COMPARISON OF THE EFFECTS OF A HAWLEY AND PERFECTOR/SPRING ALIGNER RETAINERS ON POST-ORTHODONTIC OCCLUSION

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An Abstract Presented to the Faculty of the Graduate School of Saint Louis University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Dentistry

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Abstract

The purpose of this study was to evaluate the short-term changes in posterior occlusion produced by the Perfector®/Spring Aligner and Hawley retainers. This prospective clinical study randomly assigned 50 patients who had completed full orthodontic treatment into a Hawley retainer group or a Perfector/Spring Aligner retainer group. Objective and subjective measures were collected on the day the retainers were delivered (T1) and approximately two months later (T2). Blu Mousse® (Parkell Bio-Materials, Farmingdale, NY) was used to quantify posterior areas of contact (<50 μm) and near contact (50-350 μm). The patient’s perception of occlusion was assessed using a seven-item questionnaire. Areas of contact and near contact (ACNC) in the Hawley group were 6.71 mm² at T1 and 10.97 mm² at T2. ACNC in the Perfector/Spring Aligner group were 8.44 mm² at T1 and 12.95 mm² at T2. ACNC increased significantly (p<.05) in the Hawley group (4.50 mm²) and in the Perfector/Spring Aligner group (3.26 mm²). Spearman correlations showed that T1 ACNC were positively related with T2 ACNC and negatively related with T2-T1 ACNC changes. According to the qualitative analysis, the

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patients wearing Perfector/Spring Aligner retainers felt they had significantly greater improvements in how well their back teeth fit together, how well they could chew tough meats, and how much pain the felt when they bit down. In conclusion, this study demonstrated that ACNC increased substantially and similarly in patients wearing Hawley and Perfector/Spring Aligner retainers. Qualitatively, changes over time were perceived to a greater extent by patients wearing Perfector/Spring Aligner retainers than Hawley retainers.
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2007
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Dedication

I dedicate this project to my husband Ryan and our daughter Annika.
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Establishing ideal occlusion is perhaps a primary goal of orthodontic therapy. Once the teeth are brought into proper occlusion through fixed or removable appliances, the patient enters the retention phase. Although the “active” component of treatment has been discontinued, the next stage is not entirely passive, and subtle changes in post-orthodontic occlusion should be anticipated. Some of these changes are desirable and others are not. For this reason, the orthodontist typically prescribes a retainer and continues observation until the teeth have settled into their final position. Both the “Hawley” retainer and the Perfector® (a modification of the Tooth Positioner) are commonly used in orthodontics during the retention phase. However, the effects of these devices on posterior occlusion has not been objectively evaluated. Furthermore, it is presently unknown if one method of retention is more effective than the other. The goal of this study is to objectively quantify the posterior occlusal changes that occur during two months of retention and to determine if there are quantitative or qualitative differences in
posterior occlusion between the Hawley and Perfector/Spring Aligner retainers.
Chapter 2: Review of the Literature

Review of Topics

This review is divided into four sections. First, concepts of “ideal occlusion” will be defined, with distinctions made between anterior and posterior occlusion. Historically, anterior occlusion has received greater attention in the literature than posterior occlusion, probably due to the esthetic importance of the anterior teeth. However, posterior occlusion is the focus of this study because it is less well understood and relates more closely to function and stability. Second, the various methods to measure occlusion will be reviewed. The purpose of this section is to discuss the reliability and drawbacks of the various methods in order to introduce the importance of an objective and quantifiable approach for measuring posterior occlusion. Third, retention will be described historically, as well as from a current perspective. This section will conclude with detailed descriptions of the retainers used in this study, including their functional components and theoretical modes of action. Finally, retention studies evaluating post-orthodontic posterior occlusion will be reviewed and compared. The purpose of
this last section is to describe in detail what is known and unknown about post-orthodontic occlusion in order to establish the significance of this study.

**Ideal Occlusion**

**Introduction**

The importance of obtaining ideal occlusion has been a recurrent theme in the orthodontic literature. In 1900, Edward H. Angle published a textbook titled *Treatment of Malocclusion of the Teeth and Fractures of the Maxillae*, edition 6. This classic text guided dentists in their diagnosis and treatment of malocclusion in the twentieth century. Angle developed a classification system that is still used today to describe the antero-posterior relationship of the upper and lower molars.\(^1\) Charles Tweed, another pioneer of orthodontics, published the 1944 article titled “Indications for the extraction of teeth in orthodontic procedures”. In this article, Tweed suggested that obtaining good occlusal contacts would affect the stability of orthodontic treatment.\(^2\) Larry Andrews further defined ideal occlusion in 1972. He developed the six keys to normal occlusion, which contributed to the development of the modern day straight-wire appliance. In this
landmark article, Andrews described a more specific method of evaluating the specific relationships of the teeth and dental arches. Present-day, orthodontists continue to value the concepts of ideal occlusion. A contemporary orthodontic textbook recently stated that the “operational goal” of orthodontics is to obtain optimal occlusion. Consequently, future research will continue to focus on developing methods of identifying and describing ideal occlusion.

Definitions

Ideal occlusion has been a focus of dentistry since the early twentieth century. In 1900, Angle defined occlusion using the antero-posterior relationship of the upper and lower first molars. He described normal occlusion as a “Class I” relationship when the mesiobuccal cusp of the upper first molar occluded with the buccal groove of the lower first molar. A “Class I malocclusion” exists if these molars have a normal relationship, but the teeth do not have a smooth line of occlusion. A “Class II” relationship was described as the lower first molar in a position that is distal relative to the upper first molar, and a “Class III” was defined as a lower first molar in a position that is mesial to the upper first molar.
Anterior occlusion occurs when incisal edges of mandibular teeth contact the lingual surfaces of maxillary incisors. The contacts on the anterior teeth are much lighter than on posterior teeth, and sometimes there is an absence of contact altogether. In fact, Roth, McHorris and Beyron have described ideal occlusion as lack of anterior occlusal contact, determined by maxillary and mandibular incisor clearance of 0.5 mm in centric occlusion. Okeson described posterior occlusion as the relationships between cusp tips and central fossae and also between cusp tips and marginal ridges.

Reports pertaining to the total number of ideal occlusal contacts vary because it depends on the amount of anterior contact (if any) as well as whether one or two marginal ridges are contacted by the opposing posterior cusp tip(s). For example, Okeson described a potential for having between 34 and 48 contacts in ideal occlusion, allowing each cusp tip to contact either one or two marginal ridges, while Ricketts reported 48 contacts in an ideal occlusion.

Maximum intercuspatation is commonly used in dentistry to describe posterior occlusion, and it has been shown to be a repeatable position. The term functional occlusion is used to describe occlusal contacts of maxillary and mandibular
teeth during function, such as speech, mastication, and swallowing.\textsuperscript{11}

**Importance of Ideal Occlusion: Function**

Obtaining ideal posterior occlusion is significant because it affects human function, including masticatory performance and bite forces. Angle classification, number and size of occlusal contacts, and platform area (PA) of posterior teeth have been shown to affect masticatory efficiency.\textsuperscript{12-19} Bakke et al.\textsuperscript{20} found a strong correlation between adult bite force and occlusal contact, which they interpreted as positive occlusal stability. In children, Ingervall and Minder\textsuperscript{21} reported a positive correlation between bite force and the number of teeth in contact, as well as the number of interocclusal contacts. Moreover, this correlation was stronger in girls than in boys and was the strongest for the number of maxillary posterior teeth in contact. A study by Julien et al.\textsuperscript{22} reported that contact area, posterior ramus height, and bite force affected masticatory performance in adults, and that individuals with greater contact areas had better masticatory performance.

Owens et al.\textsuperscript{23} demonstrated that subjects with larger areas of contact and near contact (ACNC) were better able
to break down foods and that patients with malocclusions had smaller ACNC than those with normal occlusions. They also showed that Class I subjects had greater areas of contact than Class II subjects or Class III subjects. This was the first published study to demonstrate the significance of near contact to median particle size. Subjects with larger near contact areas demonstrated better chewing efficiency when compared to subjects with smaller contact areas. Areas of contact and near contact were quantitatively calculated through scanned impression materials and optical determination of light transmission. Actual contact was defined as a material contact thickness at or below 50\(\mu\text{m}\), and near contact was defined as a material contact thickness between 50\(\mu\text{m}\) and 350\(\mu\text{m}\). Recently, Toro et al.\textsuperscript{24} and English et al.\textsuperscript{25} also showed that individuals with malocclusion are not able to break down foods as well as individuals with normal occlusion. These studies demonstrate the functional importance of obtaining ideal occlusion and emphasize the significance of areas of contact and near contact in mastication.
Importance of Ideal Occlusion: Stability

Obtaining occlusal stability is one of the goals of orthodontics. There are many theories regarding the attainment of stability, and investigators have examined the stability of different treatment modalities, including untreated subjects, extraction therapy, non-extraction therapy and rapid palatal expansion-lip-bumper therapy. These studies demonstrate the importance of testing the stability of different occlusal factors and orthodontic techniques.²⁶⁻²⁹

A Class I molar relationship is traditionally assumed to be the desired outcome of orthodontic treatment. Using dental casts, Harris and Behrents²⁹ studied the longitudinal stability of molar relationships in 61 orthodontically untreated subjects. The subjects were followed between the ages of approximately 20 years to 55 years. Results demonstrated that the Class I molar relationships were stable, whereas the Class II and Class III relationships were not.

