3	10	9	5	9	0	0	36
5	4	2	7	3	6	3	0	25
6	2	4	8	2	6	2	0	24
7	4	5	1	0	6	2	0	18
8	3	7	2	1	4	1	0	18
9	5	2	2	5	4	3	0	21
10	3	6	4	1	5	7	0	26
11	2	3	5	1	4	0	0	15
12	4	5	2	3	4	4	1	23
13	4	1	4	2	0	1	0	12
14	0	2	6	2	9	4	0	23
15	5	6	2	4	7	10	0	34
16	5	4	3	1	6	4	0	23
17	3	6	3	4	6	0	2	24
18	1	2	4	1	4	3	1	16
19	5	4	2	8	18	6	0	43
20	4	8	8	5	2	6	0	33

APPENDIX 2

Tables

TABLE 5.--Analysis of Continuous Variables for Participants at T_1 and T_2

	Mean (mm)	SD	P-value
Mx crowding T_1	0.078	0.84	
Mx crowding T_2	0.393	1.01	
T_2-T_1	0.315	1.12	0.136
Md crowding T_1	0.004	0.68	
Md crowding T_2	-0.394	0.81	
T_2-T_1	-0.398	0.92	* 0.025
Overbite T_1	2.054	0.71	
Overbite T_2	2.220	0.71	
T_2-T_1	0.166	0.61	0.149
Overjet T_1	2.691	0.85	
Overjet T_2	3.051	0.77	
T_2-T_1	0.360	0.72	* 0.010
Md intercanine width T_1	26.323	1.90	
Md intercanine width T_2	26.293	1.76	
T_2-T_1	-0.029	0.62	0.794
Md intermolar width T_1	44.687	2.13	
Md intermolar width T_2	44.498	1.90	
T_2-T_1	-0.189	0.87	0.243

(*) Statistically significant at $P < 0.05$

TABLE 6.--Analysis of ABO Scores for Participants at T_1 and T_2

	Median	Range	P-value
Alignment/Rotations T_1	3	8	
Alignment/Rotations T_2	4	11	
T_2-T_1	1	10	0.175
Marginal Ridges T_1	5	10	
Marginal Ridges T_2	4	7	
T_2-T_1	-1	5	* 0.004
Buccolingual Inclination T_1	4	9	
Buccolingual Inclination T_2	4	9	
T_2-T_1	0	6	0.379
Overjet T_1	3	7	
Overjet T_2	2.5	7	
T_2-T_1	-1	8	0.412
Occlusal Contacts T_1	5.5	17	
Occlusal Contacts T_2	5	14	
T_2-T_1	-2	21	* 0.012
Occlusal relation T_1	2	15	
Occlusal relation T_2	2	14	
T_2-T_1	0	7	0.435
Interproximal contacts T_1	0	2	
Interproximal contacts T_2	0	4	
T_2-T_1	0	4	* 0.023
Total Score T_1	27	30	
Total Score T_2	22	39	
T_2-T_1	-1.5	20	* 0.021

(*) Statistically significant at $P < 0.05$

TABLE 7.--Analysis of Continuous Variables for Group I and Group II

	Group I			Group II			I/II
Variable	**Mean (mm)**	**SD**	**P-value**	**Mean (mm)**	**SD**	**P-value**	**P-value**
Mx Crowding T_1	-0.044	0.96		0.172	0.75		0.509
Mx Crowding T_2	0.235	0.68		0.514	1.21		0.430
T_2-T_1	0.279	0.88	0.275	0.342	1.30	0.296	0.877
Md Crowding T_1	-0.014	0.53		0.018	0.79		0.896
Md Crowding T_2	-0.115	0.74		-0.608	0.82		0.096
T_2-T_1	-0.101	0.67	0.599	-0.626	1.04	* 0.024	0.105
Overbite T_1	2.282	0.67		1.880	0.72		0.126
Overbite T_2	2.285	0.70		2.170	0.73		0.663
T_2-T_1	0.004	0.70	0.984	0.290	0.53	* 0.039	0.231
Overjet T_1	2.958	0.81		2.488	0.84		0.132
Overjet T_2	3.062	0.74		3.044	0.81		0.952
T_2-T_1	0.104	0.70	0.604	0.556	0.68	* 0.004	0.088
Md Intercanine Width T_1	26.746	1.94		25.999	1.86		0.297
Md Intercanine Width T_2	26.443	2.05		26.179	1.56		0.703
T_2-T_1	-0.303	0.60	0.091	0.179	0.56	0.207	* 0.033
Md Intermolar Width T_1	44.635	2.12		44.726	2.21		0.910
Md Intermolar Width T_2	44.538	1.93		44.468	1.94		0.923
T_2-T_1	-0.0977	0.57	0.549	-0.259	1.05	0.326	0.597

(*) Statistically significant at $P < 0.05$

TABLE 8.--Analysis of ABO Scores for Group I and Group II

	Group I			Group II			I/II
Variable	**Median**	**Range**	**P-value**	**Median**	**Range**	**P-value**	**P-value**
Alignment/Rotations T_1	4	8		3	5		0.250
Alignment/Rotations T_2	4	6		4	10		0.315
T_2-T_1	-1	10	0.386	2	8	* 0.019	* 0.015
Marginal Ridges T_1	5	9		5	9		0.851
Marginal Ridges T_2	4	7		4	7		0.834
T_2-T_1	-1	4	0.053	-1	5	* 0.036	0.884
Buccolingual Inclination T_1	5	7		4	9		0.802
Buccolingual Inclination T_2	5	9		4	9		0.950
T_2-T_1	0	4	1.000	0	5	0.205	0.645
Overjet T_1	3	6		4	6		0.616
Overjet T_2	2	7		3	7		0.967
T_2-T_1	1	8	0.944	-1	6	0.182	0.391
Occlusal Contacts T_1	5	11		9	17		0.572
Occlusal Contacts T_2	4	13		5	14		0.706
T_2-T_1	4	13	0.168	-3	13	* 0.038	* 0.0001
Occlusal relation T_1	2	15		2	10		0.983
Occlusal relation T_2	2	14		2	8		0.754
T_2-T_1	0	6	1.000	0	5	0.398	0.558
Interproximal contacts T_1	0	2		0	1		0.586
Interproximal contacts T_2	0	1		1	4		0.060
T_2-T_1	0	2	0.787	1	3	* 0.006	* 0.011
Total Score T_1	26	30		28	24		0.884
Total Score T_2	21	39		24	19		0.094
T_2-T_1	-3	20	0.099	-1	18	0.084	0.691

(*) Statistically significant at $P < 0.05$

TABLE 9.--Analysis of Continuous Variables for Participants and Non-participants

	Participants		Non-participants		
	Mean (mm)	SD	Mean (mm)	SD	P-value
Mx crowding T_0	0.12	3.19	-1.86	2.97	* 0.030
Mx crowding T_1	0.08	0.84	0.11	1.05	0.926
Md crowding T_0	-0.39	2.40	-1.24	1.79	0.158
Md crowding T_1	0.004	0.68	-0.001	0.38	0.975
Overbite T_0	3.53	1.34	3.60	1.09	0.833
Overbite T_1	2.05	0.71	1.77	0.68	0.160
Overjet T_0	4.17	1.53	3.58	1.04	0.110
Overjet T_1	2.69	0.85	2.59	0.38	0.552
Md intercanine width T_0	26.35	2.79	26.19	2.20	0.819
Md intercanine width T_1	26.32	1.90	26.59	2.34	0.674
Md intermolar width T_0	45.30	3.29	44.30	3.07	0.282
Md intermolar width T_1	44.69	2.13	44.54	1.98	0.808

