PHYSIOLOGIC ADAPTATION TO LINGUAL APPLIANCES DURING THE INITIAL EIGHT WEEKS OF TREATMENT

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A thesis submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Science in the School of Dentistry (Orthodontics).

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ABSTRACT

ROBERT CURTIS SANBORN III: Physiologic Adaptation to Lingual Appliances During the Initial Eight Weeks of Treatment  
(Under the direction of Dr. Rose Sheats)

A prospective pilot study of adult patients treated with customized lingual orthodontic appliances (Incognito™, Bad Essen, Germany) was undertaken to measure the intensity and duration of functional impairment and orthodontic tooth pain. Six patients, fully bonded in both arches at UNC School of Dentistry, completed standardized questionnaires at specified time points over an eight week period after appliance placement. Functional impairment, including speech, was reported using a 5 – point Likert Rating Scale while tooth pain was scored using an 11 – point Numerical Rating Scale. Functional impairment and tooth pain were highest at 48 and 72 hours respectively. Pronunciation problems were highest at 24 hours and declined to near baseline by week 3. Tooth pain subsided by the conclusion of week 2; functional impairment improved by the end of week 3. The results of this investigation may help orthodontists provide details to patients about adaptation to customized lingual orthodontic appliances.
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SECTION I
LITERATURE REVIEW

The average adult seeking orthodontic treatment desires a more esthetic appliance than traditional metal brackets which are placed on the labial aspect of the teeth. Fritz et al. determined that the main reason for orthodontic treatment was esthetics. This demand for an esthetic appliance prompted the creation of brackets fabricated from plastic or porcelain and coated archwires that mask the metal appearance of orthodontics appliances. These options are more esthetic than traditional metal brackets, though the “ultimate esthetic appliance” is only possible by placing brackets on the lingual surface of the teeth. Although the creation of lingual orthodontics has offered an esthetic option for orthodontic treatment, past difficulties with the thickness of the brackets, as well as tongue irritation, soreness and speech impairment, have resulted in few orthodontists dedicating their time to this novel technique. Recent improvements in laboratory processes are making treatment with lingual appliances increasingly more efficient and effective and are thus enhancing the likelihood of this therapeutic alternative being integrated into routine orthodontic practices.

History of Lingual Orthodontics

The lingual technique was introduced in 1975 by Dr. Craven Kurz, using a design based on a modification of his current labial appliances. In 1976 research and development of a non-edgewise lingual appliance was initiated by Ormco® in cooperation with Dr. Alexander Wildman. Later that year, Dr. Kurz submitted specific designs and concepts to the U.S. Patent Office for rights to his unique appliance design. Soon thereafter, Dr. Kurz’s
vision of a lingual bonded edgewise appliance was brought to reality through a partnership with Ormco® (Glendora, CA, USA) and the creation of the Ormco-Kurz lingual appliance.  

Dr. Kinya Fujita (Kanagawa Dental University, Japan) described appliances with a lingual bracket design and mushroom shaped archwires that conform to the lingual archform. Dr. Fujita determined that he could move each tooth in three dimensions from the lingual side and further demonstrated that this technique was very useful in the treatment of patients who desire nearly invisible orthodontic appliances for improved esthetics or prevention of trauma during exercise. Dr. Fujita’s report confirmed the experiences of Dr. Kurz and Ormco®, verifying that lingual appliances were a viable alternative to labial appliances. Early successes in clinical research prompted Ormco® to establish a Lingual Task Force in 1980, which was comprised of seven orthodontists from around the country. Ormco® and the Task Force members felt strongly that the appliances should not be marketed until a workable system had been developed and tested. The initial results of lingual orthodontics were promising, with such advantages over labial orthodontics as: no damage to labial or buccal surfaces of the teeth, no labial or buccal gingival hypertrophy or gingivitis, and better visualization of tooth alignment and facial contours. Nonetheless, lingual treatment has inherent disadvantages such as: increased chairside time required for bracket placement and biomechanical difficulties due to decreased interbracket distance.

Pre-fabricated vs. Customized Lingual Appliances

In recent years, developments in laboratory procedures and clinical aspects have produced more simplified, successful treatment outcomes. The initial bracket shape of the first lingual appliance, designed by Dr. Kurz and Ormco®, was pre-fabricated and had a high profile and considerable bulk. This high profile appliance initially resulted in increased
shearing of brackets due to biting forces, as well as tongue irritation and speech impairment, which resulted in much disillusionment for practitioners already wary of attempting a new treatment approach.² Twenty years later, Dr. Dirk Weichmann created the first CAD/CAM generated, individualized, lingual system known as Incognito™, currently marketed as iBraces™ by Lingualcare® (Dallas, TX, USA) and 3M Unitek® (St. Paul, MN, USA) in the United States.⁷-⁸ This newest version of lingual braces provides a reduced profile of the bracket system, creating an appliance similar in thickness to that of bonded retainer especially in the buccal segment. Recent improvements in lingual appliances have included optimization of laboratory procedures, indirect bonding⁹-¹⁰ and computerized appliance and archwire fabrication.¹⁰ In contrast to labial appliances, lingual appliances require extensive individualization because of the greater variability of the lingual tooth surfaces.⁷ The use of a CAD/CAM design allows for greater customization, which leads to a decreased thickness and lower profile for the bracket bases. The appliances and archwires are created after scanning study models from various perspectives using high-resolution three dimensional scanners (GOM, Braunschweig, Germany). The brackets are then designed individually and fabricated by means of rapid prototyping (Degunorm M®, Degussa, Hanau, Germany).¹¹ After fabrication of the customized appliances, archwires are formed and individually customized by a bending robot (Orametrix®, Dallas, TX, USA) reducing the need for individual detailed archwire bends by the practitioner.

