UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

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Influence of different orthodontic upper retainers in speech: analysis by laypersons and acoustic analysis

Influência de diferentes contenções ortodônticas superiores na fala: análise por leigos e análise acústica

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Tese constituída por artigos apresentada a Faculdade de Odontologia de Bauru da Universidade de São Paulo para obtenção do título de Doutor em Ciências no Programa de Ciências Odontológicas Aplicadas, na área de concentração Ortodontia.

Orientador: Prof. Dr. José Fernando Castanha Henriques

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FOLHA DE APROVAÇÃO

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“Lute com todas tuas forças, agarra-te a todas as oportunidades, e nunca prejudique ninguém. São somente 3 atitudes para ter sucesso de forma honrosa”

Rodrigo Higa

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ABSTRACT

Influence of different orthodontic upper retainers in speech: analysis by laypersons and acoustic analysis

Introduction: The aim of this study was to evaluate the influence of different upper retainers in speech, through Perceptual Auditory Analysis by the laypersons and acoustic analysis. **Methods:** Eighteen volunteers were selected to use four types of upper retainers: conventional Wrap-Around (CWA), modified horseshoe Wrap-Around (HWA), modified anterior hole Wrap-Around (AHWA) and vacuum-formed (VF). They were used for 21 days each, with intervals of 7 days without use among them. Speech evaluation was performed in vocal excerpts recordings made before installation of the retainers (T0), immediately after the installation of each retainer (T1), and 21 days after the installation (T2). The Perceptual Auditory Analysis of laypersons was performed by means of the visual analogue scale of 100 mm, while the acoustic analysis consisted of the mean diadochokinesia (DDK) rate evaluation, as well as the formant frequencies F1 and F2 of the fricative consonants. One-way ANOVA and two-way ANOVA were used. **Results:** In the Perceptual Auditory Analysis of laypersons, there was a worsening in the values of T0 to T1 in all the retainers, but only for CWA and VF the values were statistically lower. In T2 the values increased, but for the VF the value still remained statistically lower than T0 while for the AHWA the difference of T0 for T2 was practically null. There were no changes in DDK values. For the formant frequencies, in general way there was a difference from T0 to T1 and a little difference from T0 to T2, whereas in the comparison among the devices the CWA presented greater changes in the F1 formants of some consonants, whereas AHWA presented lower values, with the others devices showing intermediate values. **Conclusions:** In both types of analysis (subjective and objective), there was a change in speech after the installation of each retainer, with an improvement after 21 days of use. The laypersons considered larger speech disorders involving VF, and smaller ones involving AHWA. For the acoustic analysis, the changes were greater for CWA, whereas for AHWA there were lower changes.

Key words: Orthodontic Appliance Design; Orthodontics, Corrective; Recurrence; Speech; Speech Sound Disorder.

RESUMO

Influência de diferentes contenções ortodônticas superiores na fala: análise por leigos e análise acústica

Introdução: O objetivo deste estudo foi avaliar a influência de diferentes contenções superiores na fala, através de análise perceptiva auditiva por leigos e análise acústica. **Métodos:** Dezoito voluntários foram selecionados para utilizar quatro tipos de contenções superiores, sendo elas: placa Wrap-Around convencional (WAC), Wrap-Around modificada em formato de "ferradura" (WAF) Wrap-Around modificada com "orifício anterior" (WAO) e contenção termoplástica transparente (CTT). Elas foram usadas por 21 dias cada, com intervalos de 7 dias sem utilização entre elas. A avaliação da fala foi realizada em gravações de trechos vocais realizadas antes da instalação das contenções (T0), imediatamente após a instalação de cada contenção (T1), assim como após 21 dias de uso destas (T2). A análise perceptiva auditiva dos leigos foi realizada através da escala visual analógica de 100 mm, enquanto a análise acústica consistiu na avaliação da média da taxa de diadococinesia (DDC), bem como a frequência dos formantes F1 e F2 das consoantes fricativas. Os testes ANOVA a um critério e ANOVA a dois critérios foram utilizados. **Resultados:** Na análise perceptiva auditiva dos leigos houve uma piora nos valores de T0 para T1 em todas as contenções, mas somente para WAC e CTT os valores foram estatisticamente menores. Em T2 os valores voltaram a aumentar, mas para CTT ainda houve um valor estatisticamente menor do que T0 enquanto para WAO a diferença de T0 para T2 foi praticamente nula. Não houve alterações nos valores da DDC. Para os formantes, de uma maneira geral houve uma diferença de T0 para T1 e pouca diferença de T0 para T2, enquanto na comparação entre os aparelhos a WAC apresentou alterações maiores nos formantes F1 de algumas consoantes, enquanto WAO apresentou valores menores, e os demais dispositivos valores intermediários. **Conclusões:** Nos dois tipos de análise (subjetiva e objetiva) houve alteração na fala após a instalação de cada contenção, havendo uma melhora após 21 dias de uso. Os leigos consideraram maiores as alterações da fala envolvendo a CTT, e menores envolvendo WAO. Para a análise acústica os valores foram piores para WAC, enquanto para WAO as alterações foram menores.

Palavras-chave: Desenho de Aparelho Ortodôntico; Ortodontia Corretiva; Recidiva; Fala; Transtorno Fonológico.