Long-term stability has been demonstrated in a variety of orthodontic treatment approaches that produced good post-treatment occlusal relationships. For example, Elms et al.²⁷ demonstrated the long-term stability of Class II Division 1 nonextraction therapy. Boley et al.²⁶ examined
the long-term stability of Class I premolar extraction treatment and found satisfactory long-term results. More recently, rapid palatal expansion-lip bumper therapy followed by full appliance therapy has been shown to have good long-term stability.\textsuperscript{28} These studies reflect the broad spectrum of factors that could affect orthodontic stability. Many studies focus on the diagnosis and treatment factors that may affect stability, whereas other aspects, such as the stability of occlusal contact, have not been explored. While it has long been believed by orthodontists that ideal occlusion enhances long-term stability, there has been remarkably little research conducted to provide insights pertaining to this potentially important relationship.

Methods to Measure Posterior Occlusion

Introduction

Anterior occlusion and posterior occlusion serve different purposes. The purpose of anterior teeth is to guide the mandible through lateral movements and to provide anterior guidance, while the main function of the posterior teeth is to maintain the vertical dimension of occlusion and to aid in masticatory performance.\textsuperscript{5} The maxillary
anterior teeth are aligned labially and contact the mandibular anterior teeth in a way that does not allow for heavy contact, while the posterior teeth are aligned vertically to withstand heavy forces. Consequently, the contacts in anterior teeth are lighter when compared to posterior teeth, and may be absent altogether. The focus of this study is on measuring posterior occlusion because it relates more closely to masticatory function and performance.

Investigators have used different methods to measure and record posterior occlusion in maximum intercuspation. Assessing the molar relationship is a common method of evaluating posterior occlusion, but it is limited to the sagittal plane. Using Angle’s molar classification is a way of determining the relationship between the upper and lower first molars, but it does not quantify the amount of occlusal contact in the vertical plane.

Common methods of evaluating tooth contact include articulating indicators (paper, film or silk), photo-occlusion, the T-scan method and polyether or silicone bite registrations. However, the reliability, accuracy, consistency and/or reproducibility of some of these methods have been questioned. These methods will be described along with the problems associated with them. This section
will end with a discussion of a more recent and reliable method of measuring posterior occlusion using optical scans of silicon-based impression materials.

Articulating Indicators

Articulating indicators, commonly used in dentistry to mark occlusion, are made of special materials that transfer color from the indicator to the occlusal contact area. Such indicators can be made of different materials, such as paper, nylon, or silk. They are also manufactured in different thicknesses and can be thin and smooth or thick and course. When using articulating indicators, the operator instructs the patient to bite on to the articulating material, which transfers color to the area(s) of occlusal contact. The operator can then view and count the number and location of contacts by observing the marks on the teeth. Importantly, this method does not mark areas of near contact. Carossa et al. evaluated the influence of recording strip thickness and operator-dependent factors when measuring posterior contact areas. Thirteen dental students and 13 “expert” dental professionals recorded the contact area, force and time of biting using articulating strips 8μm and 40 μm thick. Both operator groups obtained greater contact areas with the thicker strips, and dental
students applied stronger and shorter bitings than experts with the thinner articulating strips. Moreover, the biting time influenced the amount of occlusal markings when the thinner strips were used. This study demonstrated that the occlusal measurements were affected by paper thickness, operator experience, biting force, and time. Millstein and Maya\(^3\) came to similar conclusions. They tested material, color and thickness of different articulating indicators (including film, silk, nylon and paper) using articulator-mounted casts and a video camera to record the images. The authors found that the thickness, color and material of the indicator all had significant effects on the size of the markings. In total, 10 indicators of occlusion were compared, and the authors demonstrated that the markings were not repeatable. These studies indicate that articulating indicators may not be reliable for measuring posterior contact.

Photo-occlusion

In 1985, Gazit and Lieberman introduced the photo-occlusion technique as a new method of measuring occlusal contacts. This method of recording occlusion involves subjects biting onto an occlusal wafer with sustained pressure for 10 seconds. The wafer is then projected onto
a polariscope and analyzed quantitatively and qualitatively. A polariscope is an instrument used for measuring or exhibiting the polarization of light or for examining substances in polarized light. For example, it is often used to determine stress and strain in substances such as glass (www.infoplease.com/dictionary/polariscope). Quantitative measurements are obtained by tracing the contacts viewed on the polariscope, and the qualitative analysis is based on the colored stress patterns that are produced, which reflect the degree of penetration into the wafer. The authors described light contact as up to 40% penetration into the wafer, medium between 40% and 60% penetration, and heavy as over 60% penetration into the occlusal wafer.\footnote{32}

However, the photo-occlusion technique was later demonstrated to be unreliable as a method of measuring occlusion. In 1986, Gazit and Lieberman investigated the reproducibility of the photo-occlusion technique and also compared it to the articulating indicator technique. Consecutive occlusal records were taken on 11 male dental students with Class I occlusion using both the photo-occlusion technique and the articulating indicator technique. Consecutive occlusal records were taken with both methods again one month later. Results indicated that
neither technique was highly reproducible, and that the articulating indicator technique was less reliable than the photo-occlusion technique.

T-Scan

In 1987, Maness et al. introduced the T-Scan, a computerized method of registering the time, number, distribution and relative force of tooth contacts. The T-Scan system was designed with a piezoelectric foil sensor, a sensor handle and hardware and software to analyze the data. The foil sensor is 60 μm thick and consists of conductive ink on a polyester film substrate. The film is held in a plastic intra-oral carrier. Using the T-scan system software, information on the bite force can be measured in two ways: as a force movie or as a force snap shot. The force movie is a 3-second continuous recording of force consisting of 180 frames and the force snap shot is an instantaneous measurement. Subsequently, the force record obtained with the T-Scan can be kept as a record of occlusal contact.

Hsu et al. evaluated the sensitivity and reliability of the T-Scan. Forty-seven randomly selected patients were analyzed to determine the sensitivity threshold of the T-Scan sensor. To test the reliability of the sensor’s
occlusal markings, the occlusal contacts were measured under reproducible forces in an articulator. This study determined that the T-Scan did not have the same sensitivity throughout the surface and always recorded fewer occlusal contacts than were actually present. The authors concluded that the T-Scan system was biased and not reproducible for recording occlusal contacts.

Polyether Impression Material

Impression materials have also been used to register posterior occlusion. Durbin and Sadowsky\textsuperscript{12} measured posterior occlusion by injecting polyether rubber impression material onto the occlusal surfaces of patients while instructing them to “bite firmly on your back teeth and hold the position” for two minutes. The perforations in the material were transferred to study models with a pencil and counted to determine the numbers of contacts. This method does not measure areas of contact or near contact.

Razdolsky et al.\textsuperscript{36} also used a polyether rubber impression material to measure posterior occlusion. They injected the impression material onto the mandibular occlusal surfaces and instructed patients to “bite firmly on your back teeth and hold the position”. A radiographic viewing screen in a
dark room was used to count actual contacts, defined as perforations in the material. The registrations were transferred to study models with a red marker. Near contacts were subjectively identified and counted as a “change in color” from yellow to transparent white and were transferred to the study models with a black marker.

Silicone-based Impression Material

Haydar et al.\textsuperscript{37} used a soft silicone based impression material to register occlusal contacts. The impression material was injected onto the lower occlusal surface and the patients were instructed to bite firmly onto their back teeth for 30 seconds. The registration materials were held up to daylight and perforations that let light through were counted as contacts, and the “very thin transparent” sections without perforations were subjectively identified and counted as near contacts. The contacts were transferred to the upper cast and the midpoint of the near contacts were marked onto the cast. Pictures of the models were taken in an occlusal view and the photographs were standardized. The contacts were traced on acetate paper and actual and near contacts were combined.

Sauget et al.\textsuperscript{38} used a polysiloxane impression material to record occlusal contacts. The material was injected over
the occlusal surfaces of the mandibular teeth and the patients were instructed to bite firmly in maximum intercuspsation. Actual contacts were counted as perforations in the material and near contacts were counted if their material was 0.20 mm or less thick, as measured with an Iwanson caliper.

Dincer et al. also used a silicon putty impression material to count the number of contacts and near contacts. The perforations in the material were counted as actual contacts and the translucent areas were subjectively identified and counted as near (light) contacts. Contacts and near contacts were then transferred to study models with different colors.