In comparison to the pre-fabricated brackets (PF), the customized brackets (CU) appear to have shorter adaptation times, are more comfortable and provide similar biomechanical principles and mechanics as labial appliances.⁷
Pain and discomfort are two of the most important reasons that patients, especially adults, are discouraged from seeking orthodontic treatment. Patients in orthodontic treatment often describe pain or discomfort as a feeling of pressure, tension, ache and soreness of teeth. The pain intensity usually increases gradually from two hours after application of force to peak level at 24 hours, and resolution of the pain by the seventh day. Pain and discomfort are inherently subjective and its measurement necessarily relies on patient self report. Pain studies traditionally use either a Numerical Rating Scale (NRS) or a Likert Rating Scale (LRS). The NRS often consists of a six or eleven point scale (0 – 5 or 0 – 10) that is anchored by extreme descriptors of pain “no pain” to “worst pain imaginable” and can be administered either verbally or graphically. The LRS consists of a five point scale (1 – 5) that is anchored by descriptors “no trouble” to “lots of trouble.” Both the NRS and LRS have been shown to provide valid and sensitively reliable information for clinical use.

Multiple publications have documented patient’s oral discomfort during lingual orthodontic treatment with PF lingual appliances. Sinclair et al. examined speech impairment and current level of pain with lingual appliances in 17 native English-speaking patients, treated with PF lingual appliances. Current level of pain and speech impairment were assessed through the use of a Visual Analog Scale (VAS) with patients reporting significant increases in perception of pain and speech problems two days after placement and decreasing thereafter. After one month of treatment, each patient was given a retrospective survey to evaluate tongue soreness, pain, eating and speech problems. All patients reported some degree of discomfort, which lasted
fewer than 14 days, while approximately 18% of participating patients reported tongue lesions and soreness for more than one month after appliance placement.

Miyawaki et al. assessed 111 patients with PF lingual appliances in the maxillary arch and buccal appliances in the mandibular arch, treated between one and two years previously, using a retrospective discomfort questionnaire. 18 Patients responded to questions concerning the type, intensity and duration of discomfort during treatment with PF lingual appliances. They found that 10% of patients reported discomfort, associated with tongue soreness and lesions, between two weeks and three months after appliance placement. The results suggest that tongue soreness may be related to mandibular lingual appliances. 18

Fritz et al. assessed 110 patients, with PF lingual appliances, using a retrospective questionnaire given after completion of their treatment. 1 The majority of the data collected were taken from patients who had started their lingual appliances between one and two years previously and thus some of their primary negative experiences may have been forgotten, decreased, or resolved during that time. The results revealed that 65% of all patients noted injuries or irritations of the tongue and restricted functional space for the tongue as the main impairment by the lingual appliance. 1 Eighty-two percent of their patients reported that most discomfort occurred between one and three weeks.

In 1997, Fillion et al. examined patients treated with PF lingual appliances using a questionnaire after approximately one month of treatment. 9 The results showed that 36% of patients experienced adaptation periods longer than three weeks, with 44% of patients stating that the tongue contact with appliances was the most bothersome. 9 Nonetheless, 88% reported that treatment did not hinder their professional or social activity.
Caniklioglu et al. requested patients to record any intraoral problems after insertion of appliances and to complete a seven-part retrospective survey after three months of treatment with PF lingual appliances. They compared labial to lingual appliances and determined the largest difference was in the localization of functional impairment, with patient discomfort being localized to tongue irritations and restricted functional space for lingual patients. Tongue soreness and restricted space may have been due to increased irritation and size of PF lingual brackets, which have a higher profile than CU brackets. This study suggested that lower profile brackets could improve patient comfort during treatment.

Multiple studies by Hohoff et al. have provided insight into patient discomfort and adaptation to PF lingual appliances. A study from 2003 analyzed patients with PF lingual appliances confined to the maxillary arch in which patients were given a standardized questionnaire directly before placement, within 24 hours and three months after placement. Approximately 76 – 90% of patients that responded reported continued discomfort to some degree after three months of treatment with lingual appliances. A study from 2004 noted that differences in thickness of the same lingual appliances were found to have a significant impact on tongue space restrictions and lesions. In 2003, a similar study on another sample of patients found that the smaller the lingual appliance, the less pronounced the induced irritations of the tongue. These studies recommended that “detailed briefing” on the extent and duration of potential impairments in oral comfort and functions was advisable prior to placement of lingual appliances.