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LIST OF ABREVIATIONS AND ACRONYMS

CWA	Conventional Wrap-Around
HWA	Horseshoe-shaped Wrap-Around
AHWA	Anterior hole Wrap-Around
VF	Vacuum-formed
T0	Time 0
T1	Time 1
T2	Time 2
DDK	Diadochokinesia
SD	Standard Deviation
MBGR	Marchesan, Berrentin-Felix, Genaro, Rehder
TMJ	Temporomandibular joint

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1 Introduction

1 INTRODUCTION

Orthodontic retainer is used to prevent the natural tendency of the teeth in to return to their initial position, commonly called relapse.(MELROSE; MILLETT, 1998; LITTLEWOOD et al., 2006) Several types of retainers are described in the literature, but according systematic review, there are no data that scientifically consolidate the clinical choice of retainer, i.e., no significant evidence that a type of retainer is more interesting in relation to its function than other. Due to lack of scientific evidence related to the retention phase, current recommendations are based on personal preferences and not scientific criteria.(LITTLEWOOD et al., 2006)

Hawley retainer, originally described by Hawley in 1919,(HAWLEY, 1919) is one of the retainers most widely used for a long time. It is currently constituted of an acrylic portion that involves the entire palate, although there is a modification of the Hawley presenting relief in the central portion of the palate, taking the shape of a horseshoe.(JOONDEPH, 2012)

Another type of orthodontic device that have been increasingly used is the vacuum-formed (VF). Although it was developed in the 70s, it gained popularity after the advent of the clear aligners. In addition, the simplicity and convenience of manufacture technique, the cost and demand for esthetic devices reinforce the increase in its use.(HICHENS et al., 2007; BARLIN et al., 2011) An important aspect to be discussed is the increased number of occlusal contacts after the end of active orthodontic treatment during the retention phase. Investigations show that the VF, for covering the occlusal surface, impair the vertical adjustment and increase the number of contacts post treatment, which usually occurs with the Hawley.(SAUGET et al., 1997; HOYBJERG; CURRIER; KADIOGLU, 2013)

In Brazil, a survey conducted in orthodontic laboratories of the São Paulo city, showed that the most requested devices are the Hawley and wrap-around retainer.(ASSUMPÇÃO et al., 2012) Other Brazilian researchers submitted a questionnaire about the clinical procedures used during the retention phase to all specialization courses registered in the Federal Concil of Dentistry, and found that the most commonly used maxillary retainers are Hawley (28%), the wrap-around (22%)

and VF (12%).(LIMA et al., 2012) A study conducted in England with 240 orthodontists showed that VF is the choice of the majority of the orthodontists in detriment of fixed retention and Hawley, both in private practice (45%) and British National Health Service (56%).(SINGH; GRAMMATI; KIRSCHEN, 2009) In United States, a study conducted in 2010 with 658 orthodontists members of the American Association of Orthodontists revealed other behavior, where Hawley was the first choice among the retainers to 58% of the respondents, followed by VF (30%).(VALIATHAN; HUGHES, 2010)

It is noticed that the usage time of the retainer is long and intense, so it must, besides keeping the teeth in their position, be comfortable for the patient, a feature that is directly related to cooperation of the use.(WONG; FREER, 2005; VALIATHAN; HUGHES, 2010; AB RAHMAN; LOW; IDRIS, 2016) Ultimately, the success of the retation phase with removable appliances depends directly on the collaboration and it will always be under suspicion. Yet, the feedback from patients about their cooperation will always be subjective and hard to be translated into objective data.(ACKERMAN; THORNTON, 2011)

The effect of retainers on speech articulation can also affect the formation of vowels as well as consonants. During the production of vowel sounds the shape of the supralaryngeal vocal tract continually changes. Thus, several resonances, ranging from low frequency to high frequency and produced by positioning the articulators in the vocal tract, and a set of articulatory parameters are used to describe them: the highest point of the tongue on the horizontal axis (front, back), the highest point of the tongue on the vertical axis (close, open), and lip shape (rounded, unrounded).(BOWERS; TOBEY; SHAYE, 1985) Thus, a particular combination of articulator positions is associated with a vocal tract shape, which is in turn associated with a particular pattern of resonances. The resonances of the vocal tract are called formants.(SHRIBERG; KENT, 2003) Formant frequencies are determined by the length and shape of the supralaryngeal vocal tract. Formants are visible on an acoustic display of speech as pronounced bands of energy such as spectrograms.

Formant frequencies represent an objective measure that may be useful in studying the effects of treatment on vocal function. Formants are the resonant harmonics in the speech spectrum and are described as being the characteristic

partials that help identify the vowel to the listener. Formants are believed to be responsible for the phonetic characterization of vowel quality and are essential components in the perception of speech.(ATAL; HANAVER, 1971; BAKEN; ORLIKOFF, 2000)

Studies about the negative influence of removable orthodontic retainers in the speech are not new, and the first one date of 1957, with suggestions of the temporary character of these changes.(FELDMAN, 1956) In 1967 it was suggested that thinner devices and with roughness in the anterior palate region allow better adaptation of the speech and that, in general, this process occurred in a period of 2 weeks.(ERB, 1967)

A study was performed in the 1990s evaluating different types of HR in the maxillary arch and its influence on speech.(STRATTON; BURKLAND, 1993) The differences in appliances specially involved the design of the palatal acrylic cover, that was approximately 5 mm of thick in these devices. The retainers evaluated were conventional Hawley, horseshoe-shaped Hawley acrylic and one Hawley without acrylic in the palate anterior region of canine to canine, and these teeth were stabilized by a wire that touch their palatine faces and is incorporated to the acrylic in the posterior region.