Optical Scanning

Recently, a more objective and quantifiable method of measuring posterior occlusion was developed and utilized in several studies. Julien et al., Parkinson et al. and Owens et al. reported a method of evaluating posterior occlusion in which optical scans of silicone occlusal registrations were used to evaluate posterior occlusion. Blu Mousse, a silicone-based occlusal registration material, was applied to the mandibular first molars and premolars and the subjects were instructed to bite down
firmly into maximum intercuspation until the material was set.\textsuperscript{23} The registrations were placed in a standard position and scanned with the mandibular occlusal surface facing downward. A software program, Image Tool, (University of Texas Health Science Center, San Antonio) was used to trace the platform area of the mandibular first molar and premolars of the magnified image (3X). The software program calculated the platform area of the teeth and determined the frequency distributions of pixels delimited by the platform area in gray scales. Calibration wedges of Blu Mousse impression material were used to develop a calibration curve, which related the known thicknesses of Blu Mousse to the gray scales. This curve allowed the investigators to determine the thickness of sample registrations based on gray scale values of the area scanned. Therefore, the areas of contact and near contact (ACNC) were quantified optically on the basis of light transmitting through the registration material. ACNC were measured up to 0 and 350\textmu m in thickness.\textsuperscript{22, 23} According to Sakaguchi et al.,\textsuperscript{41} pixel densities of scanned silicone-based impression materials are only detectible in increments of 50\textmu m.
Conclusion

Historically, various methods have been used to measure posterior occlusion. Articulating paper or film, silk, the photo-occlusion technique, and the T-Scan have all been utilized to determine areas of contact and areas of near contact. However, many of these methods have been shown to be unreliable and inaccurate. Silicone impression materials have been demonstrated to register occlusal contacts more accurately, and several investigators have used this material to register posterior occlusion. However, only recently has a quantifiable method of measuring near contacts been made available. Optical scans of silicone-based impression materials provides a more objective method of measuring posterior occlusion because the total area of contact and near contact can be traced and measured quantitatively in 50 μm increments.

Quality of Life Measurements and Occlusion

In addition to objective measurements of posterior occlusion, it is also important to obtain subjective measures of how patients perceive their occlusion. Quality-of-life measurements are becoming increasingly important in orthodontics with the emergence of evidence-
based dentistry. In 2005, the American Association of Orthodontics issued an official definition of “Evidence-based dentistry” defined as the following:

“Evidence-based dentistry (EBD) is an approach to oral health care that requires the judicious integration of systemic assessments of clinically relevant scientific evidence, relating to the patient’s oral and medical condition and history, with the dentist’s clinical expertise and the patient’s treatment needs and preferences.” ⁴³

Questionnaires are typically used to measure patients’ needs and preferences. For example, the aesthetic component of the Index of Orthodontic Treatment Need (IOTN) and the Child Perceptions Questionnaire 11-14 (CPQ11-14) are commonly used to assess orthodontic treatment needs and concern. The IOTN was introduced in 1989 as a method of measuring treatment need in people or populations and to aid in treatment planning of those who needed orthodontic treatment the most.⁴⁴ The aesthetic component of the IOTN is often used to determine the aesthetic treatment need of dental and/or orthodontic patients.⁴⁵ The CPQ 11-14 is an oral-health quality of life questionnaire for children between the ages of 11 to 14 and is used to measure the impact of malocclusion on a child’s quality of life.⁴⁶⁻⁴⁸

The validation and use of patient questionnaires such as the CPQ 11-14 and the aesthetic component of the IOTN
demonstrate that relationships exist between dental traits and quality of life. Although the CPQ 11-14 and aesthetic component of the IOTN are useful questionnaires in the initial assessment of patient’s orthodontic treatment needs and concerns, they do not specifically address the patient’s perception of posterior occlusion or function. To date, there have been no reports published on patient perception of post-orthodontic occlusion. Recent regulations proposed by the American Association of Orthodontics in 2005 indicate a strong need for studies assessing clinical data with patient’s needs and preferences. Developing a questionnaire assessing a patient’s perception of occlusion would address this concern. A clinical study involving post-orthodontic posterior occlusion and quality of life measurements could therefore be deemed highly relevant.

Retention

Introduction

The purpose of retention is to prevent relapse and to make minor corrections. Retainers are traditionally placed following removal of orthodontic appliances. Calvin Case wrote that “permanency in the correction and
Retention of our regulated cases is the most importance factor in orthodontia” C.A. Hawley considered retention principles so important that he developed a removable retainer. Over the years, many different types of retainers, including removable, fixed, passive and active have been developed. The goal of this section is to discuss the significance of retention and describe the different methods of retention available.

Significance of Retention

Retention is important because gingival and periodontal fibers need time for reorganization following orthodontic movement. Because teeth that have been moved in or through bone have a tendency to move back to their original position, they should be retained in order to ensure stability after orthodontic treatment. Reitan orthodontically rotated teeth in dogs and histologically demonstrated the persistence of the connective tissue fibers in the supracrestal periodontal tissues after a retention period of 232 days. In 1969, Rietan showed post-treatment relapse was affected by tissue changes in the periodontium and tooth position following treatment.

Retention is also important because changes in growth may change the final orthodontic result. It has been
demonstrated that slow growth occurs throughout adulthood, and the growth pattern that contributed to the original malocclusion may continue following orthodontic treatment. Moreover, continued Class II, Class III, deep bite or open bite growth patterns could affect relapse after orthodontic treatment. In an evaluation of cephalometric changes in the craniofacial complex from adolescence to midadulthood, West and McNamara determined that significant growth changes occurred in mandibular and midfacial lengths and also in posterior and lower anterior facial heights. Additional conclusions regarding the growth and stability of orthodontically treated and untreated subjects were described by Driscoll-Gilliland and colleagues. First, significant growth in posterior and anterior lower facial height can be expected beyond the age of adolescence. Second, lower incisor irregularity increases from late adolescence through early-to-middle adulthood in both treated and untreated subjects. Third, an untreated subject’s tooth size arch length discrepancy increases more when compared to that of a treated subject. Finally, larger increases in space irregularity can be attributed to a greater growth in the vertical dimension and lower incisor eruption. These studies describe the importance of
considering the effect of future growth on orthodontic stability.

Finally, retainers can be used to produce limited amounts of active tooth movement. The labial bow on a Hawley retainer can be activated to achieve small amounts of anterior tooth movement. Also, springs can be embedded in the acrylic of a retainer to allow for minor tooth corrections if needed. According to Proffit, minor incisor irregularities and occlusal discrepancies can be corrected with retainers.

**Current Retention Protocols**

In modern orthodontics, there are two general classifications of retention: active and passive. Removable appliances that qualify as passive retainers include Hawley retainers, wraparound retainers and positioners used as retainers. Fixed retainers are also passive. They are bonded to the teeth and include bonded lingual retainers and fixed retainers to maintain pontic or implant space. A separate class of retainers include active retainers which are used to realign irregular incisors or correct occlusal discrepancies.
Hawley Retainer

The original Hawley maxillary and mandibular retainers were constructed with a labial bow adjustment loop at the canines and a lingual palatal plate which was adapted to the lingual surfaces of the teeth. For intraoral retention of the appliance, ball clasps or Adams clasps are often included on the maxillary retainer and occlusal rests are constructed on the mandibular retainer. Maxillary and mandibular Hawley retainers do not cover the occlusal or incisal portion of the teeth, thereby allowing for interocclusal contact. Generally, patients are instructed to wear removable Hawley retainers full time for the first few months after removal of their fixed appliances, followed by night-time wear only.

Wraparound Retainer

The wrap-around retainer is another method of removable retention. The features of a wrap-around retainer include a plastic bar along the labial and lingual surfaces of the maxillary and mandibular teeth. Another common design of the maxillary wrap-around retainer includes palatal acrylic with a circumferential labial bow. The occlusal surfaces of the teeth are not covered by the wrap-around retainer,
allowing interocclusal contact between the maxillary and mandibular teeth.

Clear overlay retainer

The clear overlay retainer was introduced in 1971 by Ponitz as an “invisible” removable retainer. Impressions are taken of the patients’ upper and lower arches and poured with stone to construct models. A plastic sheet is heated and placed immediately over the model. Pressure from a vacuum unit adapts the plastic closely to the model.\(^{61}\) In 1993, the Essix\(^{\text{®}}\) retainer was introduced by Sheridan et al.\(^{62}\) The Essix retainer is fabricated from a plastic, copolyester Essix sheet material and trimmed to fit over the teeth. Essix retainers are generally constructed from 0.75mm (0.030”) materials which are thermoformed to 0.15 inches in thickness.\(^{63}\) The clear overlay retainers and Essix retainers cover the occlusal and incisal surfaces of the maxillary and mandibular teeth and do not allow for interocclusal contact. Patients are instructed to wear the Essix retainer full time for a short period and then only at night.\(^{59}\)

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\(^{61}\) Raintree Essix, Inc.
Bonded Retainers

Fixed retention is indicated in cases where instability is anticipated and long-term retention is necessary. The first fixed bonded “invisible” retainer was reported by Knierim in 1973. Fixed retainers are constructed from wires adapted to the lingual of the teeth and bonded into place. A 0.030 mm round steel wire is commonly used to retain the lower teeth from canine to canine; it is only attached to the lingual of the canines and allowed to rest passively against the incisors. This type of retention is commonly known as the “3x3 retainer”. For fixed retention of a maxillary diastema, a more flexible wire (0.0175 braided steel) is commonly bonded to the lingual surfaces to allow the teeth to move independently. 