(*) Statistically significant at $P < 0.05$

TABLE 10.--Analysis of ABO Scores for Participants and Non-participants

	Participants		Non-participants		
	Median	Range	Median	Range	P-value
Alignment/Rotations	3	8	3	5	0.070
Marginal Ridges	5	10	4.5	9	0.559
Buccolingual Inclination	4	9	4	8	0.722
Overjet	3	7	2.5	8	0.178
Occlusal Contacts	5.5	16	5	18	0.378
Occlusal relation	2	15	3	10	0.188
Interproximal contacts	0	2	0	2	0.945
Total Score	27	30	23	31	0.263

(*) Statistically significant at $P < 0.05$

TABLE 11.--Intra-examiner Reliability

Variable	Mean/Median of the differences	SD/Range	P-value
Mx crowding	-0.061	0.323	0.565
Md crowding	0.192	0.379	0.143
Overbite	0.030	0.291	0.752
Overjet	-0.050	0.075	0.064
Md intercanine width	-0.080	0.169	0.170
Md intermolar width	-0.063	0.197	0.338
Alignment/rotations	0	4	0.715
Marginal Ridges	0.500	2	0.281
Buccolingual Inclination	0	2	0.787
Overjet	-0.500	3	0.272
Occlusal Contacts	0.500	4	0.401
Occlusal relation	0	4	0.800
Interproximal contacts	0	0	NA
Total Score	-10.50	23	0.006

(*) Statistically significant at $P < 0.05$

APPENDIX 3

Institutional Review Board Approval

Case Western Reserve University
Institutional Review Board
NOTICE OF APPROVAL

Responsible Investigator: **Manish Valiathan**
Department: **Dental Clinic Ortho**
IRB Protocol #: **20050606**
Title: ***A Prospective Clinical Trial on Short-Term Stability Without Retention***
Co-Investigator: **Nadia Lyotard**

Approval Date: **July 15, 2005**
Continuing Review Deadline: **June 30, 2006**
Expiration Date: **July 14, 2006**

The Institutional Review Board (IRB) has APPROVED the above new protocol through the full 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.

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

Appendix 4

Consent Forms

Informed Consent for A Prospective Clinical Trial on Short-Term Stability Without Retention

Background information

You are being asked to participate in a study evaluating the need for orthodontic retainers. You were selected as a possible participant because you are reaching the end of your active orthodontic treatment.

The current belief is that retainers should be worn immediately following orthodontic treatment. The scientific literature on this subject is very limited and presents contradictory recommendations. Some researchers believe that retainers are not required at all, others suggest permanent life-long retention.

Due to this contradictory evidence, orthodontists have come to provide their patients with some type of retention after orthodontic treatment. Retainers do however have disadvantages such as compromised speech, esthetics, increased difficulty in maintaining good oral hygiene, interfering with normal movements of teeth that improve their fit, and costs.

These disadvantages are justified if retainers are indeed necessary to maintain treatment results. It is the purpose of this study to determine the need for retainers after orthodontic treatment.

Procedure

If you consent to being a participant in this research we would do the following:

- Now that it has been determined that you are ready to get your braces off, we would remove the wires while leaving the braces on. We would take a mold of your

teeth and schedule a follow-up appointment 4 weeks later. These procedures will add about 15 minutes to your appointment.

- At the follow-up appointment, a new mold will be taken and a clinical exam will be performed to determine if any changes took place in the last 4 weeks. If no changes occurred, an appointment will be made to remove the braces. If any negative changes are noted, the previously removed wires will be replaced for 4 to 8 weeks and your braces will come off on a scheduled date. These procedures will take 20-30 minutes and require an additional appointment.

These procedures will allow us to compare the two molds and determine if any changes occurred.

Risks and Benefits to Being in the Study

There are no foreseeable risks associated with the material used to make molds. At this date no allergic or toxic reaction to the material has ever been reported. At this point in their treatment, all patients have had molds taken at least twice during the course of routine orthodontic care. Molds are used for diagnosing, treatment planning, and in the fabrication of appliances during the course of treatment. The procedures involved may however entail risks to the subject that are currently unforeseeable.

A disadvantage of you participating in this study is the potential delay in the removal of your braces. If negative changes are observed after 4 weeks they will need to be corrected. This could add another 4 to 8 weeks to your treatment.

There are no direct benefits from participating in this study. If you decide to participate in this study you will have the satisfaction that your contribution helped clinicians have a better understanding of the retention process and will thus provide patients with better service.

Compensation

There will be no additional treatment cost for participating to this study. If you decide to participate, you will receive, in addition to the retainers that are part of your normal treatment protocol, one free set of retainers valued at $100. These will be identical to the ones included in your normal treatment protocol. They will be a spare set if your retainers are lost or broken. These will be given to you the day your braces are removed.

You will not receive this set of additional free retainers if you decide to discontinue your participation before your braces are removed or if your participation is terminated.

Confidentiality

Access to research records will normally be limited to researchers. However, the University's Institutional Review Board (IRB) and other regulatory agencies may review the research records to ensure that the rights of human subjects are being adequately protected. The information gathered via molds will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a participant.

Participation

Your participation is purely voluntary. If you choose not to participate, it will not affect your current relations with the University. There is no penalty or loss of benefits for not participating or for discontinuing your participation.

Your compliance can greatly affect the results of this study. Therefore, if you are unable to keep the 4 week follow-up appointment or reschedule it within the week, your participation in this study will be terminated.

In the event your participation is terminated, your relation with Case's orthodontic clinic will not be affected in any way. You will receive care and attention

until your treatment is completed regardless of the status of your participation to this study

You will be provided with any significant new findings that may make you decide that you want to stop participating.

Contacts and Questions

The researchers conducting this study are Dr. Manish Valiathan and Dr. Nadia Lyotard. You may ask any questions you have now. If you have any questions later, you may contact them at (216) 368-3249 or (216) 368-0673.

If the researchers cannot be reached, or if you would like to talk to someone other than the researchers about concerns regarding this study, research participants' rights, or other human subjects issues, please contact Case Western Reserve University's Institutional Review Board at (216) 368-6925 or write to:

Case Western Reserve University
Institutional Review Board
10900 Euclid Avenue
Cleveland, OH 44106-7230

You will be given a copy of this form for your records

Statement of Consent

I have read the above information. I have received answers to the questions I have asked. I consent to participating in this study.

Print Name of Participant: _____

Signature of the Participant: _____

Signature of the Person obtaining Consent: _____

Date: _____

Parental Consent for A Prospective Clinical Trial on Short-Term Stability Without Retention

Background information

You are being asked to allow for your child to participate in a study evaluating the need for orthodontic retainers. Your child was selected as a possible participant because he/she is reaching the end of their active orthodontic treatment.