In the first stage of the study all devices have been used by a patient, who was one of the authors and also hearing care professional. He pronounced a phonetically balanced text without retainer and after installing each of the 5 retainers randomly. In each of these times the patient was assessed by 13 evaluators, 11 hearing care professionals, by means of a clearness speech scale that varied according to the number of distorted words. The horseshoe-shaped HR showed statistically better grades. In the second stage, the three devices with better grades were tested in 9 patients and assessed by 18 evaluators in the same way. The results showed that devices with a reduction of palate acrylic were more interesting to speech, compared to the total of acrylic palate cover ones. (STRATTON; BURKLAND, 1993)

In an investigation methodologically most current and elaborated, the effect of the classic Hawley in pronunciation phonetically balanced syllables was evaluated The Hawley had shaped slightly in horseshoe-shaped and a thickness standard between 2 and 3 mm. After orthodontic treatment, 15 patients were included in the study and

recordings of the pronunciation of syllables were made without retainer, with the maxillary and mandibular Hawley and only with maxillary or mandibular Hawley. The recordings were made at the installation time and 1 and 7 days after installation, and later they are analyzed by hearing care professionals evaluators, which recorded the number of syllables changed in each phase. It was observed that speech articulation problems, initially present especially in the fricative phonemes, decreased with time, and after a week, practically disappeared or decreased to a level that does not hurt the clearness of the pronunciation. Another interesting finding was that the alterations on the first day of use of the retainer were significant in the ratings with the maxillary and mandibular retainers used concomitantly or when only the maxillary one was present. Patients using only the mandibular retainer showed no significant changes, demonstrating the clear and preponderant influence of the maxillary device on the injury to speech.(HAYDAR et al., 1996)

Until recently, studies about the interference in the speech caused by orthodontic retainers were performed with subjective evaluation, by perception of patients or hearing care professional evaluation.(HAMLET, 1973; GARBER; SPEIDEL; SIEGEL, 1980; GARBER et al., 1980; STRATTON; BURKLAND, 1993; HAYDAR et al., 1996; DE FELIPPE et al., 2010) The objective evaluation of these effects made possible with the introduction of the acoustic analysis in the methodology. (HARDCASTLE; GIBBON; JONES, 1991; LUNDQVIST et al., 1995; SUMITA et al., 2002) Previously, this tool successfully already was used to evaluate the effects of other orthodontic or surgical procedures in the speech, as rapid maxillary expansion and orthognathic surgery.(NIEMI et al., 2006; SARI; KILIC, 2009; STEVENS et al., 2011)

According to these studies, the rapid maxillary expansion appliances change the F1 and F2 formants of the vowel "i" when installed, and that they only return to the normal initial standards after 2 to 3 months with the device in position.(STEVENS et al., 2011) In surgical Class III patients who underwent mandibular setback, almost all vowels showed significant changes in the formants in post-surgical time, but especially in anterior and low vowels the formants remained changed 6 months after surgery.(AHN et al., 2015)

With this new tool, a study evaluated the effect of Hawley in formants of vowels by the acoustic analysis. For this, were selected 12 patients that received the maxillary and mandibular Hawley, evaluated in 4 times (immediately after installation, after one week, one month and three months of the installation), objectively by acoustic analysis of the formants of vowels, and subjectively with consonant articulation test in phonetically prepared syllables. Only patients who did not have any articulation of speech problems previosly were included. The results showed distortions in the "s" and "z" consonants as well as in the F1 formants (increase) and F2 (reduction) of the "i" vowel. These changes were more evident in the first periods evaluated, especially immediately after installation and after a week of use. Moreover, these changes were more evident in patients with Hawley in the maxillary and mandibular arch or only in the maxillary arch. In the evaluation after 1 month of use and especially after three months, clear standardization it was observed. However, some patients still showed small disturbances in the speech after 3 months.(KULAK KAYIKCI et al., 2012)

The current literature on the retainers used in orthodontics is limited, especially if we analyze the changes in speech produced by different retainers. In addition, all studies found only evaluated the Hawley retainer. According to a recent systematic review, there are no randomized prospective clinical studies to evaluate the influence of different retainers used after orthodontic treatment in speech, with qualitative and quantitative analyzes.(MAI et al., 2014)

2 ARTICLES

2 ARTICLES

The articles presented in this Thesis were written according to the American Journal of Orthodontics and Dentofacial Orthopedics instructions and guidelines for article submission.

- ARTICLE 1 - Perception of laypersons on speech changes promoted by upper orthodontic retainers
- ARTICLE 2 - Influence of upper orthodontic retainers on speech: an acoustic analysis

2.1 ARTICLE 1

Perception of laypersons on speech changes promoted by upper orthodontic retainers

ABSTRACT

Introduction: The aim of this study was to evaluate the influence of different upper retainers in speech, through Perceptual Auditory Analysis by the laypersons. **Methods:** Eighteen volunteers were selected to use four types of upper retainers: conventional Wrap-Around (CWA), modified horseshoe Wrap-Around (HWA), modified anterior hole Wrap-Around (AHWA) and vacuum-formed (VF). They were used for 21 days each, with intervals of 7 days without use among them. Speech evaluation was performed in vocal excerpts recordings made before installation of the retainers (T0), immediately after the installation of each retainer (T1), and 21 days after the installation one (T2). The Perceptual Auditory Analysis of laypersons was performed by means of the visual analogue scale of 100 mm. One-way ANOVA and two-way ANOVA were used. **Results:** there was a worsening in the values of T0 to T1 in all the retainers, but only for CWA and VF the values were statistically lower. In T2 the values increased, but for the VF the value still remained statistically lower than T0, while for AHWA the difference of T0 for T2 was practically null. **Conclusions:** there was a change in speech after the installation of each retainer, with an improvement after 21 days of use. The laypersons considered larger speech disorders involving VF, and smaller ones involving AHWA.

Key words: Orthodontic Appliance Design; Orthodontics, Corrective; Recurrence; Speech; Speech Sound Disorder.