Positioners

Another appliance commonly used during the post-orthodontic retention phase is the tooth positioner. Kesling developed the tooth positioner to reposition the teeth using functional forces. According to Kesling, the teeth will settle into idealized occlusion if the appliance is worn by the patient with the appropriate clenching exercises. However, this notion has not been systematically tested. According to the manufacturer,
construction of the tooth positioner requires a specific protocol. Appliances are removed and impressions are taken immediately. The impressions are poured into two sets of models, one to serve as a control, and the other to be reset through tooth dissection and rearrangement into wax. According to Kesling,\textsuperscript{66} the teeth are to be reset to the desired arch form, axial positioning, and occlusion. The reset model is then used to construct the tooth positioner. The models are articulated onto an articulator with a fixed hinged position, and the bite is opened to simulate the physiologic rest position. The original positioner was constructed as a one-piece rubber appliance that covers the labial, buccal and lingual surfaces of the maxillary and mandibular teeth. According to Kesling,\textsuperscript{66} the rubber material allows it to stretch over the teeth and the “resiliency” of the material allows the teeth to move toward their predetermined position. Since the introduction of the tooth positioner in 1945, various elastomers have been used to construct tooth positioners, including rubber, urethane, thermoplastic vinyl and polyvinyl siloxane.\textsuperscript{67} These materials were utilized to improve elasticity and patient comfort.
The Perfector® is the most recent version of the TP Orthodontics tooth positioner. Like the original tooth positioner, it is fabricated using patient’s models that have had the teeth removed and reset into new positions to create an “ideal” wax set-up. However, the Perfector is constructed of a silicone material with labial acrylic, a wire bow and seating springs for posterior retention. According to the manufacturer, the silicone material has been improved because it is more pliable and taste-free. The anterior labial acrylic and wire bow were added to provide rotation and overjet control as well as to aid in retention of the appliance. The seating springs were also added to aid in retention and to help with initial seating of the Perfector. The patient is instructed to wear the Perfector at nighttime while sleeping and also to perform clenching exercises during the day while wearing the Perfector. For the first 2 weeks, the patient is instructed to perform clenching exercises for 3 to 4 hours a day in addition to wearing the Perfector while sleeping. For the next 4 weeks, the patient is instructed to perform clenching exercises for 2 to 3 hours a day in addition to nighttime wear. For the final 2 weeks, the patient is instructed to perform 2 hours of clenching exercises a day.

* TP Orthodontics, Inc.
in addition to wearing the Perfector at night. According to TP Orthodontics, Inc., the Perfector was designed to allow for the following types of correction: settling of teeth, alignment of anterior teeth, interproximal space closure (2-3mm per arch), correction of anterior and posterior crossbites, improvement of arch coordination, rotations if needed, maintenance of anteroposterior interarch relationships, improved axial inclinations, leveling of the curve of Spee, closure of anterior openbites by preventing tongue thrusts and minor overjet correction. According to the manufacturer, most corrections are obtained during the first six weeks.  

Post-Orthodontic Occlusion and Retention

Introduction

Orthodontic treatment has a definite and profound effect on occlusion, and the occlusal changes that occur can be easily observed and recorded. It has been demonstrated that orthodontic treatment decreases the number of occlusal contacts. Conversely, post-orthodontic occlusion studies indicate that contacts increase during the retention period. Consequently, one of the goals of retention is to allow the teeth to “settle.” It has been suggested
that the type and duration of retention also affect the amount of settling that occurs.\textsuperscript{32,36,37,70} The purpose of this section is to describe post-orthodontic occlusal studies and to discuss the contact changes that occur during retention.

\textbf{Past Studies}

Post-orthodontic occlusion studies demonstrate that occlusal contacts increase following removal of fixed orthodontic appliances. Using the photo-occlusion technique, Gazit and Lieberman\textsuperscript{32} measured occlusal contacts on 12 patients who had been treated with fixed appliances. The number of anterior and posterior occlusal contacts were recorded at the end of treatment, one month later, and one year later. All patients were free of retention appliances for 3 months prior to the last (i.e., one year) recording. The authors did not report the type of retention that was used immediately after the fixed appliances were removed. They reported an average of 11.2 contacts on the day of band removal. One month later, the recordings were variable (4 patients showed a decrease in number of contacts and 8 showed an increase in number of contacts). One year later, the average number of contacts for all 12 patients had increased to 17.4. This represented a gain of
6.2 anterior and posterior contacts from the day of band removal to one year post-debond. The authors reported that 3 out of the 12 patients had anterior contacts for the duration of the study.

Dincer et al.\textsuperscript{39} reported similar results in 2003 when examining post-orthodontic occlusal contact changes. They examined the occlusal contacts of 20 orthodontically treated individuals at the beginning and the end of 9 months of retention. A control group of 20 subjects with ideal occlusion was compared to this group. The 20 treated individuals had Class I malocclusion and were all treated with standard edgewise mechanics and four premolars extractions. The treated patients were retained with upper and lower removable Hawley retainers full-time for six months and then nighttime only for the remaining three months of the study. Silicone putty was used to register the posterior occlusion, and perforations in the material were counted as contacts and transluscent areas were counted as near contacts. Both actual and near contacts were transferred to study models using different colors. Before retention, the authors reported a total number of 11.4 posterior contacts (actual and near) in the premolar, first molar and second molar region. At the end of the 9-month retention period, the authors reported a total of 19
posterior contacts (actual and near) in the premolar, first molar and second molar region. The 7.6 gain in posterior contacts was reported as a “significant increase in contacts” during the 9 month retention period.

Other post-orthodontic occlusion studies have evaluated not only the gain in occlusal contacts over time but also whether the type of retention affects the occlusal contacts. Durbin and Sadowsky\textsuperscript{70} studied posttreatment occlusal changes of 38 patients, evaluated at the end of orthodontic treatment and again 3 months later. In this study, 23 patients were retained with conventional retainers (upper and lower Hawley retainers) and 15 patients were retained with gnathological rubber tooth positioners. Importantly, the subjects were not randomly assigned to their respective groups. Instructor preference and patient acceptance determined the type of retainer used for this study, suggesting different post-treatment occlusal characteristics of the two groups. Areas of anterior and posterior contact were counted (near contact areas were not measured) using a polyether rubber impression material. The authors reported that the mean total number of contacts increased from 10.11 (end of orthodontic treatment) to 11.53 (3 months later). The number of contacts on the posterior teeth increased from
Overall, during the 3 month posttreatment period, the total contacts increased 14.1% and the total posterior contacts increased 16.3%. The number of contacts on anterior teeth and the number of anterior teeth in contact decreased over the 3 month retention period in 37% of the cases.

When comparing the positioner group to the Hawley retainer group, Durbin and Sadowsky\textsuperscript{70} reported an increase in posterior contacts from 7.77 to 8.87 (Positioner group), and from 9.30 to 10.93 (Hawley retainer group), resulting in a gain of 1.10 posterior contacts for the positioner group and 1.63 posterior contacts for the Hawley retainer group. The total number of posterior teeth in contact before and after 3 months of retention increased from 9.73 to 10.66 (Positioner group) and from 10.65 to 11.39 (Hawley retainer group). The difference in number of posterior teeth in contact before and after retention was 0.93 for the Positioner group and 0.74 for the Hawley group. Based on these results, the authors concluded that the tooth positioner was statistically more effective than the Hawley retainer (p<.05). However, they also reported the additional gain in the positioner group as minimal.

Razdolsky et al.\textsuperscript{36} conducted a follow-up study to the Durbin and Sadowsky study.\textsuperscript{70} Twenty-eight of the 38 patients
from the original study and an additional 12 patients were evaluated 11 to 21 months following removal of their orthodontic appliances. During this study, 28 patients were retained with a maxillary Hawley and fixed lingual retainer, 3 patients had a tooth positioner followed by a maxillary Hawley retainer, and 8 patients had maxillary and mandibular Hawley retainers. One patient was retained with only a maxillary retainer. The removable retainers were worn full time for the first 6 to 12 months following removal of orthodontic appliances and then only at night for the duration of the study. The number of actual and near contacts on second molars, first molars, premolars, canines and incisors were counted on the day of appliance removal and 11-21 months later. A polyether rubber impression material was again used to register the anterior and posterior occlusion. The actual contacts were counted as perforation in material and the near contacts were counted as a change in the registration material from yellow to transparent white. The total number of contacts (actual and near) increased from 36.6 on the day of appliance removal to 58.2 at the follow-up visit (11-21 months later). The increase in the total number of contacts was 21.6. The authors explained the gain as an increase in the number of actual and near contacts on the posterior
teeth. This study did not compare the Hawley and tooth positioner.