The current belief is that retainers should be worn immediately following orthodontic treatment. The scientific literature on this subject is very limited and presents contradictory recommendations. Some researchers believe that retainers are not required at all, others suggest permanent life-long retention.

Due to this contradictory evidence, orthodontists have come to provide their patients with some type of retention after orthodontic treatment. Retainers do however have disadvantages such as compromised speech, esthetics, increased difficulty in maintaining good oral hygiene, interfering with normal movements of teeth that improve their fit, and costs.

These disadvantages are justified if retainers are indeed necessary to maintain treatment results. It is the purpose of this study to determine the need for retainers after orthodontic treatment.

Procedure

If you consent to your child being a participant in this research we would do the following:

- Now that it has been determined that your child is ready to get his/her braces off, we would remove the

wires while leaving the braces on. We would take a mold of your child's teeth and schedule a follow-up appointment 4 weeks later. These procedures will add about 15 minutes to the appointment.

- At the follow-up appointment, a new mold will be taken and a clinical exam will be performed to determine if any changes took place in the last 4 weeks. If no changes occurred, an appointment will be made to remove the braces. If any negative changes are noted, the previously removed wires will be replaced for 4 to 8 weeks and your child's braces will come off on a scheduled date. These procedures will take 20-30 minutes and will require an additional appointment.

These procedures will allow us to compare the two molds and determine if any changes occurred.

Risks and Benefits to Being in the Study

There are no foreseeable risks associated with the material used to make molds. At this date no allergic or toxic reaction to the material has ever been reported. At this point in their treatment, all patients have had molds taken at least twice during the course of routine orthodontic care. Molds are used for diagnosing, treatment planning, and in the fabrication of appliances during the course of treatment. The procedures involved may however entail risks to the subject that are currently unforeseeable.

A disadvantage of your child participating in this study is the potential delay in the removal of the braces. If negative changes are observed after 4 weeks they will need to be corrected. This could add another 4 to 8 weeks to the treatment.

There are no direct benefits from participating in this study. You will have the satisfaction that your child's contribution helped clinicians have a better understanding of the retention process and will thus provide patients with better service.

Compensation

There will be no additional treatment cost for participating to this study. If you decide to have your child participate, he/she will receive, in addition to the retainers that are part of the normal treatment protocol, one free set of retainers valued at $100. These will be identical to the ones included in the normal treatment protocol. They will be a spare set if your child's retainers are lost or broken. These will be given to him/her the day the braces are removed.

Your child will not receive this set of additional free retainers if he/she decides to discontinue his/her participation before the braces are removed or if his/her participation is terminated.

Confidentiality

Access to research records will normally be limited to researchers. However, the University's Institutional Review Board (IRB) and other regulatory agencies may review the research records to ensure that the rights of human subjects are being adequately protected. The information gathered via molds will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a participant.

Participation

Your child's participation is purely voluntary. If he/she chooses not to participate, it will not affect his/her current relations with the University. There is no penalty or loss of benefits for not participating or for discontinuing your participation.

Your child's compliance can greatly affect the results of this study. Therefore, if your child is unable to keep the 4 week follow-up appointment or reschedule it within the week, his/ her participation in this study will be terminated.

In the event your child's participation is terminated, his/her relation with Case's orthodontic clinic will not

be affected in any way. He/she will receive care and attention until the treatment is completed regardless of the status of his/her participation to this study.

You will be provided with any significant new findings that may make you decide that you want your child to stop participating.

Contacts and Questions

The researchers conducting this study are Dr. Manish Valiathan and Dr. Nadia Lyotard. You may ask any questions you have now. If you have any questions later, you may contact them at (216) 368-3249 or (216) 368-0673.

If the researchers cannot be reached, or if you would like to talk to someone other than the researchers about concerns regarding this study, research participants' rights, or other human subjects issues, please contact Case Western Reserve University's Institutional Review Board at (216) 368-6925 or write to:

Case Western Reserve University
Institutional Review Board
10900 Euclid Avenue
Cleveland, OH 44106-7230

You will be given a copy of this form for your records

Statement of Consent

I have read the above information. I have received answers to the questions I have asked. I consent to have my child participate in this study.

Print Name of Participant: _____

Signature of the Participant: _____

Signature of the Parent or Guardian: _____

Signature of the Person obtaining Consent: _____

Date: _____

Child Assent Form

Hi, my name is Nadia Lyotard. I am doing a project at Case Western Reserve University to see if retainers are necessary to keep your teeth straight after having braces.

The only thing I need to do is take a mold of your teeth the day you get your braces off. This is the same type of mold we took at the beginning of your treatment. On this same day, I will remove your wires but leave the braces on for another month. At you next appointment 4 weeks later, I will take a second mold and examine your teeth. If no changes occurred since your last visit, we will take your braces off. If we see some changes, we will place the wires back in your month for 4 to 8 weeks and then remove your braces.

This project will allow me to compare the two molds taken and will help us find out if retainers are necessary to keep your teeth in their new position.

It is perfectly fine if you do not want to take part in this project. If you want to take part in this study, I will give you a free set of retainers the day your braces come off.

If you are willing and want to take part, you can still change your mind at any time without any problems. Your parent(s) know that I am asking you to do this. Would you like to participate in this project?

I have read the above and agree to participate in this study.

Child Participant's Printed Name: _____
Child Participant's Signature: _____
I agree to permit my child to participate in this study.
Parent's Signature: _____

Appendix 5

ABO-OSG Criteria and Rationale

CRITERIA AND RATIONALE

The ABO Objective Grading System for scoring dental casts and panoramic radiographs contains eight criteria. These are: alignment, marginal ridges, buccolingual inclination, occlusal relationships, occlusal contacts, overjet, interproximal contacts, and root angulation. The rationale for using these criteria is stated in the following section.

Alignment is usually a fundamental objective of any orthodontic treatment plan. Therefore, it seems reasonable that any assessment of quality of orthodontic result must contain an assessment of tooth alignment. In the anterior region, the incisal edges and lingual surfaces of the maxillary anterior teeth and the incisal edges and labial-incisal surfaces of the mandibular anterior teeth were chosen as the guide to assess anterior alignment. These are not only the functioning areas of these teeth, but they also influence esthetics if they are not arranged in proper relationship. In the maxillary posterior region, the mesiodistal central groove of the premolars and molars is used to assess adequacy of alignment. In the mandibular arch, the buccal cusps of the premolars and molars are used to assess proper alignment. These areas were chosen since they represent easily identifiable points on the teeth, and represent the functioning areas of the posterior teeth. The results of the four field tests show that the most commonly malaligned teeth were the maxillary and mandibular lateral incisors and second molars, which accounted for nearly 80% of the mistakes.

Marginal ridges are used to assess proper vertical positioning of the posterior teeth. In patients with no restorations, minimal attrition, and no periodontal bone loss, the marginal ridges of adjacent teeth should be at the same level. If the marginal ridges are at the same relative height, the cementoenamel junctions will be at the same level. In a periodontally healthy individual, this will result in flat bone level between adjacent teeth. In addition, if marginal ridges are at the same height, it will be easier to establish proper occlusal contacts, since some marginal ridges provide contact areas for opposing cusps. Based upon the four field tests, the most common mistakes in marginal ridge alignment occurred between the maxillary first and second molars. The second most common problem area was between the mandibular first and second molars.