Until 2003, studies of pain and discomfort were conducted solely on patients who received PF appliances. To date, two publications have documented patient’s functional
impairment during lingual orthodontic treatment with CU lingual appliances, which are designed with a lower profile.\textsuperscript{11,24}

Stamm et al. compared PF to CU lingual appliances in relation to subjective oral comfort.\textsuperscript{11} Forty-two patients were allocated to either PF appliances (n = 18) and or CU appliances (n = 24), and a subjective questionnaire was used to compare oral discomfort. They reported that all CU appliance patients had considerably more comfortable experiences, fewer problems, and shorter adaptation periods than patients with PF appliances, but a small proportion of patients recorded uncomfortable experiences even with CU appliances. The study was unable to identify predictors of better tolerance to either appliance.\textsuperscript{11}

Wiechmann et al. compared the influence of malocclusion on the amount of discomfort of patient treated with CU appliances.\textsuperscript{24} Twenty-one female patients participated and completed a prospective standardized questionnaire before and the day after placement of lingual appliances. This study noted that the amount of discomfort and dysfunction induced by the CU appliances were relatively lower compared to other lingual techniques and could be due to the thinness of the appliance.

\textit{Speech Disturbances with Lingual Orthodontics}

The placement of orthodontic appliances on the lingual aspect of the teeth offers an alternative to traditional labial appliances, though this technique’s popularity is affected by potential disturbances in patient’s speech performance. Multiple publications have documented patient’s speech disturbance and adaptation during lingual orthodontic treatment\textsuperscript{1,9,11,17-20,21-23} with PF lingual appliances.

Caniklioglu et al., in the previously cited study, assessed speech disturbances with a seven- part questionnaire distributed to 30 labial and 30 lingual appliance patients.\textsuperscript{20} Speech
disturbances were reported by 100% of lingual appliance participants. Seven of the thirty patients (23.3%) reported speech disturbance persisted throughout the entire three months of the study. Overall, the adaptation period for speech and discomfort was approximately four weeks.

Fillion et al. used a survey for PF lingual appliance patients approximately one month into treatment and reported that 82% spoke normally within the first month of starting treatment. Severity of speech disturbances depended on the area of tongue contact, with sibilants being more likely to be affected. They concluded that the patients should be informed as honestly as possible of the adaptation period, that this disturbance may hinder social and professional activities, and that speech may become more difficult at the end of the day due to fatigue.

Fritz et al., using a retrospective questionnaire given approximately one to two years post-treatment, showed that speech disturbances, such as lisping, were reported by 24% of patients with PF lingual appliances. Miyawaki et al. retrospectively questioned retention patients previously treated with PF lingual appliances, and found that 63% – 76% of patients overcame the speech difficulties by time of deband. Speech disturbances with “s” and “t” sounds may have been caused by appliances in the mandibular arch and therefore patients should be forewarned of the possibility of these disturbances with lingual appliances.

Sinclair et al. assessed 17 patients during orthodontic treatment with PF lingual appliances. Speech was analyzed by recordings of 48 monosyllabic words derived from initial and final consonants that were believed to be vulnerable to the effects of lingual treatment due to their points of articulation (linguo-dental, linguo-alveolar, and linguo-palatal
consonants). Recordings were accomplished at three intervals per recording session (pre-bonding, post-bonding, 48 hours, one week, and one month). Data were analyzed by two judges trained in speech pathology. Results showed that significantly more speech errors occurred 10 minutes, 48 hours and one month after appliance placement than before placement. It was noted that speech one week after placement was not found to be significantly different from that before treatment. This study stated that patients should be counseled on changes in their own speech difficulties at the beginning of treatment.

Hohoff et al. used a prospective evaluation of 23 patients with PF lingual appliances and sound recordings obtained at specified time points: directly before placement, within 24 hours after placement and three months after placement. This study evaluated the /s/ sound due to its sensitivity to morphological changes in the maxillary incisors and commonality in most languages throughout the world. Results showed that a significant deterioration in speech articulation occurred by 24 hours after placement and lasted to some extent until the final recording at three months post-placement.

In a prospective survey to 22 patients with PF lingual appliances, Hohoff et al. found that speech articulation deteriorated significantly after appliance placement and up to three months later. Another study by Hohoff et al. surveyed 41 patients before placement, within 24 hours after placement and three months after placement of PF lingual appliances. Results showed that articulation was most affected by changes in tongue placement and may last for up to three months post-placement.

Until 2003, studies of speech impairment were conducted solely on patients who received PF appliances. To date, two publications have documented patient’s speech impairment during lingual orthodontic treatment with CU lingual appliances.
Stamm et al. prospectively assessed speech adaptation to customized lingual appliances in 24 patients, using a standardized questionnaire: directly before insertion, within 24 hours of placement and three months after placement. Patients with CU lingual appliances reported significantly fewer speech disturbances than those with PF lingual appliances, and adaptation to these disturbances occurred by the end of the third month of treatment. No data were obtained between 24 hours and 3 months, thus no information was available pertaining to the time course for speech adaptation. This study concluded that the decreased number of disturbances could be attributed to the smaller dimension CU appliances and thus information given to patients about the adaptation and duration of restrictions with lingual appliances should be differentiated according to the bracket system used.

Hohoff et al. prospectively surveyed 12 native German speaking patients with the use of removable thermoplastic retainers with different sized PF and CU lingual brackets. A semi-objective, auditive evaluation of articulation was made by 3 speech professionals, with evaluation of the /s/ sound using a Likert Rating Scale: directly before placement, 10 minutes after placement and 24 hours after placement. A subjective evaluation of articulation was also completed by the patient using a standardized questionnaire one day after placement. Patients reported that the smaller the bracket dimension, the lesser perceived degree of speech impairment. It must be recognized however that the design of this study may not replicate patient’s actual experiences with lingual brackets adhered directly to their teeth.