Haydar and coworkers\textsuperscript{37} also compared the tooth positioner to the Hawley retainer, but found no group differences based on post-orthodontic occlusion. In this study, 20 patients were divided into two groups, a Hawley retainer group and a positioner group. The authors did not state whether the subjects were randomly assigned into the Hawley or Positioner group. A non-treated control group of 10 subjects with normal occlusion were also examined. Using a soft silicone-based impression material, anterior and posterior contacts were measured by having the patients bite down into the material, counting the number of contacts when holding the registration material toward daylight, and transferring the perforations to upper casts. The contacts were measured the day the braces were removed (T1) and again 3 months later (T2). The total number of contacts at T1 were 21.2 (Hawley group), 24.8 (Positioner group) and 39.4 (Control group). At T2, the mean number of contacts were 22.4 (Hawley group), 27.0 (Positioner group) and 40.5 (Control group). This resulted in a gain of 2.2 contacts in the positioner group and 1.2 contacts in the Hawley group. Statistically, the authors reported no
difference in the number of contacts between the Hawley group and the tooth positioner group.

The post-orthodontic occlusal changes of the Hawley retainer has also been compared to a clear overlay retainer. Sauget et al.\textsuperscript{38} examined 30 patients at debonding (T1), 1 week later at retainer delivery (T2), and after 3 months of retention (T3). At the time of debonding, the subjects were randomly assigned into the Hawley or Clear overlay retainer group. Vinyl polysiloxane impression material was used to record occlusal contacts. True contacts were counted as perforations in the material, and near contacts were counted if they were 0.20mm or less when measured with an Iwanson caliper. Anterior and posterior registrations were evaluated. At T1, the authors reported 34.3 total contacts (actual and near, anterior and posterior) for the Hawley group and 31.8 for the clear overlay retainer group. At T2 (the time of retainer deliver, one week following debond), there were no significant differences between the two retainer groups. At T3 (after 3 months of retention), the authors reported a mean number of 45.7 total contacts in the Hawley group and 36.7 total contacts in the clear overlay retainer group. When comparing actual and near posterior contacts only, the authors reported a change in the Hawley group from 25.3
posterior actual and near contacts at T1 to 35.9 posterior actual and near contacts at T3. In the clear overlay retainer group, the posterior actual and near contacts at T1 were 23.7 and the posterior actual and near contacts at T3 were 27.9. The authors concluded that the differences between the Hawley and clear overlay retainer were significant and that the Hawley retainers allowed more settling of the posterior teeth while the clear overlay retainers held the teeth in their debanding position.

Conclusion

It is difficult to compare post-orthodontic occlusion studies because various methods have been used to measure contacts, and some of these methods were not as reliable as others. Also, various authors measured contacts differently. Some counted posterior and anterior contacts, while others counted only posterior contacts. Some studies measured both actual and near contacts and other studies counted only the actual contacts.

Due to the methodology discrepancies among the post-orthodontic occlusion studies, only broad conclusions can be made regarding the affect that retention has on post-orthodontic occlusion. First, the number of posterior contacts appears to increase during the retention phase.
Second, the number of contacts has been demonstrated to increase for many months following removal of orthodontic appliances (up to 21 months). Finally, the type of retention may have an effect on post-orthodontic occlusion. When compared to a clear overlay retainer, the Hawley retainer appears to allow for more settling. Comparisons between the Hawley retainer and tooth positioners vary. Only two direct comparisons between the Hawley retainer and tooth positioner have been reported, but the results of these studies could have been biased because they did not randomly assign the patients into the two test groups.

**Future Studies**

Obtaining ideal occlusion is one of the major goals of orthodontic therapy. After the fixed orthodontic appliances are removed, the primary goal is to maintain and/or improve the occlusion. To that end, the orthodontist must make the important decision as to what type of retainer to use for each patient.

Historically, anterior occlusion has played an important role in evaluating the dentition in maximum intercuspation, probably due to the esthetic nature of the front teeth.
However, posterior occlusion is the focus of this study because it affects function and possibly stability.

An important aspect of evaluating post-orthodontic occlusion is determining if there is a qualitative or quantitative difference in retainer appliances. In the past, many studies used unreliable methods of measuring posterior occlusion, such as articulating indicators, photo-occlusion, or the T-scan method. Perhaps even more importantly, previous investigators have focused on counts when measuring posterior occlusion as opposed to quantifying the total area of contact. Currently, there are no reports that compare the total area of contact obtained by different retention devices. Also, many of the post-orthodontic occlusion studies did not evaluate near contacts, and those that did again relied on counts rather than total areas of contacts. Evaluating the total area of contact and the presence of near contact(s) is important because it describes the relative amount of occlusal contact and provides more quantitative information than counting contacts alone.

Methods of retention and differences in post-orthodontic occlusion have been reported, but not all types of retainers have been tested. Two studies have compared Hawleys to tooth positioners, but they did not randomly
assign the patients. Furthermore, these two studies arrived at different conclusions. So far, there are no studies comparing the Perfector/Spring Aligner to the Hawley retainer(s). Overall, the lack of standardization of retainer post-orthodontic occlusion studies suggests a need for future research.

Fundamentally, the Hawley and Perfector/Spring Aligner are different devices, yet they are both used as retainers. Comparing the two retainers would enable us to understand more about the specific nature of post-orthodontic occlusal changes. Russell\textsuperscript{71} issued a report indicating an “urgent need” for high-quality randomized control trials in the field of retention. Knowing more about the qualitative and quantitative differences between a Hawley and Perfector/Spring Aligner retainer would allow an orthodontist to make a more objective decision when deciding what kind of retainer to choose for his or her patients.

Another aspect that has not been evaluated is patient perception of occlusion during the post-orthodontic retention period. In the past, information pertaining to patient perception has been limited to the perception of dental appearance or the perception of body image and self-concept. These reports focused on the awareness of
malocclusion and patient satisfaction with appearance. Perceptions of posterior occlusion during the retention phase have not been explored. There is a need for qualitative level studies that focus on how the patient’s quality of life might be affected by post-orthodontic occlusal changes.

The emergence of evidence-based dentistry indicates a strong need for clinically relevant scientific studies upon which the clinician can make informed decisions. The goal of this study is to determine whether and how the type of retention used after orthodontic treatment affects posterior occlusion of teeth. Specifically, optical scanning of silicone-based impression material will be used to test whether Hawley and Perfector/Spring Aligner retainers produce differences in 1) interocclusal areas of contacts and near contacts and 2) patient’s perception of occlusion.
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Chapter 3: Comparison of the Effects of a Hawley and
Perfector®/Spring Aligner Retainers on Post-orthodontic
Occlusion

Abstract

Purpose: To evaluate the short-term changes in posterior occlusion produced by the Perfector/Spring Aligner and Hawley retainers. Methods: This prospective clinical study randomly assigned 50 patients who had completed full orthodontic treatment into a Hawley retainer group or a Perfector/Spring Aligner retainer group. Objective and subjective measures were collected on the day the retainers were delivered (T1) and approximately two months later (T2). Blu Mousse® (Parkell Bio-Materials, Farmingdale, NY) was used to quantify posterior areas of contact (<50μm) and near contact (50-350μm). The patient’s perception of occlusion was assessed using a seven-item questionnaire.

Results: Areas of contact and near contact (ACNC) in the Hawley group increased significantly (p<.05) from 6.71mm² at T1 to 10.97 mm² at T2; ACNC in the Perfector/Spring Aligner group increased from 8.44 mm² at T1 to 12.95 mm² at T2. There were no significant (p<.05) differences in the

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increases of ACNC that occurred between the Hawley group (4.50 mm$^2$) and the Perfector/Spring Aligner group (3.26 mm$^2$). Spearman correlations showed that T1 ACNC were positively related with T2 ACNC and negatively related with T2-T1 ACNC changes. In comparison with the Hawley group, the patients wearing Perfector/Spring Aligner retainers reported significantly greater improvements in how well their back teeth fit together, how well they could chew tough meats, and how much pain the felt when they bit down.

**Conclusions:** Area of contact and near contact (ACNC) increased substantially and similarly in patients wearing Hawley and Perfector/Spring Aligner retainers. Changes over time were perceived to a greater extent by patients wearing Perfector/Spring Aligner than Hawley retainers.
Introduction

Establishing an ideal occlusion is one of the primary goals of orthodontic therapy. While anterior occlusion is important for esthetic reasons, posterior occlusion holds several important implications for masticatory function and retention. First, the quality of the posterior occlusion affects human function. Individuals with better fitting posterior teeth exhibit better masticatory performance\textsuperscript{1-10} and higher bite forces.\textsuperscript{11,12} Second, posterior occlusion appears to be related to the stability.\textsuperscript{13,14} For example, it has been shown that individuals with Class I normal occlusion maintain their occlusal relationship, while individuals with Class II and Class III malocclusion change occlusal relationship over time.\textsuperscript{15}

While it is well established that occlusal contacts increase during retention, the increases reported are variable and the retainer effects remain controversial. Gazit and Lieberman\textsuperscript{16} reported 11.2 contacts (anterior and posterior) on the day of orthodontic band removal and 17.4 contacts after one year of Hawley retainer wear, which is similar to increases (from 11.4 to 19) of actual and near contacts demonstrated by Dincer and colleagues\textsuperscript{17} after a nine month Hawley retention. The Tooth Positioner has been
reported to be more effective than the Hawley retainer after three months of wear, even though posterior contacts increased less with the Positioner (14%) than with the Hawley (18%).