Buccolingual inclination is used to assess the buccolingual angulation of the posterior teeth. In order to establish proper occlusion in maximum intercuspation and avoid balancing interferences, there should not be a significant difference between the heights of the buccal and lingual cusps of

the maxillary and mandibular molars and premolars. The Directors use a special step gauge to assess this relationship. Some latitude is allowed, however in past field tests significant problems were observed in the buccolingual inclination of the maxillary and mandibular second molars.

Occlusal relationship is used to assess the relative anteroposterior position of the maxillary and mandibular posterior teeth. In order to achieve accuracy and reliability in measuring this relationship, results of previous field tests have shown that the most verifiable method of scoring this criterion is to use Angle's relationship. Therefore, the buccal cusps of the maxillary molars, premolars, and canines must align within 1 mm of the interproximal embrasures of the mandibular posterior teeth. The mesiobuccal cusp of the maxillary first molar must align within 1 mm of the buccal groove of the mandibular first molar.

Occlusal contacts are measured to assess the adequacy of the posterior occlusion. Again, a major objective of orthodontic treatment is to establish maximum intercuspation of opposing teeth. Therefore, the functioning cusps are used to assess the adequacy of this criterion; i.e., the buccal cusps of the mandibular molars and premolars, and the lingual cusps of the maxillary molars and premolars. If cusp form is small or diminutive, that cusp is not scored. In past field tests, the most common problem area has been inadequate contact between maxillary and mandibular second molars.

Overjet is used to assess the relative transverse relationship of the posterior teeth, and the anteroposterior relationship of the anterior teeth. In the posterior region, the mandibular buccal cusps and maxillary lingual cusps are used to determine proper position within the fossae of the opposing arch. In the anterior region, the mandibular incisal edges should be in contact with the lingual surfaces of the maxillary anterior teeth. In past field tests, the common mistakes in overjet have occurred between the maxillary and mandibular incisors and second molars.

Interproximal contacts are used to determine if all spaces within the dental arch have been closed. Persistent spaces between teeth after orthodontic therapy are not only unesthetic, but can lead to food impaction. In past field tests, spacing is generally not a major problem with ABO cases.

Root angulation is used to assess how well the roots of the teeth have been positioned relative to one another. Although the panoramic radiograph is not the perfect record for evaluating root angulation, it is probably the best means possible for making this assessment. If roots are properly angulated, then sufficient bone will be present between adjacent roots, which could be important if the patient were susceptible to periodontal bone loss at some point in time. If roots are dilacerated, then they are not

graded. In past field tests, the common mistakes in root angulation occurred in the maxillary lateral incisors, canines, second premolars, and mandibular first premolars.

GUIDE FOR GRADING CLINICAL CASE REPORTS MODEL ANALYSIS

ALIGNMENT

In the maxillary and mandibular anterior regions, proper alignment is characterized by coordination of alignment of the incisal edges and lingual incisal surfaces of the maxillary incisors and canines (fig. 1), and the incisal edges and labial incisal surfaces of the mandibular incisors and canines (fig. 2).

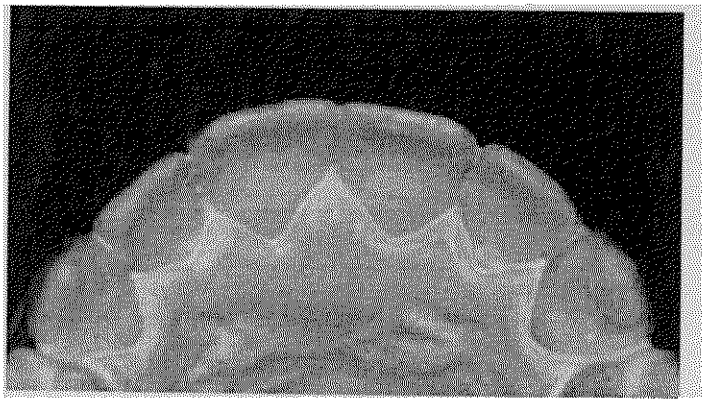


figure 1

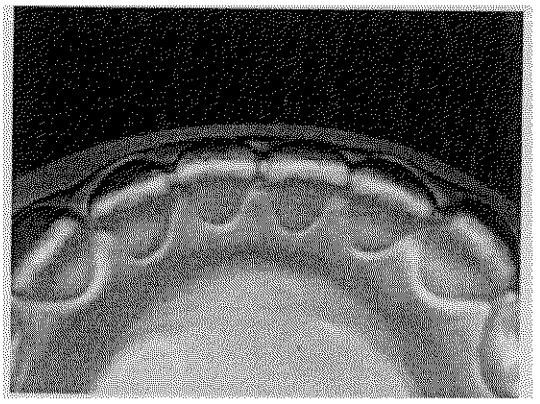


figure 2

In the mandibular posterior quadrants, the mesiobuccal and distobuccal cusps of the molars and premolars should be in the same mesiodistal alignment. In the maxillary arch, the central grooves (mesio-distal) should all be in the same plane or alignment (fig. 3). If all teeth are in alignment, or within 0.50 mm of proper alignment, no points are subtracted from the candidate's score.



figure 3

ALIGNMENT (Cont'd)

If the mesial or distal alignment at any of the contact points is 0.50 mm to 1 mm deviated from proper alignment (fig. 4a,b), 1 point shall be subtracted for the tooth that is out of alignment. If adjacent teeth are out of alignment, then 1 point should be subtracted for each tooth.

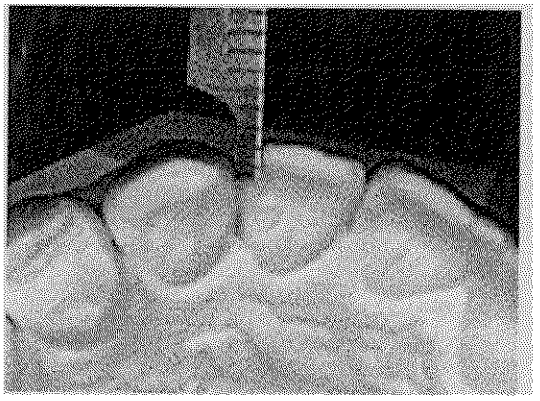


figure 4a



figure 4b

If the discrepancy in alignment of a tooth at the contact point is greater than 1 mm, then 2 points shall be subtracted for that tooth (fig. 5a,b). No more than 2 points shall be subtracted for any tooth.



figure 5a



figure 5b

MARGINAL RIDGES

In both maxillary and mandibular arches, marginal ridges of adjacent posterior teeth shall be at the same level, or within 0.50 mm of the same level (fig. 6).