INTRODUCTION

The retention phase in the orthodontic treatment is extremely important, however, it is often necessary the patients' collaboration in order to be effective, since in the maxillary arch the most of the retainers are removable. Therefore, the retainer should be as comfortable as possible and should not negatively influence your quality of life.[1-4]

The most common upper retainer devices are Hawley, which are made of stainless steel wire and acrylic resin, existing some variations with respect to their design, especially in the acrylic design. However, the vacuum-formed retainer (VF) became popular after the esthetic aligners rise, and has been increasingly used, mainly due to its esthetics, ease of manufacture and low cost.[5-7]

The choice of retainer by orthodontist has not been based on scientific findings, since there is no evidence to support the superiority of any type of retainer. Therefore, it is based on other aspects such as professional preference, costs, initial malocclusion, mechanics used, esthetics, and patient comfort. [3-5]

Among these aspects, the comfort of the patient is influenced by several factors, among them the influence on speech. Clinically it is possible to notice that after the installation of the upper retainers there is a change in the patient's speech, and therefore many studies have evaluated these alterations.[8-13] These studies found distortions of linguoalveolar, linguopalatal and linguodental sounds, immediately after the installation. However, they concluded that these changes tend to disappear completely after the first seven days. [9,12]

The first studies that evaluated the influence of orthodontic retainers on speech aimed evaluating the changes in a subjective way, assisted by speech therapists for a more careful evaluation.[8,9] There were changes in speech immediately after the installation of the retainers, mainly related to the consonants /d/ and /t/, which tend to decrease or even disappear after a certain period of use of the retainer.[9] Erb[8] related Hawley's design to speech changes. By increasing the thickness of the acrylic, greater changes could be observed. Moreover, when roughnesses in the anterior portion of the acrylic were performed, these changes tended to be lower.

Other more recent studies have evaluated the changes in speech in orthodontic retainers objectively by means of acoustic analysis.[11-13] These methods have been very useful and accurate in identifying greater speech disorders, mainly because of the

possibility of quantifying these changes. Kulak Kaiykci et. al[12] found distortions in the vowel /i/, while Atik et al.[11] observed greater distortions in vowels /a/ and /e/. Wan et. al[13] also found distortions in several consonants and vowels in both VF and Hawley.

However, there are no studies that evaluate the perception of laypersons for speech changes in orthodontic retainers, since it is not known whether these people perceive these changes as well as professionals or computer programs. This group includes people who do not belong to the area of dentistry or speech therapy. Thus, the purpose of this study is to evaluate if lay people identify changes in speech caused by different contentions, and if there is a difference between these devices for these people.

MATERIAL AND METHODS

Sample size calculation

For calculation of the sample size, authors considered the score attributed by laypersons for speech changes, considering a standard deviation of 21, alpha error of 5% and test power of 80%. Thus, 15 volunteers were required. Twenty volunteers were initially recruited, which after the losses during the study concluded in a total number of 18.

The participants were selected voluntarily among undergraduate and postgraduate students of the Bauru Dental School – University of São Paulo, Bauru - SP, Brazil, using the following inclusion criteria:

- Brazilians, between 20-40 years of age, native speakers of the Portuguese language;
- Presence of first and second permanent molars;
- Presence of an acceptable occlusal relationship, with class I molar relation (Variations up to ¼ of class II or III were accepted).

The exclusion criteria used for this study were:

- Presence of anterior or posterior crossbite or edge-to-edge bite, anterior open bite, deep bite (> 50%), marked overjet (> 4 mm), crowding greater than 2 mm and generalized anterior diastema.
- Be under orthodontic treatment or have it completed less than 12 months, minimizing the effect of possible orthodontic relapse in speech production;

- Use any type of maxillary retainer in the last 2 months.
- Presence of edentulous spaces; Craniofacial anomalies; Intellectuals deficits, syndromes, neurological disorders and psychiatric, smoking, alcoholism and anterior laryngeal surgery;
- Presence of lingual frenulum alteration, according to MBGR protocol,[14] considering the measure of the maximum interincisal distance with the lingual apex touching the incisive papilla, divided by the interincisal distance with maximum buccal opening. Values lower than 0.5 characterized the frenulum alteration and sample exclusion.
- Presence of signs of temporomandibular joint (TMJ) dysfunction, according to MBRG protocol,[14] investigated by means clinical examinations related to the presence or absence of: TMJ noises and palpation pain in the TMJ or in the trapezius, sternocleidomastoid, anterior superficial and temporal masseter muscles. The presence of one of these excluded the volunteer from the sample.
- Presence of pathological vocal alteration, confirmed after a speech therapist evaluation, composed of auditory perceptual analysis by the emission of the vowel "a" sustained by 6 seconds, count from 1 to 10 and a spontaneous conversation of 30 seconds.

The following retainers were used: conventional Wrap-around (CWA), modified with modified horseshoe shaped Wrap-around (HWA), anterior hole Wrap-around (AHWA), and vacuum-formed (VF). All the retainers used in this study were made by the same laboratory technician (Fig.1).

This study characterized a Randomized Crossed Clinical Trial, where the criteria proposed in CONSORT STATEMENT 2010 were followed. Participants (N = 18) were randomly distributed and stratified by gender (numbers were determined for groups and volunteers, unknown to who performed the random allocation), through a computerized program in 4 subgroups with 5 or 3 subjects each.

Each subgroup used one of the four types of upper retainer for 21 days (+ 1 day), with full-time use orientation, removing the retainer only during feeding and sleep, as well as social events. After this period, they remained without the retainer for 1 week (washout period) and then used another type of retainer for the same time.

In the same way, it occurred with the other devices and, thus, all used the 4 retainers proposed. Thus, the crossed design was characterized, where the volunteers

were their own controls to evaluate the changes produced in the speech and the perceptions generated by the retainers. The phonetic evaluations were performed before (T0), immediately after the installation (T1) and 21 days (+- 1 day) after the installation (T2) of each device (Fig 2).