Despite encouraging results from the studies described, disadvantages to lingual appliances exist. Patient disadvantages of lingual braces include irritation to the tongue, restricted functional space for the tongue, and speech difficulties. Clinical disadvantages
of lingual braces include: greater variation of lingual surfaces of the teeth, decreased interbracket span, and difficulty in finishing with second order movements. \(^6,25\)

**Rationale for Current Study**

While many investigations have been carried out on PF lingual appliances, few studies into tooth pain and functional impairment with CU lingual appliances have been reported. Currently, only three studies have been published \(^11,23-24\) with the use of CU systems. Most studies were retrospective, most studies did not compare pre- and post-placement patient information, two of the studies only assessed pain and impairment with the use of either removable appliances or appliances only in the maxillary arch, and no studies were done in the United States with native English speaking subjects. It was noted by Sinclair et al. \(^17\) and Miyawaki et al. \(^18\) that orthodontists should pay particular attention to patients during the first week of treatment.

**Purpose**

The purpose of this research is to examine the physiologic response to orthodontic treatment during the first eight weeks of treatment in adults, with particular attention to the first week of treatment, using fixed CU lingual appliances to determine if there is any difference in the patient’s intensity and duration of tooth pain and functional impairment before and after placement of CU lingual appliances. This study will provide data to more accurately inform a patient of the potential impairments with the lower profile CU lingual appliances.
REFERENCES


SECTION II
MANUSCRIPT

INTRODUCTION

The current trend for more esthetically pleasing orthodontic appliances has resulted in an increase in demand for adult orthodontics and is a response to adult patients seeking dental treatment not only to maintain health and function of their dentition but also to enhance their appearance. It is well known that adults have a negative reaction toward the appearance of conventional fixed orthodontic appliances and do not want them to show. Even though brackets made of plastic and porcelain and coated archwires have appeared in the market, the only true solution to providing the ultimate in esthetics during treatment is to attach the fixed appliances to the lingual surfaces of the teeth.\textsuperscript{1} While the technique of lingual orthodontics is not new, it has never gained widespread popularity due to patient intolerance and provider disillusionment. A new approach to lingual appliances offers more promise because the brackets are customized for each patient and have a lower profile. Improvements in laboratory techniques for bracket positioning, computer aided archwire manufacturing with the opportunity to form precise finishing bends for individual teeth, a practicable clinical bonding protocol, and the use of individual archwires with temperature dependent superelasticity overcome some of the previous operator concerns with lingual appliances and offer the clinician improved efficiency.\textsuperscript{1-3}

Since the introduction of the lingual appliance in the late 1970s, multiple studies have dealt with the technical and clinical aspects of the pre-fabricated (PF) lingual technique but
few reports have appeared which investigate the newer customized (CU) lingual appliances with patient comfort, adaptation to, and tolerance of these appliances. Currently, three studies \(^{4-6}\) have been published describing adaptation to CU appliance systems, none of which were conducted in the United States with native-English speaking subjects.

Lingual orthodontic patients are usually informed that there may be some tongue discomfort and speech difficulty associated with the insertion of the appliance. However, the intensity and duration of the problems associated with customized lingual appliances have not been characterized in detail, and many orthodontists are still hesitant to employ this technique without further reassurance of the patient’s ability to adapt to lingual appliances.

The purpose of this research was to examine the physiologic response to lingual orthodontic treatment during the first eight weeks of treatment in adults, using fixed CU lingual appliances. It was undertaken to determine the intensity and duration of tooth pain and functional impairment associated with CU lingual appliances.

**MATERIALS AND METHODS**

*Sampling Method*

The study design was a prospective pilot study. Patients were enrolled consecutively between August 2007 and August 2008 in the Graduate and Faculty clinics at the Department of Orthodontics, University of North Carolina School of Dentistry, Chapel Hill, North Carolina. Exclusion and inclusion criteria (Table 1-2) were applied to interested patients to determine eligibility. The study was approved by the Biomedical Institutional Review Board. Patients who successfully completed the study were compensated $50.00 for their participation.
Table 1 Patient inclusion criteria

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<td>1. Healthy adults (over the age of 18) being treated at the University of North Carolina School of Dentistry Graduate and Faculty Orthodontic Clinics</td>
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<td>2. Native speaking, literate English patients</td>
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<td>3. Full treatment of both arches with fixed customized lingual appliances</td>
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<td>4. Informed consent obtained from patient</td>
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*No patient was excluded on the basis of sex or ethnicity*

Table 2 Patient exclusion criteria

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<th>Exclusion Criteria</th>
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<td>1. Orthognathic surgery procedures required for orthodontic treatment</td>
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<tr>
<td>2. Patients with obvious speech/hearing impairment or defects</td>
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*No patient was excluded on the basis of sex or ethnicity*

Study Design

The study sampling plan was non-random, using convenience sampling due to the anticipated challenges of patient recruitment. Patients initially screened for lingual orthodontic treatment in the UNC Graduate or Faculty clinic were eligible for this study. Those individuals were then invited to participate in the study during their case presentation (CP) appointment, an appointment where patients are presented treatment options and agree to a specific treatment plan. If at the CP the patient accepted, the principal or co-investigator described the study, and informed consent and Health Insurance Portability and Accountability Act (HIPAA) were obtained (Figure 1). Blinding of patients was not possible
due to the nature of the treatment. After consent and HIPAA were obtained, demographic data were collected from each patient.