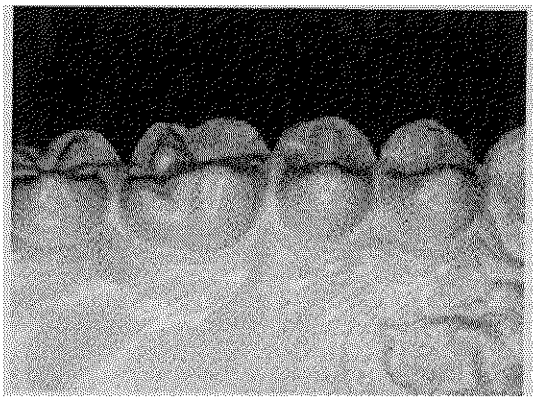


figure 6

If adjacent marginal ridges deviate from 0.50 to 1 mm (fig. 7), then 1 point shall be subtracted for that interproximal contact. If the marginal ridge discrepancy is greater than 1 mm (fig. 8), then 2 points shall be subtracted for that interproximal contact. No more than 2 points will be subtracted for any contact point. The marginal ridge will be considered as the most occlusal point that is within 1 mm of the contact at the occlusal surface of adjacent teeth.

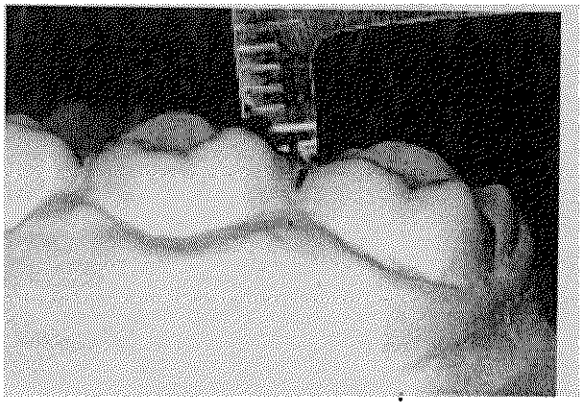


figure 7

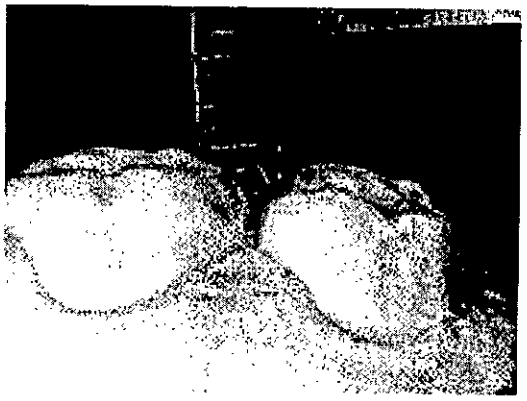


figure 8

BUCCOLINGUAL INCLINATION

The buccolingual inclination of the maxillary and mandibular posterior teeth shall be assessed by using a flat surface that is extended between the occlusal surfaces of the right and left posterior teeth. When positioned in this manner, the straight edge should contact the buccal cusps of contralateral mandibular molars. The lingual cusps should be within 1 mm of the surface of the straight edge (fig. 9). In the maxillary arch, the straight edge should contact the lingual cusps of the maxillary molars and premolars. The buccal cusps should be within 1 mm of the surface of the straight edge (fig. 10).



figure 9

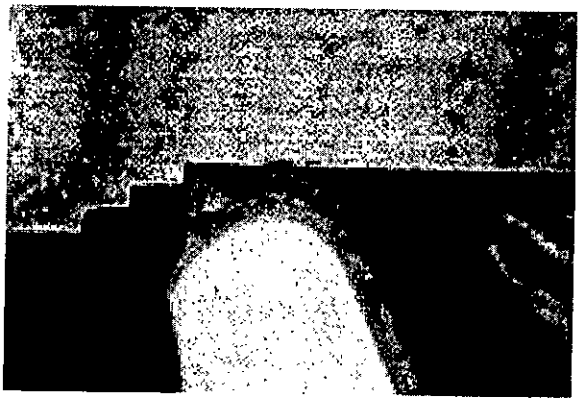


figure 10

If the mandibular lingual cusps or maxillary buccal cusps are more than 1 mm, but less than 2 mm from the straight edge surface (fig. 11a,b), 1 point shall be subtracted for that tooth.



figure 11a

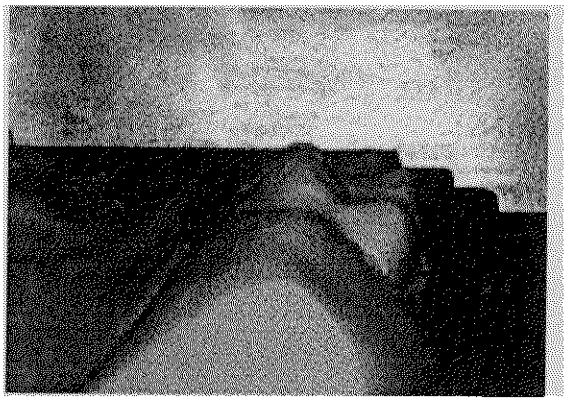


figure 11b

BUCCOLINGUAL INCLINATION (Cont'd)

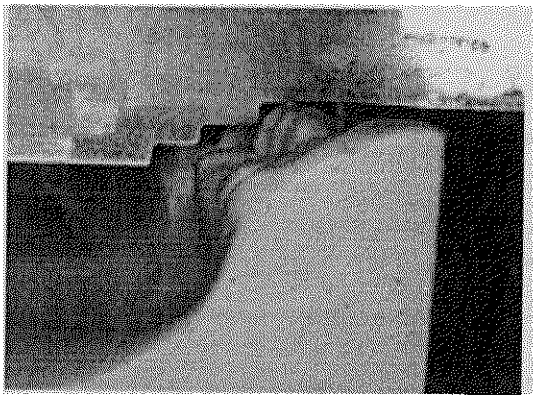


Figure 12A



Figure 12B

If the discrepancy is greater than 2 mm (fig. 12a,b), then 2 points are subtracted for that tooth. No more than 2 points shall be subtracted for any tooth.

OCCLUSAL CONTACTS

This section of the evaluation determines the adequacy of occlusal contact of the premolars and molars. The buccal cusps of the mandibular premolars and molars (fig. 13) and the lingual cusps of the maxillary premolars and molars (fig. 14) should be contacting the occlusal surfaces of the opposing teeth. Each mandibular premolar has one functional cusp. Each mandibular molar has two functional buccal cusps. The maxillary premolars have one functional lingual cusp. However, the maxillary molars may have only a mesiolingual functional cusp.

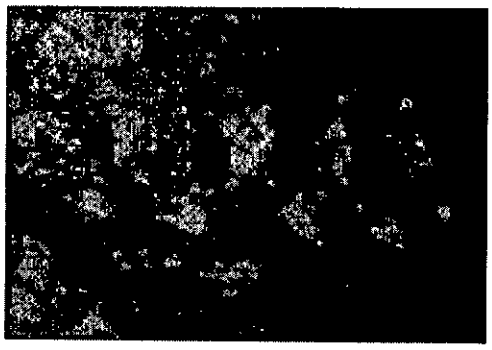


figure 13

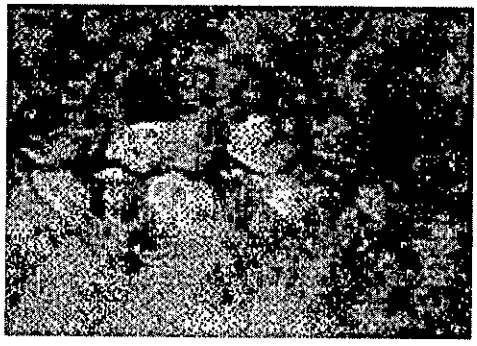


figure 14

OCCLUSAL CONTACTS (Cont'd)

If the distolingual cusp is short or diminutive (fig. 15), it should not be considered in the evaluation. If this cusp is prominent, but does not contact with the opposing arch, then points may be deducted. If the cusps are in contact with the opposing arch, no points are deducted.



figure 15

If a cusp is out of contact with the opposing arch, and the distance is 1 mm or less (fig. 16), then 1 point is subtracted for that cusp. If the cusp is out of contact and the distance is greater than 1 mm (fig. 17), then 2 points are subtracted for that cusp. No more than 2 points are subtracted for each cusp.