The speech recordings for later analysis were made with AKG headphone, model C444PP, connected to the Creative soundcard, of the Audigy II brand, positioned at 60 degrees of the lips commissure. The recordings were made with the program Sound Forge 9.0 (Sony), in sample rate of 44,100Hx, mono channel, in 16Bit.

For the Perceptual Auditory Analysis, the test followed principles described in the literature, using the section focused on the speech of the MBGR protocol,[14] in which the volunteers were requested to produce an automatic speech, consisting of the counting from 1 to 10, days of the week and the months of the year.

Speech samples were evaluated by 10 laypersons randomly selected (this group includes individuals who are not related to speech therapy or dentistry) by means Visual Analogue Scale of 100 mm (Fig. 3). They voluntarily participated in the study. The layperson was instructed to mark the speech quality level from 0 to 100 on the scale, where 0 represents poorer pronunciation and 100 represents the best speech quality possible. They were instructed to assign a score at the end of each heard audio. All the laypersons assigned scores for all 162 audios, i.e., all volunteers with all retainers in all periods were heard and analyzed.

Statistical Analysis

The laypersons repeated 30% of the sample at least 1 month after the first evaluation. Random error evaluation was made using the Dahlberg formula, while the systematic error evaluation was done by the paired t-test, with $p > 0.05$ for statistically significant differences.

Shapiro Wilk tests were used to verify the normal distribution of the variables. Since all had normal distribution, parametric tests were used.

To evaluate the differences between the periods, one-way ANOVA test was used. To evaluate the differences between the retainers, two-way ANOVA test was used, using the value of the difference of T0 to other periods.

All statistical analyses were performed with Statistica software (Statistica for Windows – Release 10.0 - Copyright Statsoft, Inc. Tulsa, Okla), at the $P<0.05$ level of significance.

RESULTS

Random error evaluation for the variables of the laypersons scores attributed to audios was a maximum of 8.56. This value was considered small. Systematic errors were not found ($p = 0.33$).

In relation to the periods, a statistically significant difference was observed for CWA, where T1 had worse scores than T0. In T2 these scores increased, and were statistically similar with both T1 and T0. The VF also presented a statistically significant difference; however, both T1 and T2 had lower scores compared to T0. The other two retainers presented no statistical difference among the periods (Table I).

In the comparison among the retainer with respect to period, a high difference from T1 in relation to T0 for VF was observed, when compared with the other retainers. The smallest differences were observed for HWA and AHWA retainers. In all devices, the values of the difference from T0 to T2 were smaller than from T0 to T1. For AHWA, this difference was almost null (Table II).

DISCUSSION

Some studies have investigated the influence of removable upper retainer devices, but none of them presented a single blind crossover study, where only the evaluators did not know which group belonged to the evaluated volunteer, and the same volunteers used all retainers.[8-13,15-18] Differently from these studies, we evaluated speech changes in the same group of 18 patients who used the four retainers in different phases, which favors the comparisons.

Studies on speech disorders have been performed for more than half a century, and have evolved since then.[8,9,11-13] Researchers have sought to study this topic because speech changes is one of the factors that influence the patient in the cooperation of the use of this device.[18] Until a few years ago, methodologies were composed of subjective speech analysis performed by specialized speech therapists.[8-10] Recently, with the progress of the spectrogram, studies using acoustic analysis have been used to quantify these changes in a more detailed way.[11-13] However, speech therapists and computer software will often identify problems that are not perceptible to non-specialist people. In this study, it was possible to establish an overview of the

perception of the laypersons in relation to these changes. The statistical difference found in this study showed that they could perceive that there is difference in speech in the different phases.

The results of the Perceptual Auditory Analysis performed by laypersons revealed that there was a worsening of the scores between the T0 and T1 moments in all the retainers analyzed, while in T2 the mean of the scores increased again. These results are in agreement with other studies that also pointed out a significant speech changes after the installation of the retainers and a decrease of these changes after a period of time.[8,9,12,13] Thus, it is safe to say that there is a capacity of the structures involved in speech function of adapting to device after a time. However, this adaptation time is not well established in the literature.

Some studies showed shorter periods of adaptation, around 2 weeks,[8,9] while others showed a longer period[11,12] reaching more than 2 months for adaptation. In this study, the late evaluation was done after 21 days of installation of retainer, and although the groups involving this period (T2) had better scores than T1, these were still lower than T0, except for the AHWA group who presented a difference in relation to T0 very close to zero. Thus, it is possible to affirm that for total adaptation of the patient's speech, it would be necessary to wait an even longer period for most of the retainers.

The retainer that presented the highest changes in the scores in relation to T0 was the VF. This contention, in addition to presenting a small mean score for T1, also presented this characteristic for T2, compared with the other groups. These results allow us to say that this device generated more significant disturbs in speech. Although VF does not present acrylic on the palate, theoretically resulting in an improvement in speech changes, it significantly interferes with occlusion, also increasing the vertical dimension of the patient.[19,20] These factors may have influenced the smaller scores for this device.

The findings of this study differ from others that compared VF with Hawley plate.[11,13] Atik et. al.[11] compared the effects of VF with horseshoe-shaped Hawley, using acoustic analysis of the "e" and "a" vowel formants, and the “voice onset time” parameter for consonants. The results indicated changes in both retainers, but they were more intense for Hawley. Wan et al.[13] also compared these two devices using acoustic analysis, and presented similar results to the previous study.

Reasons for the difference in the results of these studies for this present one may be the different design of the sample, the methodology applied (in this study were laypersons who evaluated the pronunciations subjectively, while the others were performed acoustic analysis), and the retainer design, since they used Hawley while this study used Wrap-Around. Hawley has an Adams clamp that passes through the points of contact, often interfering with occlusion, unlike the Wrap-Around, which can have steel wire around the buccal and lingual portion of teeth, not interfering with occlusion.