Haydar et al. found that actual and near contacts increased less over three months in the Hawley group (6%) than in the Positioner group (9%), but the differences were not statistically significant. Hawley retainers (42%) appears to produce greater increases in ACNC than clear overlay retainers (18%). The existing comparisons may be biased; there are currently no randomized controlled trials evaluating the effects of different retainers.

In addition to their study designs, the methods commonly used to quantify posterior occlusion may be unreliable and provide only limited information. Articulating indicators that have been used only mark occlusal contacts and their reliability has been questioned. The T-scan method is limited because subjects bite onto, but not through the 0.004” thick strip used to record contacts; low reproducibility of the T-scan has also been reported.

Polyether impression materials and silicone-based impression materials have been used to count posterior occlusal contacts, which provides only incomplete information about posterior contacts. A more objective and
quantifiable method of measuring posterior areas of contact and near contact (ACNC)\textsuperscript{9,10,25} has been developed, based on optical scans of silicone occlusal registrations. ACNC are sufficiently sensitive to distinguish between different types of malocclusion\textsuperscript{25} and have been directly related with masticatory performance.\textsuperscript{10}

The Hawley retainer and the Perfector (a modification of the Tooth Positioner) are commonly used during the retention phase, but their effects on posterior occlusion have not been established. On that basis, the purpose of this clinical trial was to evaluate the posterior occlusal changes (ACNC) that occur during the first two months of retention in patients randomly assigned to wear either Hawley or Perfector/Spring Aligner retainers.
Materials and Methods

Objective Evaluation of Occlusion

Fifty subjects, 15.1 ± 1.4 years of age, were recruited between March 1, 2006 and June 8, 2006 from Saint Louis University Center for Advanced Dental Education, Department of Orthodontics. The subjects were selected based on having completed full orthodontic treatment and Class I molar and canine relationships. Subjects were excluded if they had any medical or dental history of temporomandibular dysfunction, large restorations on the posterior teeth, allergies to the materials used in the study, periodontal disease and/or muscular dysfunction. Subjects were also excluded if they did not agree to follow retainer wear instructions. The study was approved by the Biomedical Institutional Review Board at Saint Louis University.

Subjects were randomly allocated into two treatment groups. There were 22 subjects allocated to a Hawley retainer group (9 males and 13 females) and 28 subjects allocated to a Perfector/Spring Aligner retainer group (13 males and 15 females). The Perfector/Spring Aligner group was oversampled due to the greater number of expected dropouts. Sample size requirements were based on power
analyses using published estimates of variation\textsuperscript{10,25} and differences deemed to be clinical relevant.

After recruitment and allocation into their respective groups, subjects were debonded and two upper and lower alginate impressions were taken. One set was used to fabricate an upper and lower clear overlay retainer (Figure 3.1), which was immediately delivered with instructions for full-time wear until the study appliances were delivered (the laboratory required 4.2 weeks ± 1.3 weeks to fabricate the study retainers). The second set of alginate impressions was used to fabricate models, which were sent to a laboratory for retainer construction. The Hawley retainer group was prescribed upper and lower Hawley retainers (Figure 3.2); the Perfector/Spring Aligner group was prescribed a Perfector and a lower spring aligner (Figure 3.3).

Subjects wore either upper and lower Hawley retainers (Fig. 3.2) or a Perfector retainer and a lower spring aligner (Fig. 3.3). The Hawley retainer group was instructed to wear their upper and lower retainers full-time. The Perfector/Spring Aligner retainer group was instructed to wear both the Perfector and lower spring aligner at night while sleeping according to the manufacturer’s instructions. They were also instructed to
wear the Perfector and perform clenching exercises three to four hours during the first two weeks, followed by two to three hours during the next four weeks, and for two hours during the final two weeks of the study.

Data were collected at two occasions: T1 was the day the Perfector and spring aligner or Hawley retainers were delivered and T2 was 7.8 weeks ± 1.0 week later. Data was collected immediately before delivery of the study retainers. In order to assess tooth contacts, bilateral posterior occlusal registrations in maximum intercuspation were obtained using Blu Mousse® (Parkell Bio-Materials, Farmingdale, NY), a silicone bite registration material (Figure 3.4). The Blu Mousse was applied to the mandibular first molars and premolars, and the subjects were instructed to bite down firmly into maximum intercuspation and maintain the bite for approximately 30 seconds. Duplicate bilateral registrations were taken at each measurement occasion (Fig. 3.4).

The Blu Mousse occlusal registrations were processed as previously described.9,10,25 Each occlusal registration was placed in holders, maintained at a standardized position, and scanned at 300 DPI with the mandibular occlusal surfaces facing downward (Figure 3.5). After scanning, the outline of the mandibular first molar and premolars of the
scanned images were traced (Figure 3.6) using the Image Tool® (University of Texas Health Science Center, San Antonio) software program, which calculated the platform area of the teeth and the frequency distribution of pixels within the platform area based on 256 possible gray scales.

Calibration step wedges of Blu Mousse of eight known thicknesses were used to establish the relationship between each of the 256 gray scales and the thickness of the occlusal registration. The thickness of each of the eight wedges was measured two times using a Digimatic Micrometer (model MDC, Mitutuyo Corp, Tokyo, Japan). Each calibration step wedge was scanned four times and the average gray scale was calculated. To increase reliability, this process was repeated four to five times for each specimen. Based on the averaged thicknesses and their corresponding averaged gray scales, a calibration curve was established to relate the thickness of Blu Mousse and the pixel gray scales (Figure 3.7). The calibration curve was used to calculate contact thickness ranging from 0 μm (perforation in the impression material) to 350 μm (the upper limit for light penetration) at 50 μm increments.
Subjective Evaluation of Occlusion

The patient’s perception of his/her occlusion was assessed at T1 and T2 using a seven-item questionnaire. The questionnaire was initially validated based on feedback from ten patients. The questions were designed to measure three aspects of each patient’s occlusion: 1) how well their teeth fit together 2) their level of occlusal discomfort and 3) their masticatory function. A 148 mm visual analogue scale, with “very well”, “none”, or “no slide” and “very poor”, “very much”, or “large slide” as anchors, was used with the following questions:

Q1. How well do your back teeth fit together when you bite down hard?

Q2. Do your back teeth contact each other evenly when you bite down hard?

Q3. How well can you chew tough meats, such as steak or chops, with your back teeth?

Q4. How well can you chew fresh vegetables, such as carrots or celery, with your back teeth?

Q5. How much pain do you feel when you bite down hard on your back teeth?

Q6. How much discomfort do you experience when you bite down hard on your back teeth?
Q7. When you bite down hard, do you feel your back teeth slide?

Statistical Analyses

The skewness and kurtosis statistics showed significantly departures from normality for many of the distributions. As such, central tendencies and dispersion were described using medians and interquartile ranges. Changes over time were evaluated using a Wilcoxon signed-rank test. A Mann-Whitney test was used to evaluate group differences. Spearman rho correlations were used to evaluate associations between of ACNC at T1, T2, and changes between T2-T1.
Results

Posterior areas of contact and near contact (ACNC) showed significant increases (p<.17) ranging from 0.20 to 0.99 mm² (Table 3.1). The Hawley retainer showed the greatest increase (0.99 mm²) in ACNC at the 50-100 μm level; the Perfector/Spring Aligner showed the greatest increase (0.70 mm²) at the 300-350 μm level. However, there were no significant group differences at any thickness.

The cumulative ACNC increased significantly (p<.008) at all levels. Total cumulative ACNC increased from 6.71 mm² at T1 to 10.97 mm² at T2 in the Hawley group, representing a 63% increase. The total cumulative ACNC in the Perfector/Spring Aligner group increased 53%, from 8.44 mm² at T1 to 12.95 mm² at T2. The cumulative changes in ACNC were 4.50 mm² in the Hawley group and 3.26 mm² in the Perfector/Spring Aligner group. There were no significant differences in cumulative changes between the Hawley and the Perfector/Spring Aligner at any of the levels.

ACNC of individual thicknesses at T1 were positively correlated with ACNC of individual thicknesses at T2 (Table 3.2). Spearman’s correlations ranged from 0.40 to 0.56, with slightly higher associations at the thicker levels. ACNC of individual thicknesses at T1 were negatively
correlated with the T2-T1 ACNC changes. Likewise, ACNC of cumulative thicknesses at T1 were positively and negatively correlated with cumulative ACNC at T2 and T2-T1 ACNC changes, respectively (Table 3.3). At both individual and cumulative thicknesses, T1 contact areas (<50μm) were not correlated with the T2-T1 changes that occurred at the contacts (<50μm) and 50-100μm level.