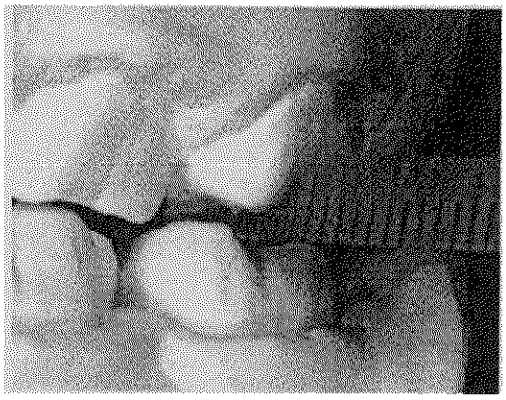


figure 16

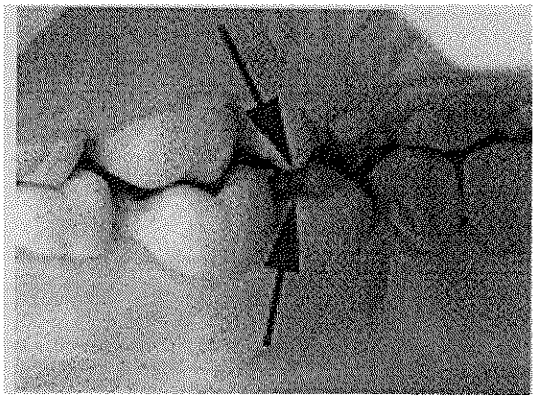


figure 17

OCCLUSAL RELATIONSHIP

This section of the evaluation determines whether the occlusion has been finished in an Angle Class I relationship. Ideally, the maxillary canine cusp tip should align with (or within 1 mm of) the embrasure or contact between the mandibular canine and adjacent premolar (fig. 18). The buccal cusps of the maxillary premolars should align with (or be within 1 mm of) the embrasures or contacts between the mandibular premolars and first molar

(fig. 18). The mesiobuccal cusps of the maxillary molars should align with (or be within 1 mm of) the buccal grooves of the mandibular molars (fig. 18).



figure 18

If the maxillary buccal cusps deviate between 1 and 2 mm from the aforementioned positions (fig. 19), then 1 point shall be subtracted for that maxillary tooth. If the buccal cusps of the maxillary premolars or molars deviate by more than 2 mm from ideal position (fig. 20), then 2 points shall be subtracted for each maxillary tooth that deviates. No more than 2 points shall be subtracted for each maxillary tooth. In some situations, the posterior occlusion may be finished in either an Angle Class II or Class III relationship, depending upon the type of tooth extraction in the maxillary or mandibular arches.



Figure 19



Figure 20

OCCLUSAL RELATIONSHIP (Cont'd)

In a Class II situation (fig. 21), the buccal cusp of the maxillary first molar should align with the embrasure or interproximal contact between the mandibular second premolar and first molar. The buccal cusp of the maxillary second molar should align with the embrasure or interproximal contact between the mandibular first and second molars. If the final occlusion is finished in a Class III relationship (when mandibular premolars are extracted), the buccal cusp of the maxillary second premolar should align with the buccal groove of the mandibular first molar (fig. 22). The remaining occlusion distal to the maxillary second premolar and mandibular first molar are adjusted accordingly.



figure 21



figure 22

OVERJET

The overjet is evaluated by articulating the models and viewing the labiolingual relationship of the maxillary arch relative to the mandibular arch. In order to determine the proper relationship of the casts, the examiner must rely on the trimming of the backs of the bases of the models. The models are set flat on their backs, in order to determine this assessment (fig. 23).

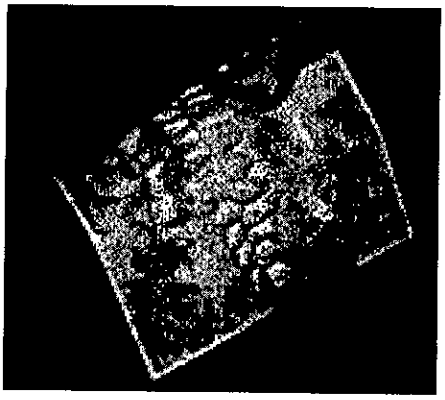


figure 23

OVERJET (Cont'd)

If the models are mounted on an articulator, then the articulated mounting shall determine the proper maxillary and mandibular model relationship. If the proper overjet has been established, then the buccal cusps of the mandibular molars and premolars will contact in the center of the occlusal surfaces, buccolingually, of the maxillary premolars and molars (fig. 24). In the anterior region, the mandibular canines and incisors will contact the lingual surfaces of the maxillary canines and incisors (fig. 25). If this relationship exists, no points are subtracted.



figure 24



figure 25

If the mandibular buccal cusps deviate 1 mm or less from the center of the opposing tooth (fig. 26), 1 point is subtracted for that tooth, If the position of the mandibular buccal cusps deviates more than 1 mm from the center of the opposing tooth (fig. 27), two points are subtracted for that tooth. No more than 2 points are subtracted for any tooth.



figure 26



figure 27

OVERJET (Cont'd)

In the anterior region, if the mandibular canines or incisors are not contacting lingual surfaces of the maxillary canines and incisors, and the distance is 1 mm or less (fig. 28), then 1 point is subtracted for each maxillary tooth. If the discrepancy is greater than 1 mm (fig. 29), then 2 points are subtracted for each maxillary tooth.

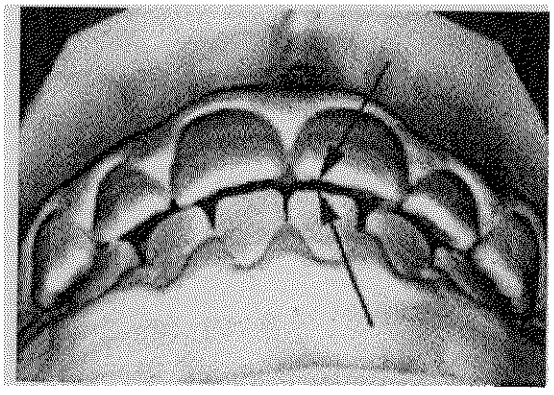


figure 28



figure 29

INTERPROXIMAL CONTACTS

This assessment is made by viewing the maxillary and mandibular dental casts from an occlusal perspective. The mesial and distal surfaces of the teeth should be in contact with one another (fig. 30). If 0.50 mm or less interproximal space exist, then no points are subtracted.