Among the Wrap-around, the retainers modified by the decrease in acrylic presented better scores than the CWA. AHWA is a device routinely used as retention for anterior open bite treatments, functioning as a tongue position educator. However, with this lower volume of the palate in the anterior region, we believe that the influence on speech could be lower. The idea that the change in volume and design of acrylic in Hawley had already been proposed by Erb.[8] His study compared Hawley with 2 and 2.5 mm thicknesses, in addition to comparing Hawley with the polished surface of acrylic with the insertion of roughness in anterior region. The study concluded that the decrease in acrylic thickness contributed to a lower speech disturbance, in the same way as the insertion of roughness, which acted as an accelerator of adaptation to retainer. In the same way, our study found better results for Wrap-Around with modification in the anterior region (AHWA), including better adaptation after 21 days.

From a clinical point of view, the choice of orthodontist in relation to retainer used should follow other criteria than the influence of speech, but according to the results of that study, if the Wrap-Around type is chosen, a least amount of acrylic possible in the anterior region is suggested. The modification of the AHWA type presented a good choice as to the speech disturbance. The slightest influence on speech is not a reason for establishing the choice of VF versus Wrap-Arounds.

CONCLUSION

According to the methodology applied, it is possible to affirm that:

- All retainers presented a decrease in speech quality according to the laypersons perception, but this decrease was statistically significant only for conventional Wrap-Around and vacuum-formed retainer.

- After 21 days of use, speech changes generally decreased, but only for modified anterior hole Wrap-Around these changes have practically disappeared.
- The vacuum formed presented the greatest changes in speech, followed by conventional Wrap-Around and the modified horseshoe-shaped Wrap-Around. Modified anterior hole Wrap-Around presented the best scores.

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FIGURE CAPTIONS

Fig 1. Retainers evaluated **A**, conventional Wrap-Around; **B**, modified horseshoe-shaped Wrap-Around; **C**, modified anterior hole Wrap-Around; **D**, vacuum-formed.
Fig 2. Subgroups randomly distributed according to the retainer, periods of use and days of phonetic evaluations.
Fig 3. Analog Visual Scale of 100 mm used.