At T1, the Perfector/Spring Aligner group perceived significantly more difficulty chewing tough meats (Q3; p=.029) and more pain when biting (Q5; p=.004) than the Hawley group. The patients in the Hawley group showed no significant changes over time in their perception of their occlusal changes (Q1-Q7). The Perfector/Spring Aligner group showed significant improvements for Q1 (p=.001), Q2 (p=.012) and Q3 (p=.026). In comparison to the Hawley group, the Perfector/Spring Aligner group perceived significant improvements (Table 3.4) in how well their back teeth fit together (Q1), how well they could chew tough meats (Q3) and how much pain they felt when they bit down (Q5).
**Discussion**

Areas of contact and near contact (ACNC) increased 63% in the Hawley group during the two months following placement of retainers. This compares well with the 55% gain of posterior and anterior contacts reported by Gazit and Lieberman\(^\text{16}\) over one year and the 67% gain of actual and near posterior contacts reported by Dincer et al.\(^\text{17}\) over nine months. Studies limited to three months post-orthodontic treatment have shown smaller relative increases in the numbers of contacts and near contacts, ranging from a 6% to 42%.\(^\text{18,19,21}\) These differences are probably due to the variable methods of evaluating posterior occlusion. Prior studies relied on counts to measure posterior occlusion, whereas this study measured the total area of contact and near contact, which is apparently more sensitive and discriminating.

The overall increase in ACNC in the Hawley group is likely a result of several factors. Removing the fixed appliances allows the teeth to settle without the interference of wires tying the teeth together. It is also possible that the teeth are “relapsing” into a vertical orientation that is closer to their pre-treatment position. The rigidity of the acrylic in the Hawley retainer prevents
relapse of the other dimensions, while the lack of interocclusal coverage allows the teeth to move vertically. Results of this study and previous studies demonstrate the dynamic nature of retention and the importance of monitoring the orthodontic patients following removal of their fixed appliances.

The Perfector/Spring Aligner increased ACNC by 53% over the two months between T1 and T2, from 8.44mm² to 12.95mm². When evaluating the tooth positioner over three months, Durbin and Sadowsky¹⁸ reported a 14% gain of posterior contacts and Haydar et al.¹⁹ reported a 9% gain of contacts (actual, near, anterior and posterior). The differences could be due to the differences between a tooth positioner and a Perfector. Although fabricated in a similar manner through re-setting the position of the teeth, the Perfector is constructed of a silicone material with labial acrylic, a wire bow and seating springs for posterior retention. These additions to the appliance, particularly the posterior seating springs, could have affected the settling of the posterior teeth. It is also possible that differences between the studies could again be due to the difference in the methods of evaluating contacts and near contacts. Previous investigators did not
consider the total area of contact and near contact in their evaluation of retainers.

Post-treatment increases in ACNC were similar for the Hawley and the Perfector/Spring Aligner retainers. This supports the findings of Haydar and coworkers\textsuperscript{19}, who showed smaller but similar increases for Hawley and Positioner retainers. In contrast, Durbin and Sadowsky\textsuperscript{18} concluded that the tooth positioner was statistically more effective than the Hawley retainer, based on slightly greater increases in the total number of posterior tooth contacts (9\% in the Positioner group and 7\% Hawley retainer group). Interestingly, they reported slightly greater increases in the number of posterior contacts for Hawley retainers (17.5\%) than for the Positioner (14\%). Importantly, Haydar et al.\textsuperscript{19} and Durbin and Sadowsky\textsuperscript{18} did not randomly allocate their patients to the Hawley or tooth positioner group, which raises the possibility of selection bias.

Despite differences in appliance design, the Hawley and Perfector/Spring Aligner retainers demonstrated similar amounts of settling. The Perfector was constructed from re-set models and fabricated of a silicone material with acrylic across the labial, a wire bow and seating springs for posterior retention. This group was instructed to wear the Perfector at night with a spring aligner and then alone.
for a few hours a day while performing “clenching” exercises. The Hawley retainers were constructed with acrylic and a labial bow from canine to canine with adjustment loops. The upper Hawley was designed with retention spurs mesial to the first molars, and the lower Hawley was designed with rests out of occlusion on the lingual groove of the first molars. This group was instructed to wear the retainers full-time.

A significant difference between the Perfector and Hawley retainer is that the Perfector is designed with inter-occlusal coverage which, according to the manufacturer, is designed to guide the teeth into a “better” position, whereas the traditional Hawley retainers do not have full occlusal coverage. This might explain why the Perfector/Spring Aligner group demonstrated its greatest settling at the 300-350μm level and the Hawley group demonstrated its greatest settling at the 50-100μm level. The interocclusal coverage of the Perfector may have prevented this group from settling into full contact.

Although the two retainers are very different in design, there were no differences in the amount of ACNC gained over two months between the two groups. This suggests that following removal of fixed orthodontic appliances, the teeth have a “set” amount of settling that
occurs regardless of how they are retained. This emphasizes the importance of finishing during fixed orthodontics because the orthodontist may have very little control over how much settling will occur after the braces are removed.

The results suggest that the subjects with initially smaller ACNC showed greater increases than patients with larger ACNC. It is possible that the subjects with less ACNC were finished at T1 in a vertical position that was further from their pre-treatment position, and therefore had more ACNC to gain. Conversely, subjects with more ACNC at T1 could have been closer to their original vertical position and had less distance that required closure. Interestingly, this negative relationship was not evident for thickness <50μm, suggesting that areas of contact (<50μm) are not related to changes that occur at the 50μm or 100μm thickness. This could be explained by the minimal T2-T1 change (0.44mm²) that occurred at the contact level in both the Hawley and Perfector/Spring Aligner groups. Overall, these correlations indicate that the teeth continue to settle following removal of orthodontic appliances.

While the patients wearing Perfector/Spring Aligner retainers perceived significant improvements in how well their back teeth fit together (Q1), how well they could
chew tough meats (Q3) and how much pain they felt (Q5) after two months of wearing the appliance, patients wearing the Hawley perceived no changes over time. The improvements in the Perfector/Spring Aligner group’s ability to chew tough meats (Q3) and pain when biting down (Q5) could have been due to the fact that they initially reported greater problems for these two areas. Even though the subjects were randomly assigned into each group, it is possible that the subjects in the Perfector/Spring Aligner group may have been more perceptive than the Hawley group.

The Perfector/Spring Aligner group also perceived greater improvements in how their back teeth fit together (Q1) than the Hawley group. While the Perfector/Spring Aligner group initially perceived their teeth to fit less well than the Hawley group, they indicated that their teeth fit substantially better after two months of wear. This is the first study to evaluate post-orthodontic perception of occlusion, and results suggest that patients are able to feel differences in their occlusion, specifically in how their back teeth fit together when they bite down hard.

This study evaluated the vertical aspect of posterior occlusion only; it is possible that the Perfector affected other aspects of the occlusion, which could change how the subjects perceived their bite between T1 and T2. The
Perfector is designed to allow for corrections that were not evaluated in this study, including alignment of anterior teeth, interproximal space closure, correction of anterior and posterior crossbites, improvement of arch coordination, rotations, maintenance of antero-posterior interarch relationships, improved axial inclinations, leveling of curve of spee, and minor overjet correction. In other words, the Perfector may be a better appliance for patients who have additional problems to be corrected.

One limitation of all retention studies, including the present, is patient compliance. It was difficult to assess if the subjects wore their retainers as prescribed. In order to control this factor, randomization and a large sample size was utilized. Another limitation was the number of Hawley subjects who dropped from the study. The Perfector/Spring Aligner group was oversampled at the start of the study because it was anticipated that more patients would drop from this group. However, none of the 28 Perfector/Spring Aligner subjects missed any of their appointments. In contrast, six Hawley patients were dropped from the study because they were not able to come in for the two month retention check appointment.
Conclusions

1. Areas of contact and near contact (ACNC) increased 63% and 53% in patients wearing Hawley and Perfector/Spring Aligner retainers for two months.

2. There were no significant differences between the Hawley and the Perfector/Spring Aligner groups in the ACNC gained.

3. T1 ACNC were positively and negatively correlated with T2 ACNC and T2-T1 ACNC changes, respectively.

4. Compared to the Hawley group, subjects wearing Perfector/Spring Aligner retainers reported significant (p<.05) improvements in how well their teeth fit together, how well they can chew tough meats, and in how much pain they feel when biting down hard.
Literature Cited


Table 3.1 Comparison of areas of contact and near contact (ACNC) of posterior occlusion with Hawley and Perfector/Spring Aligner retainers at T1 (post-treatment) and T2 (approximately two months later).