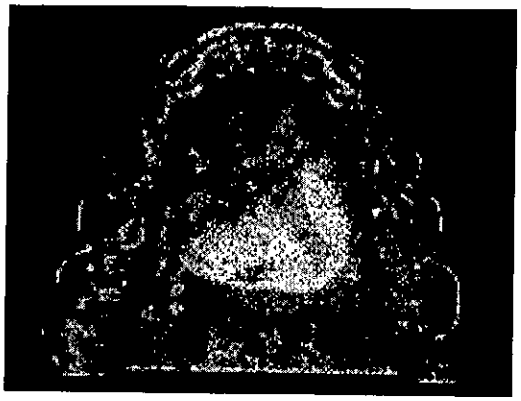


figure 30

INTERPROXIMAL CONTACTS (Cont'd)

If greater than 0.50 to 1 mm of interproximal space exists between two adjacent teeth (fig. 31), then 1 point is subtracted for that interproximal contact. If more than 1 mm of space is present between two teeth (fig. 32), then 2 points are subtracted for that interproximal contact. No more than 2 points are subtracted for any contact that deviates from ideal.

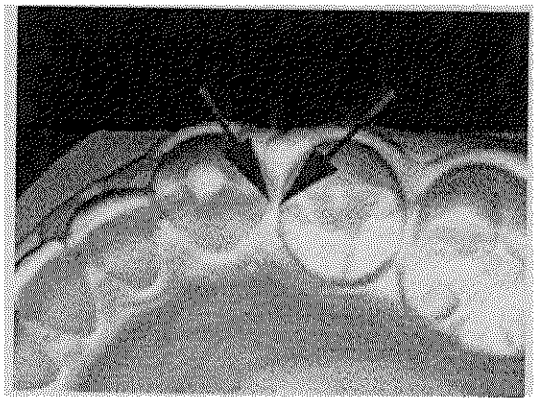


figure 31

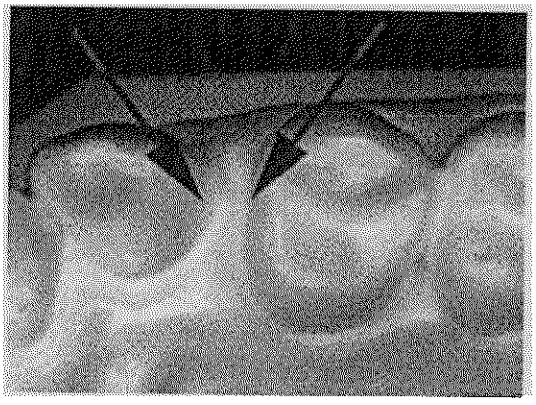


figure 32

RADIOGRAPHIC ANALYSIS

ROOT ANGULATION

The relative angulation of the roots of the maxillary and mandibular teeth is

assessed on the panoramic radiograph. Although this is not ideal, it gives a reasonably good assessment of root position. Generally, the roots of the maxillary and mandibular teeth should be parallel to one another and oriented perpendicular to the occlusal plane (fig. 33). If this situation exists, or if a deviation of the apex is 1 mm or less, then no points are subtracted.



figure 33

ROOT ANGULATION (Cont'd)

If a root is angled to the mesial or distal on the panoramic radiograph, and if the discrepancy is mild, with the apex of the affected tooth greater than 1 mm, but not touching the adjacent tooth root (fig. 34), then 1 point is subtracted for that tooth. If the root is angled to the mesial or distal and is contacting the adjacent tooth root (fig. 35), then 2 points are subtracted for that tooth.



figure 34



figure 35

PASSING SCORE

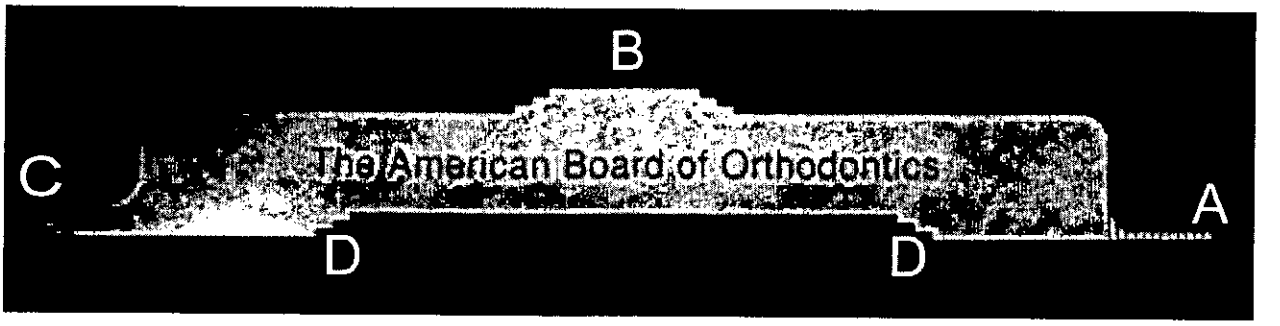
During the 1997 and 1998 field tests, both subjective and objective methods of scoring the dental casts and panoramic radiographs were used by the Directors. Based upon a comparison of these two methods, a passing score was established. In general, a case report that loses more than 30 points will fail. A case report that loses less than 20 points will generally pass that portion of the phase III examination. However, this figure only represents a part of the overall score for each case report. The quality of the records, appropriateness of the treatment plan, and objectives for positioning of the maxilla, mandible, maxillary dentition, mandibular dentition, and facial profile are also carefully scrutinized. The Board is presently field testing objective methods for grading these other aspects of the phase III examination.

SUMMARY

The Directors of The American Board of Orthodontics have spent countless hours developing this system for assessing the occlusal and radiographic results of orthodontic treatment. The usefulness of this system depends not only on its objectivity, but more importantly on the validity and reliability of the measurements. After repeated comparison of both objective and subjective systems, the Directors are confident that the "cut-off" score to pass this portion of the phase III examination is valid. Reliability will be insured through the use of a precise measuring instrument, in addition to training and calibration of the Directors before each examination. In order to be fair to all candidates, a confidence interval is established to account for interrater variability.

Although the underlying purpose of establishing this grading system is to insure reliable, objective evaluation of orthodontic records, the Board sees a much greater benefit to publishing this grading system. In the future, candidates may grade their own results before the phase III examination. Candidates will know if their results will pass the CCROE portion of the phase III examination. Furthermore, Diplomates may use this scoring system at anytime in their clinical career to determine if they are producing "Board quality" results. The Board hopes that this method of self-evaluation will help to elevate the quality of orthodontic care in the future.

THE AMERICAN BOARD OF ORTHODONTICS MEASURING GAUGE



A This portion of the gauge is 1 mm in width and is used to measure discrepancies in alignment, overjet, occlusal contact, interproximal contact, and occlusal relationships.

B This portion of the gauge has steps measuring 1 mm in height and is used to determine discrepancies in mandibular posterior buccolingual inclination.

C This portion of the gauge has steps measuring 1 mm in height and is used to determine discrepancies in marginal ridges.

D This portion of the gauge has steps measuring 1 mm in height and is used to determine discrepancies in maxillary posterior buccolingual inclination.