**Figure 1** Enrollment and retention of participants

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*Allocation*

Because this was an investigation of patient’s adaptation to CU lingual braces, no comparison group was included in this exploratory study.

*Data Collection*

To assess patient’s adaptation to functional impairment and tooth pain, patients completed standardized questionnaires designed for CU lingual appliances (Incognito™, Bad Essen, Germany) adapted from the orthognathic surgical recovery diary by Phillips et al. 7 Items in the adapted survey were generally grouped to assess patient perception of functional impairment and tooth pain.

The functional impairment items related specifically to the patient’s ability to chew, speak, function and conduct daily tasks. Responses were rated using a five point Likert Rating Scale (LRS) where 1 = No trouble, 2 = A little trouble, 3 = Some trouble, 4 = Quite a
bit of trouble and 5 = Lots of trouble. The five categories of the LRS represent an inherent order (less to more, weaker to stronger, smaller to bigger) of the items.⁸

The tooth pain items were rated by a eleven point Numerical Rating Scale (NRS) for average tooth pain during the day (biting on front teeth, biting on back teeth, chewing) and tooth pain felt during the following tasks completed at each survey time: tapping teeth together followed by biting on front teeth, followed by biting on back teeth and followed by chewing. Pain was rated where 0 = “No pain” to 10 = “As bad as you can imagine.” The NRS provides valid and reliable information for clinical use and shows good sensitivity with data that can be statistically analyzed.⁹

Participants were instructed to complete each questionnaire at specified time points before and after placement of CU lingual appliance and archwires: baseline prior to appliance placement and bedtime at each of the following time points after placement: the day of placement, two, three, five days and then weekly for eight weeks. Bedtime was chosen for completion of the home questionnaire to provide consistency and ease of remembrance. Each participant received a labeled binder with separate questionnaires for each time point and a self-addressed-stamped envelope for return of all questionnaires at completion of the eight week assessments (Table 3). A total of 13 questionnaires were administered to each patient.
Table 3 Instructions for completion of questionnaires

Complete each questionnaire at the following time points:

- Baseline (before placement)
- Day 1 at bedtime
- Day 2 at bedtime
- Day 3 at bedtime
- Day 5 at bedtime
- Week 1 at bedtime
- Week 2 at bedtime
- Week 3 at bedtime
- Week 4 at bedtime
- Week 5 at bedtime
- Week 6 at bedtime
- Week 7 at bedtime
- Week 8 at bedtime

Statistical Analysis

Because of the small sample size, analyses were considered exploratory. Variables were measured as continuous data and were summarized using descriptive statistics.

RESULTS

Characteristics of the study sample

The study sample included six adult patients (5 female, 1 male), over the age of 18, who requested and had CU lingual appliances placed between August 2007 – August 2008, and who completed all components of the study as instructed. The mean age (Table 4) at enrollment for the six patients was 41.1 years (18.9 – 53.4). Five participants were Caucasian, one was African American. All patients spoke standard American English, and lived in the local university area at the time of appliance placement. Patients with history of
speech or hearing disorders were not included in this study. No patient was excluded on the basis of sex or ethnicity.

**Table 4** Patient demographic information

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<td>Sample Size</td>
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*No patient was excluded on the basis of sex or ethnicity*

**Questionnaire Responses**

A response rate of 100% was obtained for all questionnaires administered. Tables 5 and 6 and Figures 2 and 3 summarize the mean responses of the six patients to each item of the questionnaire over time.

**Functional Impairment**

Table 5 shows the mean reported scores for each question pertaining to functional impairment during the first eight weeks after placement of CU lingual appliances. Difficulty with functional activities was greatest on the first day for eating, chewing, tongue space, tongue placement, tooth cleaning, and food collection. Problems with swallowing and gagging peaked on Day 2, while reported problems in performing daily activities was highest on Day 3. The longest reported mean discomfort was that of oral lesions which was highest on Day 5. Overall, eating, chewing and food collection reported at the highest mean peak values (4.17) while gagging (1.67), swallowing (2.83) and daily activities (2.5) was reported at the lowest mean peak values.
Table 5 Mean scores of functional impairment responses during the initial eight weeks after appliance placement

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Functional Impairment Adaptation

For all six patients, reported discomfort levels were highest during the first week after appliance placement. The average discomfort values reported for each question decreased over time with most patients reporting increased discomfort values during the first week after appliance placement, at which time reported levels had decreased to within one unit of baseline by week 3 (Figure 2), suggesting that patients adapted to these functions by that time.
**Figure 2** Mean functional impairment responses during the initial eight weeks after appliance placement

![Mean Functional Impairment over Time](chart)

Subjective Speech Impairment

Table 5 also shows the mean reported scores for “pronunciation” and “talking,” the two questions pertaining to self perception of speech impairment, during the first eight weeks after appliance placement. Difficulty with speech was greatest on the first day for talking or pronouncing words (pronunciation) while problems with talking so that others can understand you (talking) peaked on Day 2.