<table>
<thead>
<tr>
<th>Thickness (µm)</th>
<th>T1 values (mm²)</th>
<th>T2 values (mm²)</th>
<th>T2-T1 Changes (mm²)</th>
<th>T2-T1 Group Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hawley</td>
<td>Perfector/Spring Aligner</td>
<td>Hawley</td>
<td>Perfector/Spring Aligner</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>IQ* Range</td>
<td>Median</td>
<td>IQ Range</td>
</tr>
<tr>
<td>Individual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 50</td>
<td>0.69</td>
<td>0.18/1.50</td>
<td>0.74</td>
<td>0.31/1.23</td>
</tr>
<tr>
<td>50-100</td>
<td>0.87</td>
<td>0.29/1.87</td>
<td>1.16</td>
<td>0.45/1.78</td>
</tr>
<tr>
<td>100-150</td>
<td>0.96</td>
<td>0.36/2.02</td>
<td>1.10</td>
<td>0.44/1.82</td>
</tr>
<tr>
<td>150-200</td>
<td>0.90</td>
<td>0.44/1.93</td>
<td>1.09</td>
<td>0.51/1.60</td>
</tr>
<tr>
<td>200-250</td>
<td>0.95</td>
<td>0.46/2.03</td>
<td>1.21</td>
<td>0.51/1.56</td>
</tr>
<tr>
<td>250-300</td>
<td>1.11</td>
<td>0.43/2.18</td>
<td>1.33</td>
<td>0.56/1.71</td>
</tr>
<tr>
<td>300-350</td>
<td>1.42</td>
<td>0.58/2.63</td>
<td>1.62</td>
<td>0.72/2.00</td>
</tr>
<tr>
<td>Cumulative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 50</td>
<td>0.69</td>
<td>0.18/1.50</td>
<td>0.74</td>
<td>0.31/1.23</td>
</tr>
<tr>
<td>≤ 100</td>
<td>1.47</td>
<td>0.62/3.23</td>
<td>1.96</td>
<td>0.72/2.88</td>
</tr>
<tr>
<td>≤ 150</td>
<td>2.44</td>
<td>1.06/5.26</td>
<td>3.12</td>
<td>1.17/4.63</td>
</tr>
<tr>
<td>≤ 200</td>
<td>3.34</td>
<td>1.55/7.44</td>
<td>4.21</td>
<td>1.74/6.40</td>
</tr>
<tr>
<td>≤ 250</td>
<td>4.29</td>
<td>2.04/9.48</td>
<td>5.42</td>
<td>2.30/7.97</td>
</tr>
<tr>
<td>≤ 300</td>
<td>5.40</td>
<td>2.60/11.51</td>
<td>6.75</td>
<td>2.80/9.83</td>
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<tr>
<td>≤ 350</td>
<td>6.71</td>
<td>3.26/13.96</td>
<td>8.44</td>
<td>3.48/11.65</td>
</tr>
</tbody>
</table>

*Interquartile Range

**Significance p<.05
Table 3.2 Correlations and (p values) of individual thicknesses. Correlations of T1 ACNC with T2 ACNC (above the diagonal) and T2-T1 ACNC changes (below the diagonal).

<table>
<thead>
<tr>
<th>T1 &amp; T2 Changes</th>
<th>50μm</th>
<th>100μm</th>
<th>150μm</th>
<th>200μm</th>
<th>250μm</th>
<th>300μm</th>
<th>350μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>50μm</td>
<td>0.49 (&lt;0.01)</td>
<td>-0.23 (0.15)</td>
<td>0.52 (&lt;0.01)</td>
<td>0.50 (&lt;0.01)</td>
<td>0.46 (&lt;0.01)</td>
<td>0.49 (&lt;0.01)</td>
<td>0.49 (&lt;0.01)</td>
</tr>
<tr>
<td>100μm</td>
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<td>-0.52 (&lt;0.01)</td>
<td>0.43 (0.01)</td>
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<td>0.42 (0.01)</td>
</tr>
<tr>
<td>150μm</td>
<td>-0.52 (&lt;0.01)</td>
<td>-0.50 (&lt;0.01)</td>
<td>-0.53 (&lt;0.01)</td>
<td>0.43 (0.01)</td>
<td>0.45 (&lt;0.01)</td>
<td>0.46 (&lt;0.01)</td>
<td>0.48 (&lt;0.01)</td>
</tr>
<tr>
<td>200μm</td>
<td>-0.46 (&lt;0.01)</td>
<td>-0.43 (0.01)</td>
<td>-0.46 (&lt;0.01)</td>
<td>-0.50 (&lt;0.01)</td>
<td>0.48 (&lt;0.01)</td>
<td>0.48 (&lt;0.01)</td>
<td>0.50 (&lt;0.01)</td>
</tr>
<tr>
<td>250μm</td>
<td>-0.35 (0.03)</td>
<td>-0.31 (0.05)</td>
<td>-0.33 (0.04)</td>
<td>-0.37 (0.02)</td>
<td>-0.35 (0.03)</td>
<td>0.55 (&lt;0.01)</td>
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<tr>
<td>300μm</td>
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<td>-0.37 (0.02)</td>
<td>-0.36 (0.02)</td>
<td>0.53 (&lt;0.01)</td>
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<tr>
<td>350μm</td>
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<td>-0.38 (0.02)</td>
<td>-0.40 (0.01)</td>
<td>-0.38 (0.02)</td>
</tr>
</tbody>
</table>
Table 3.3 Correlations and (p values) of cumulative thicknesses. Correlations of T1 ACNC with T2 ACNC (above the main diagonal) and T2-T1 ACNC changes (below the main diagonal).

<table>
<thead>
<tr>
<th>T1 &amp; T2 Changes</th>
<th>≤ 50μm</th>
<th>≤ 100μm</th>
<th>≤ 150μm</th>
<th>≤ 200μm</th>
<th>≤ 250μm</th>
<th>≤ 300μm</th>
<th>≤ 350μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 50μm</td>
<td>0.49 (&lt;0.01)</td>
<td>0.49 (&lt;0.01)</td>
<td>0.50 (&lt;0.01)</td>
<td>0.49 (&lt;0.01)</td>
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<td></td>
</tr>
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<td>-0.23 (0.15)</td>
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<td>≤ 100μm</td>
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<td>0.47 (&lt;0.01)</td>
<td>0.47 (&lt;0.01)</td>
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<td>-0.49 (&lt;0.01)</td>
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<td>0.48 (&lt;0.01)</td>
<td>0.48 (&lt;0.01)</td>
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<td>-0.46 (&lt;0.01)</td>
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<td>≤ 250μm</td>
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<td>0.49 (&lt;0.01)</td>
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</tr>
<tr>
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<td>0.49 (&lt;0.01)</td>
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<td>-0.43 (&lt;0.01)</td>
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<tr>
<td>≤ 350μm</td>
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<td></td>
<td></td>
<td></td>
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<td>0.50 (&lt;0.01)</td>
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Table 3.4 Comparison of Questionnaire Results with Hawley and Perfector/Spring Aligner Retainers at T1 (post-treatment) and T2 (approximately two months later) Using a Visual Analogue Scale

<table>
<thead>
<tr>
<th>Question No.</th>
<th>T1 values (mm)</th>
<th>T2 values (mm)</th>
<th>T2-T1 Changes (mm)</th>
<th>T2-T1 comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>IQ Range</td>
<td>Median</td>
<td>IQ Range</td>
</tr>
<tr>
<td>Q1</td>
<td>124.7</td>
<td>139.3/110.2</td>
<td>118.8</td>
<td>131.9/101.1</td>
</tr>
<tr>
<td>Q2</td>
<td>125.0</td>
<td>136.5/118.2</td>
<td>119.5</td>
<td>137.2/97.9</td>
</tr>
<tr>
<td>Q3</td>
<td>141.9</td>
<td>145.5/139.1</td>
<td>134.5</td>
<td>142.5/128.1</td>
</tr>
<tr>
<td>Q4</td>
<td>139.2</td>
<td>144.0/125.8</td>
<td>132.5</td>
<td>143.1/127.6</td>
</tr>
<tr>
<td>Q5</td>
<td>145.2</td>
<td>147.3/143.0</td>
<td>138.0</td>
<td>143.7/131.9</td>
</tr>
<tr>
<td>Q6</td>
<td>137.8</td>
<td>145.9/111.5</td>
<td>135.0</td>
<td>142.4/115.5</td>
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<tr>
<td>Q7</td>
<td>138.0</td>
<td>144.9/125.2</td>
<td>140.0</td>
<td>142.5/125.7</td>
</tr>
</tbody>
</table>

*Interquartile Range
**Significance p<.05
Fig. 3.1 Essix Retainers
Fig. 3.2 Hawley Retainers
Fig. 3.3 Perfector and Lower Spring Aligner
Fig. 3.4  Photo of registration  
Fig. 3.5  Scan of registration  
Fig. 3.6  Tracing of occlusal table
Fig. 3.7 Calibration Curve: step-wedge thickness (Y) estimated from grey scales (X).
**Vita Auctoris**

Jennifer Kronberg Horton was born in Modesto, California on December 18, 1975. She graduated from California Polytechnic State University, San Luis Obispo in 1998 with a B.S. degree in Biochemistry. She married Ryan Campbell Horton on July 1, 2000. In 2004, she graduated with honors from the University of Southern California School of Dentistry. Following graduation from dental school, she began her studies at Saint Louis University in pursuit of a Master’s Degree from the Orthodontics program. On August 31, 2006, Jennifer and Ryan’s daughter Annika Lorelei was born.