REFERENCES

Ades A, Joondeph D, Little R, Chapko M. A long-term study of the relationship of third molars to changes in the mandibular dental arch. Am J Orthod Dentofacial Orthop. 1990;97:323-335.

Ahrens D, Shapira Y, Kuftinec M. An approach to rotational relapse. Am J Orthod. 1981;80:83-91.

Angle E.: Malocclusion of the Teeth. S. S. White Dental Mfg.Co., Philadelphia, 7th Edition, 1907

Azizi M, Shrout M, Haas A, Russell C, Hamilton E. A retrospective study of Angle Class I malocclusions treated orthodontically without extractions using two palatal expansion methods. Am J Orthod Dentofacial Orthop. 1999;116:101-107.

Bishara S, Jakobsen JR, Treder J, Nowak A. Arch length from 6 weeks to 45 years. Angle Orthod. 1995;68:69-74.

Bondevik O. Changes in occlusion between 23 and 34 years. Angle Orthod. 1996;68:75-80.

Burke SP, Silveira AM, Goldsmith LJ, Yancey JM, Van Stewart A, Scarfe WC. A meta-analysis of mandibular intercanine width in treatment and postretention. Angle Orthod. 1998;68:53-60.

Brodie AG, et al. Cephalometric appraisal of orthodontic results. Angle Orthod. 1938;8:261-265.

Case C. Principles of retention in orthodontia. Int J of Orthod and Oral Surg. Vol.6 1920

DeKock WH. Dental arch depth and width studied longitudinally from 12 years of age to adulthood. Am J Orthod. 1972;62:56-66.

Dugoni S, Lee J, Varela J, Dugoni A. Early mixed dentition treatment: postretention evaluation of stability and relapse. Angle Orthod. 1995;65:311-320.

Edwards J. A long-term prospective evaluation of the circumferential supracrestal fiberotomy in alleviating orthodontic relapse. Am J Orthod Dentofacial Orthop. 1988;93:380-387.

Glenn G, Sinclair P, Alexander R. Non-extraction orthodontic therapy: Posttreatment dental and skeletal stability. Am J Orthod Dentofacial Orthop. 1987;92:321-328.

Haruki T, Little R. Early versus late treatment of crowded first premolar extraction cases: Postretention evaluation of stability and relapse. Angle Orthod. 1998;68:61-68.

Harradine N, Pearson M, Toth B. The effect of extraction of third molars on late lower incisor crowding: A randomized controlled trial. Br J Orthod. 1998;25:117-122.

Hawley CA. A removable retainer. Dent Cosmos. 1919;61(6):449-55.

Hellman M. Transactions of the American Association of Orthodontists. 1944;34-44.

Horowitz S, Hixon E. Physiologic recovery following orthodontic treatment. Am J Orthod. 1969;55:1-4.

Housley JA, Nanda RS, Currier GF, McCune DE. Stability of transverse expansion in the mandibular arch. Am J Orthod Dentofacial Orthop. 2003;124:288-293.

Kingsley N. Treatise on Oral Deformities. Appleton and Company, New York. 1880;64-65.

Lindqvist B, Thilander B. Extraction of third molars in cases of anticipated crowding in the lower jaw. Am J Orthod Dentofacial Orthop. 1982;81:130-139.

Little R, Riedel R, Artun J. An Evaluation of changes in the mandibular anterior alignment from 10 to 20 years postretention. Am J Orthod. 1998;93:423-8.

Little R, Riedel R, Engst D. Serial extraction of first premolars-postretention evaluation of stability and relapse. Angle Orthod. 1990;60:255-62.

Little R, Wallen T, Riedel R. Stability and relapse of mandibular anterior alignment-first premolar extraction cases treated by traditional edgewise orthodontics. Am J Orthod. 1981;80:349-65.

Little R, Riedel R, Stein A. Mandibular arch length increase during the mixed dentition: Postretention evaluation of stability and relapse. Am J Orthod Dentofac Orthop. 1990;97:393-404.

Lundstrom, A. Malocclusion of the teeth regarded as a problem in connection with the apical base. Int J Orthod Oral Surg.1925;11(7):591-602.

Luppanapornlarp S, Johnston L. The effects of premolar-extraction: A long-term comparison of outcomes in "clear-cut" extraction and non-extraction Class II patients. Angle Orthod. 1993;63:257-272.

McCauley D. The cuspid and its function in retention. Am J Orthod. 1944;30:196-205.

McReynolds D, Little R. Mandibular second premolar extraction-postretention evaluation of stability and relapse. Angle Orthod. 1991;61:133-44.

Moussa R, O'Reilly M, Close J. Long-term stability of rapid palatal expander treatment and edgewise mechanotherapy. Am J Orthod Dentofacial Orthop. 1995;108:478-488.

Nance HN. The limitations of orthodontic treatment. Am J Orthod. 1947;33(4):177-223.

Paquette D, Beattie J, Johnston L. A long-term comparison of nonextraction and premolar extraction edgewise therapy in "borderline" Class II patients. Am J Orthod Dentofacial Orthop. 1992;102:1-14.

Reitan K. Tissue rearrangement during retention of orthodontically rotated teeth. Angle Orthod. 1959;29:105-113.

Richardson ME. Lower arch crowding in the third decade. Eur J Orthod. 1998;20:597-607.

Riedel R, Little R, Bui T. Mandibular incisor extraction-postretention evaluation of stability and relapse. Angle Orthod. 1998;62:103-68.

Rogers AP. Making facial muscles our allies in treatment and retention. Dent Cosmos. 1922;64(7):711-30.

Sadowsky C, Schneider B, Begole E, Tahir E. Long-term stability after orthodontic treatment: Nonextraction prolonged retention. Am J Orthod Dentofacial Orthop. 1994;106:243-249.

Sharp W, Reed B, Subtelny D, Polson A. Orthodontic relapse, apical root resorption, and crestal alveolar bone levels. Am J Orthod Dentofacial Orthop. 1984;91:252-258.

Sinclair P, Little R. Maturation of untreated normal occlusions. Am J Orthod. 1983;83:114-123.

Strang RHW. Factors of influence in producing a stable result in the treatment of malocclusion. Am J Orthod. 1946;32(6):313-328.

Strang RHW. The fallacy of denture expansion as a treatment procedure. Angle Orthod. 1949;19:12-22.

Tanner T, Haydar B, Kavuklu I, Korkmaz A. Short-term effects of fiberotomy on relapse of anterior crowding. Am J Orthod Dentofacial Orthop. 2000;118:617-623.

Tweed CH. Indications for the extraction of teeth in orthodontic procedure. Am J Orthod. 1944;30(8):405-428.

Vego L. A longitudinal study of mandibular arch perimeter. Angle Orthod. 1961;32:187-192.

Walter DC. Changes in the form and dimensions of dental arches resulting from orthodontic treatment. Angle Orthod. 1953;23:3-18.

Walter DC. Comparative changes in mandibular canine and first molar widths. Angle Orthod. 1962;32:232-241.

Webster RL. Retention. Am J Orthod. 1948;34(11):897-937.

Weinberger BW. Orthodontics: A Historical Review of its Origin and Evolution. Vol I and II. St.Louis: The CV Mosby Company, 1926.