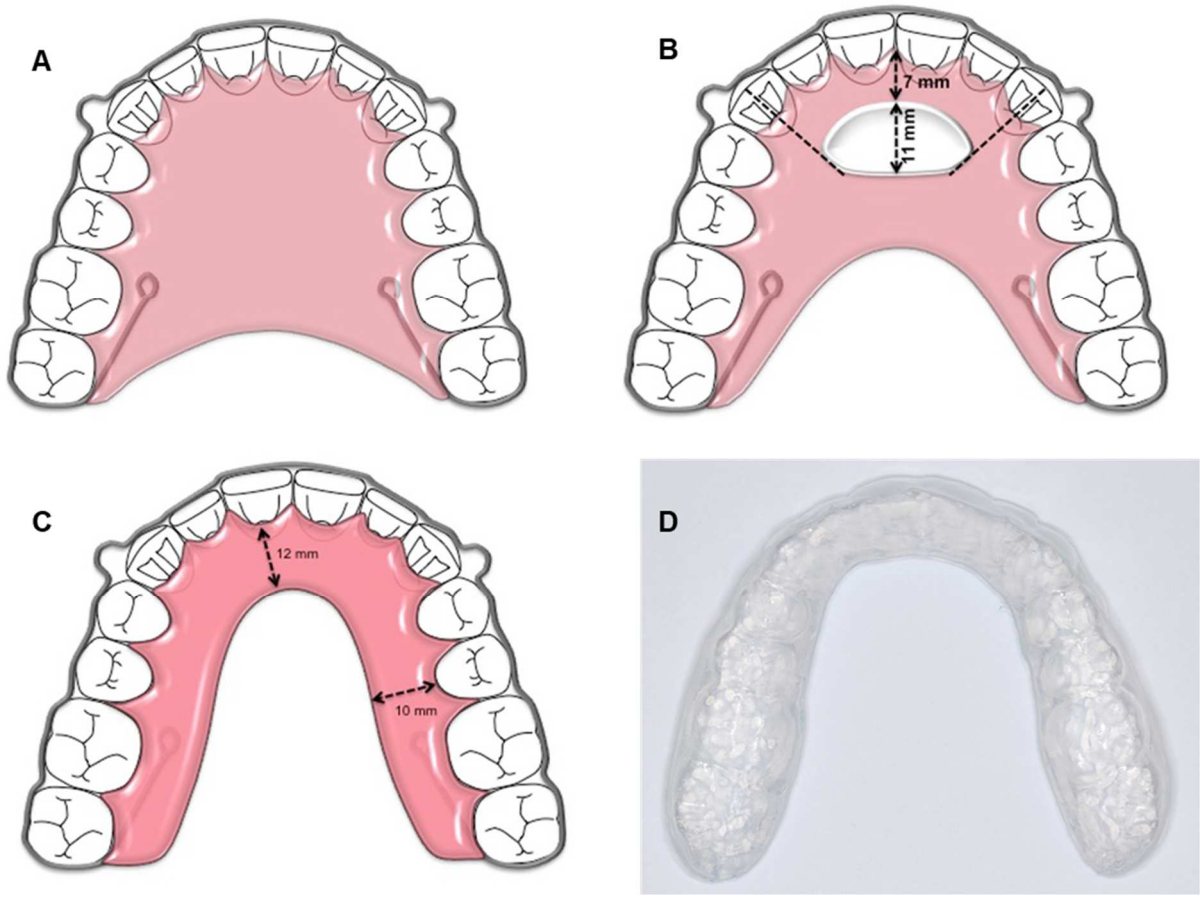

Fig. 1

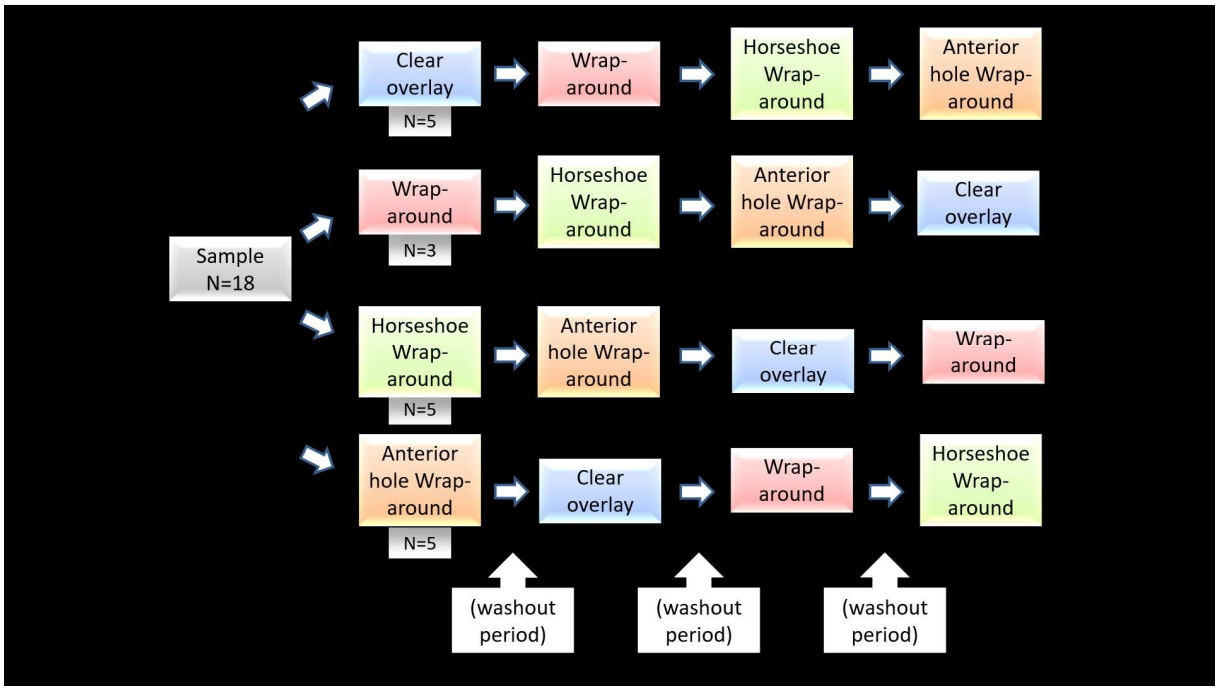
Sample
N=18
Clear overlay
N=5
Wrap-around
N=3
Horseshoe Wrap-around
N=5
Anterior hole Wrap-around
N=5
Wrap-around
Horseshoe Wrap-around
Anterior hole Wrap-around
Clear overlay
Horseshoe Wrap-around
Anterior hole Wrap-around
Clear overlay
Wrap-around
Anterior hole Wrap-around
Clear overlay
Wrap-around
Horseshoe Wrap-around
Clear overlay
Anterior hole Wrap-around
Wrap-around
Horseshoe Wrap-around
(washout period)
(washout period)
(washout period)

Fig. 2

Fig. 3

Table I: Descriptive statistics of the Perceptual Auditory Analysis of the laypersons (one-way ANOVA)

Group	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	86,5722 (18,5508) [A]	81,3833 (20,7381) [B]	84,4222 (19,5227) [AB]
HWA	86,5722 (18,5508)	83,2166 (19,4865)	85,9888 (20,8881)
AHWA	86,5722 (18,5508)	82,0333 (18,9848)	82,8833 (18,6103)
VF	86,5722 (18,5508) [A]	76,3222 (23,0563) [B]	81,25000 (20,6459) [B]

*Statistically significant at $p < 0.05$

Table II: Difference of notes between the devices in T1 and T0 with T0 (changes generated by the devices)

Group	T1 mean (SD)	T2 mean (SD)
CWA	5,18889 (24,58591) [AB]	2,15000 (20,99334) [A]
HWA	3,35556 (22,04937) [A]	3,68889 (20,14509) [A]
AHWA	4,53889 (22,43460) [A]	0,58333 (20,49141) [A]
VF	10,25000 (23,14754) [B]	5,32222 (23,20919) [AB]

*Statistically significant at p <0.05

2.1 ARTICLE 2

Influence of superior orthodontic restraints on speech: an acoustic analysis

ABSTRACT

Introduction: The aim of this study was to evaluate the influence of different upper retainers in speech, through acoustic analysis. **Methods:** Eighteen volunteers were selected to use four types of upper retainers: conventional Wrap-Around (CWA), modified horseshoe Wrap-Around (HWA), modified anterior hole Wrap-Around (AHWA) and vacuum-formed (VF). They were used for 21 days each, with intervals of 7 days without use among them. Speech evaluation was performed in vocal parts recordings made before installation of the retainers (T0), immediately after the installation of each retainer (T1), and 21 days after the installation (T2). The acoustic analysis consisted of the mean diadochokinesia (DDK) rate evaluation, as well as the formant frequencies F1 and F2 of the fricative consonants. One-way ANOVA and two-way ANOVA were used. **Results:** There were no changes in DDK values. For the formant frequencies, in general way there was a difference from T0 to T1 and a little difference from T0 to T2, whereas in the comparison among the devices the CWA presented greater changes in the F1 formants of some consonants, whereas AHWA presented lower values, with the others devices showed intermediate values. **Conclusions:** There was a change in speech after the installation of each retainer, with an improvement after 21 days of use. The changes were greater for CWA, whereas for AHWA there were lower changes.