Subjective Speech Impairment Adaptation

For all six patients, reported speech impairment levels were highest during the first week after appliance placement, but adaptation to within one unit of baseline occurred by week 3. Overall, the pattern of speech difficulties reported was similar for both questions pertaining to speech impairment (pronunciation, talking), as seen in Figure 2.
**Tooth Pain**

Table 6 shows the mean reported scores for each question pertaining to tooth pain during the first eight weeks after placement of their customized lingual appliances. Discomfort associated with tooth pain was greatest on the second day for biting on front teeth, chewing, tapping followed by biting on front teeth and tapping followed by chewing. Tooth pain associated with biting on back teeth and tapping followed by biting on back teeth peaked on the third day. Patients reported higher tooth pain responses from tapping followed by biting on back teeth than from tapping followed by biting on front teeth. Overall, patients reported that chewing was more painful than tapping and biting their teeth together.

**Table 6** Mean scores of tooth pain responses during the initial eight weeks after appliance placement

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**Tooth Pain Adaptation**

Overall, the pattern of pain values reported was similar for both sets of three questions pertaining to average tooth pain level during the day (biting on front teeth, biting on back teeth, chewing) and current tooth pain during function (tapping teeth together while biting on front teeth, tapping teeth together followed by biting on back teeth and tapping teeth together followed by chewing), as seen in Figure 3. As expected, the pain level experienced during each question decreased over time with most subjects reporting increased
tooth pain values during the first week after appliance placement, at which time reported levels had decreased within one unit of baseline by week 2 (Figure 3).

**Figure 3** Mean tooth pain responses during the initial eight weeks after appliance placement

DISCUSSION

Pain and discomfort are two of the most important reasons why patients, especially adults, are discouraged from seeking orthodontic treatment. Patients often experience a considerable amount of discomfort and pain associated with labial or lingual orthodontic treatment. This pain and discomfort is often described as a feeling of pressure, tension, ache and soreness of teeth. Pain and discomfort are inherently subjective and their measurement necessarily relies on patient self report. This prospective pilot study was designed to use subjective questionnaires to determine the intensity and duration of functional impairment and tooth pain with customized lingual appliances. For this study,
questionnaires were completed by patients at 24 hours intervals. The rationale for the time points was that a longer interval, such as ‘over the past week,’ would have failed to differentiate intensity and duration patterns within the first week, particularly among those items that were reported in previous studies to cause problems during the first few weeks after lingual appliance placement. Our sample size was small (n = 6) and older (41.1 years) than those of previous studies, but similar in that most were female. Recognizing the differing demographics, we compare findings from our limited sample size to previously conducted research on lingual appliances.

Functional Impairment

In a study in which 20 patients had pre-fabricated (PF) lingual appliances inserted in one arch and customized (CU) lingual appliances in the other, Wiechmann et al. reported that CU appliances were considerably more comfortable and presented less problems and shorter adaptation times. 2 Because CU brackets are smaller in all dimensions as related to PF brackets, it might be expected that patient’s reported values and adaptation periods would be less and shorter than those studies with PF appliances. A study by Hohoff et al. showed that the smaller a lingual appliance is in the sagittal dimension, the less pronounced the induced irritations of the tongue. 14 Our study provided results with the use of CU appliances and found that the majority of problems were related to positioning, discomfort and pain associated with the tongue, and its contact with the appliance. These problems were reported at their highest values during the first week after appliance placement, at which time values began to decline to near pre-placement levels by the completion of the third week of treatment, though one patient continued to report problems through week six of treatment. Sinclair et al. 15 and Miyawaki et al. 16 stated that 18% and 10% of their samples reported
continued tongue discomfort from one to three months after PF lingual appliance placement. Fillion et al. 17 and Fritz et al. 12 also reported that tongue discomfort was the most serious problem reported by their patients with PF lingual appliances. Continued discomfort values were reported between four and six weeks after placement by 3 out of 6 patients in our study, 50% of our sample. This is possibly due to the patient’s first archwire adjustment, which traditionally occurs at four to six weeks after appliance placement, and the new archwires or ligatures ties resulting in increased discomfort or pressure, and lesions or sores.

The majority of the values reported in our study for functional impairment were well below those reported by Hohoff et al. in which 76% of the patients questioned still reported restriction of the tongue space, changes in tongue position, or lesions to the tongue to some degree after 3 months. 14 The majority of the patients in our study reported impairments as moderate to severe, with 50% reporting severe, during the first week after appliance placement. These values are significantly more negative than in the retrospective study by Fillion et al., in which only 27% of the patients questioned reported severe impairments. 17 The results of our study may indicate more discomfort due to the fact that our study was prospective in nature, while in a retrospective study, the farther back an event lies, the more likely the primarily negative experiences are to lose significance. Also, current patients may have been better informed of the expectations with respect to discomfort that is involved with orthodontic treatment, specifically due to more information provided on discomfort involved with orthodontic treatment.

Although the reported values are different, tongue contact with the appliance is reported in all studies to be problematic. In the retrospective study by Fritz et al., given 1 – 2 years after treatment with PF appliances, 65% of 110 patients claimed to have been impaired
by injury to or irritation of the tongue and restricted functional space for the tongue,\textsuperscript{12} while in the study by Fillon et al. this applied to 44\% of the subjects sampled.\textsuperscript{17} Wiechmann et al. reported that before treatment, no patient reported discomfort or dysfunction, while the day after appliance placement, discomfort was found for the parameters “pressure spots, reddening or lesions to the tongue” and “biting,” followed by “chewing” and “restrictions of the tongue space.”\textsuperscript{6} In our study, the parameters “eating,” “lesions” and “food collection” were reported as increased at baseline, possibly due to the nature of the patient’s current malocclusion before appliance placement.

\textit{Tooth Pain}

Hohoff et al. reported that both chewing and biting were consistently more difficult for patients after placement of lingual appliances than before.\textsuperscript{18} A report by Caniklioglu et al. stated that pain was the most severe problem induced by the lingual appliance.\textsuperscript{19} This was evident in our study as patients reported baseline values of no pain, to mild pain in one patient, prior to appliance placement which increased significantly after placement. Pain values followed a similar curve in all subjects for the three questions for average tooth pain during the day, as values increased from baseline to day 1, peaked by the end of week 1 and decreased over the following week, returning close to baseline by week 2. One patient continued to report increased pain values throughout our study, thus leading to the continued overall increased response.

Pain reported by three out of six patients, 50\% of sample, for the three questions for tooth pain felt during each survey time, also showed a peaking of pain around bedtime between day 1 and day 2. This is consistent with peak pain that was reported by Sinclair et al.\textsuperscript{15} in which patients reported significant increases in pain problems at 48 hours after
lingual appliance placement. Our findings also mirror those of Ngan et al., which demonstrated that peak pain was reached in the first 24 hours after placement of labial appliances. The fact that pain peaked within 24 – 48 hours of orthodontic appliance activation, whether labial or lingual, suggests the mechanism of the tooth pain response is likely generated by the application of force to the teeth, irrespective of the appliance system.

Tooth pain experienced from biting or chewing on back teeth was significantly higher than that from biting on front teeth during the first week after appliance placement in our study, findings which are in agreement with Stamm et al. Chewing resulted in higher pain values than tapping front and back teeth together and could be explained by the fact that only a few teeth touch when tapping, while chewing calls for maximum intercuspation contact with the majority of teeth. Furthermore, because of possible crowding, anterior occlusal contacts are often not balanced among all the teeth, and can even be localized on a single tooth, thus making chewing quite difficult and painful at first. Finally, pain values may have been higher in this study due to the older age of patients in our study. Jones and Chen have demonstrated that during orthodontic therapy adult patients experience more pain and discomfort than do younger patients. Our patients were average age of 41 years, while previous studies, such as Fillion et al. and Fritz et al. were conducted on subjects with an average age of 20 years.

*Adaptation for functional impairment and tooth pain*

A major concern for patients receiving orthodontic treatment is what may be required for adjusting to their orthodontic appliances. Fillion et al. reported that the adaptation period for PF lingual appliances was more than 3 weeks for 36% of the patients interviewed by their study. Our study reported that only one out of six patients, 17% of our sample, reported
difficulties in adapting to the lingual appliances. In our study, the adaptation period was between two and three weeks for tooth pain and functional impairment, respectively. This is similar to the reports of Fritz et al.\textsuperscript{12} and Hohoff et al.,\textsuperscript{14} in which 82\% of their patients reported adaptation periods between 1 and 3 weeks. This is somewhat shorter than adaptation periods reported by Sinclair et al.\textsuperscript{15} and Fillion et al.,\textsuperscript{17} in which 36\% of their patients reported impairments beyond 3 weeks. This may have been due to the more detailed answers to the questionnaires or due to the prospective design of our current study.

\textit{Subjective Speech Disturbances}

Whereas oral comfort is reported in various retrospective studies to be the most strongly affected parameter, articulation was subjectively reported to be a major concern with the subjects enrolled in our current study. Our results were unlike the findings by Muir, who stated that speech problems associated with lingual appliances may persist for up to three months.\textsuperscript{22} Artun et al. also expressed similar findings, in that speech impairment was diagnosed in 70\% of patients with lingual appliances over a three month period.\textsuperscript{23} Only Fujita reported “no major effect” after subjectively analyzing speech in a patient at 6 days post-appliance placement; however Fujita’s study analyzed vowel formation, which does not take place in the articulation zone in which the lingual appliances are located.\textsuperscript{24} Fujita noted, but did not analyze, that pronunciation of “s, t, r and l” was distorted in a few of his patients.

Our current study reported subjects perceived difficulties relating to speech disturbances through questionnaires pertaining to talking and pronouncing words. The majority of subjects reported increased values relating to speech disturbances after placement of lingual appliances. This is similar to Fillion et al., who reported that most patients showed increased disturbances after placement of lingual appliances.\textsuperscript{17} In our study, approximately
two out of six patients, 33% of our sample, reported increased difficulty with speaking in relation to social and professional activities, higher than the results from Fillion et al., in which only 6% of patients in their study, with PF lingual appliances, felt impaired by this treatment in their social activity and approximately 12% in their professional activity. The differences between our study and Fillion’s may be due to the prospective design of our study and the type of appliances used.

Adaptation period for subjective speech disturbances

The majority of our patients reported that speech disturbances were greatest during the first week of treatment, at which time the values decreased until returning close to baseline by week three. Our findings suggest that our patients adapted to speaking with customized lingual appliances within the first three weeks after placement, while Fillion et al. reported that 82% of his patients spoke normally within four weeks after starting treatment, though questionnaires in their study were not administered until after one month of treatment with higher profile PF lingual appliances. His report also stated that speech is not systematically disturbed and that the severity of the problem depends on the area of the tongue affected, with sibilants such as “s” being more likely to “whistle” more than usual for a few days or even weeks.

While our study reported adaptation to CU lingual appliances within the first three weeks, the following retrospective studies, using PF lingual appliances, reported more prolonged adaptation: Miyawaki et al. reported that 35% of his patients expressed concerns with problems pronouncing and forming sounds throughout the entire treatment period; Fritz et al. reported that 24% of his patients expressed concern with speech impairments at 1 month post-appliance placement; Sinclair et al. reported that 18% of his patients continued
speech impairments after 1 month of treatment. While the majority of the patients in our present study demonstrated speech adaptation within the first three weeks after appliance placement, one patient nonetheless continued to report disturbances throughout the eight week study period. Our study may have found shorter periods for speech adaptation to lingual appliances either because the customized appliance has a lower profile, or because we collected data prospectively and surveyed patients on an almost daily basis for the first week after placement and then weekly thereafter for eight weeks. This allowed us to characterize in greater detail the time course for speech adaptation immediately after lingual appliances were placed whereas previous studies used greater intervals between time points.

Sinclair et al. stated that patients should be informed prior to treatment that a period of adaptation to lingual braces should be anticipated. The purpose of our research was to characterize more precisely patient’s physiologic response to CU lingual appliances during the first eight weeks of treatment, with emphasis on the first week of treatment. Specific aims were to determine if there is any difference in intensity and duration over time for: 1) functional impairment, including soft tissue discomfort and speech disturbances, associated with CU lingual appliances; 2) tooth pain resulting from CU lingual appliances.

CONCLUSIONS

There were more discomfort and speech disturbances associated with the first three weeks of treatment with customized lingual appliances, with patients reporting the highest discomfort and pain levels during the first week after appliance placement. Under the conditions of this study, we concluded the following: functional impairment and tooth pain were greatest during the first week after appliance placement, with peak reported values
occurring between the first 48 and 72 hours respectively. Tooth pain had subsided by the end of the second week; functional impairment improved by the end of the third week.

This prospective pilot study provides data to suggest that patient comfort and speech adaptation to lingual appliances are better with customized appliances than pre-fabricated appliances. Compared to previous studies using retrospective questionnaires, our use of a prospective questionnaire helped to capture patient’s immediate assessment of their physiologic adaptation to customized lingual appliances over their initial eight weeks of treatment. Patients reported that eating, chewing and food collection were the most troublesome concerns, while questions about gagging, swallowing and daily activities were the least problematic for patients during their first week of treatment. Patients were able to overcome speech problems in a shorter time period than with pre-fabricated lingual appliances. Difficulties with pronunciation were greatest on the first day after appliances were placed but improved continuously until week three at which time speech returned to near baseline.

Though limited in size, the strength of our study lies in its prospective design and collection of data at more frequent time points immediately after placement of lingual appliances. The results offer a more detailed understanding of the accommodation timeline for patients treated with these appliances and should enable orthodontists to help prospective lingual patients decide if customized lingual appliances are the right choice.
Appendix I

Example of a Demographic Page 1
For the purpose of advancing medical-dental education, I give permission for observers to be admitted to the treatment room, and for the School of Dentistry staff to make and use any records including x-rays, dental casts, x-ray tracings, and photographs of the patient for diagnostic, scientific or educational purposes. These records and clinical information contained in the patient record may be used in anonymous research studies for statistical analysis of types of care rendered. (You may refuse this by marking through this statement and initialing it.)

I confirm that I have read this form, or it was read to me, and that all blanks were filled in and all inapplicable information, if any, was crossed out before I signed below.

Signatures: ___________________________ Date: _____/____/____

Patient: ________________________________

Witness: ________________________________
Appendix II

Example of Questionnaire Page
Appendix III

Example of Customized Lingual Appliances
Appendix IV

**Impaired Biting**

- Patient 1
- Patient 2
- Patient 3
- Patient 4
- Patient 5
- Patient 6

**Impaired Chewing**

- Patient 1
- Patient 2
- Patient 3
- Patient 4
- Patient 5
- Patient 6
Impaired Swallowing

Time

Impaired Daily Activities

Time
Impaired Tongue Placement

Gagging
Patient’s Reported Functional Impairment During the Initial Eight Weeks of Treatment
Patient’s Reported Speech Impairment During the Initial Eight Weeks of Treatment
Biting on Front Teeth

Biting on Back Teeth

Time

Pain Intensity
Patient’s Reported Tooth Pain During the Initial Eight Weeks of Treatment
## Appendix V

### Function Baseline Day 1 Day 2 Day 3 Day 5 Day 7

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Means and standard deviations of functional impairment for baseline through week eight following appliance placement

(Likert Rating Scale: 1 = No trouble, 5 = Lots of trouble)
Means and standard deviations of tooth pain for baseline through week eight following appliance placement
(Numerical Rating Scale: 0 = No pain, 10 = As bad as you can imagine)
REFERENCES