Key words: Key words: Orthodontic Appliance Design; Orthodontics, Corrective; Recurrence; Speech; Speech Sound Disorder.

INTRODUCTION

Retention phase in orthodontic treatment is essential for its stability, i.e., to control the tendency of the teeth in return to their position. For this, different types of devices are used for this purpose.[1-3]

The most popular device of this type is Hawley plate, originally described by Hawley in 1919, and is one of the most widely used containments for a long time.[4] It is currently constituted of an acrylic portion that involves the entire palate, although there are modifications in the design of this acrylic, presenting relief in the central portion of the palate, taking the shape of a horseshoe.[5] This modification aims provide more comfort to the patient and less interference in speech. One variation of Hawley plate is the Wrap-around or Begg retainer, which has no Adams clamps, not interfering with the occlusal.[2]

Another type of orthodontic device that have been increasingly used is the vacum-formed (VF). Although it was developed in the 70s, it gained popularity after the advent of the esthetic aligners. In addition, the simplicity and convenience of manufacture technique, the cost and demand for esthetic devices reinforce the increase in its use.[6,7] An important aspect to be discussed is the increased number of occlusal contacts after the end of active orthodontic treatment during the retention phase. Investigations show that the VF, for covering the occlusal surface, impair the vertical adjustment and increase the number of contacts post treatment, which usually occurs with the Hawley.[8,9]

It is noticed that the usage time of the retainer is long and intense, so it must, besides keeping the teeth in their position, be comfortable for the patient, a feature that is directly related to cooperation of the use.[10-12] Ultimately, the success of the retention phase with removable devices depends directly on the collaboration and it will always be under suspicion.[13]

From 10 to 15% of patients report the negative influence of speech is reason to they not use the retainer.[3] Speech may be affected by any bone deformity, muscle or dental, or any device that hinders the movement or appearance of the articulators of speech sounds.[14-16]

The most common distortions are labiodentals [f, v] or linguoalveolar [d, t, s, z] consonants, but these disruptions are minimized after a period of retainer wear as a result of functional adaptation.[17]

The effect of retainers on speech articulation can also affect the formation of vowels as well as consonants. A particular combination of articulator positions is associated with a vocal tract shape, which is in turn associated with a particular pattern of resonances. The resonances of the vocal tract are called formants.[18] Formant frequencies are determined by the length and shape of the supralaryngeal vocal tract. They are visible on an acoustic display of speech as pronounced bands of energy such as spectrograms. As a rule, the first formant (F1) is related to the height of the tongue, while the second (F2) is related to its advancement and the rounding of the lips.[19]

Formant frequencies represent an objective measure that may be useful in studying the effects of treatment on vocal function. They are the resonant harmonics in the speech spectrum and are described as being the characteristic partials that help identify the vowel to the listener. Formants are believed to be responsible for the phonetic characterization of vowel quality and are essential components in the perception of speech.[20,21]

The current literature on the retainers used in orthodontics is limited, especially if we analyze the changes in speech produced by different retainers. In addition, all studies found only evaluated the Hawley retainer. According to a systematic review, there are no randomized prospective clinical studies to evaluate the influence of different retainers used after orthodontic treatment in speech, with qualitative and quantitative analyzes.[22]

Distortions caused by the different retainers in speech articulation can also be investigated with diadochokinesia (DDK). DDK corresponds to the ability to perform fast repetitions of relatively simple patterns composed of oppositional contractions.[21] Oral and laryngeal DDK reflect the maturation adequacy and neuromotor integration of the individual, providing information on the speed, rhythm, and precision of articulatory movements and articulator position (oral DDK), and may also provide information on laryngeal neuromuscular integrity (laryngeal DDK). It evaluates the function of phono articulatory structures such as lips, tongue, palatine veil and vocal folds.[23]

DDK tests can be performed with focus on the larynx when a vowel is repeated, or with a focus on speech, when the repetition of syllables such as /pa/ /ta/ /ka/ is performed or with different syllables in sequence, for example / pataka /. The number of syllables per second usually determines this index.[24]

The aim of this study is to evaluate the influence of different types of Hawley retainer and clear retainer in the speech, through objective analysis using formants evaluation and DDK tests.

MATERIAL AND METHODS

Sample size calculation

For calculation of the sample size, authors considered the formant F2, considering a standard deviation of 280, alpha error of 5% and test power of 80%. Thus, 15 volunteers were required. Twenty volunteers were initially recruited, which after the losses during the study concluded in a total number of 18.[14]

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maximum buccal opening. Values lower than 0.5 characterized the frenulum alteration and sample exclusion.

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The speech recordings for later analysis were made with AKG headphone, model C444PP, connected to the Creative soundcard, of the Audigy II brand,

positioned at 60 degrees of the lips commissure. The recordings were made with the program Sound Forge 9.0 (Sony), in sample rate of 44,100Hx, mono channel, in 16Bit.

For the evaluation of oral motor control, the DDK was analyzed by means of the repetition of the syllables / pataka / in an uninterrupted way. Patients were instructed to keep production as fast as possible for the determined time. Each emission will be recorded for 8 seconds, with the first two and last two seconds being deleted. The number of emissions in the interval from the third to the sixth second was considered. Among the various parameters of DDK, we selected for evaluation the mean DCK rate, which consists of the number of vocalizations per second, which represents the DDK velocity.

Acoustic analysis of the formants was performed using the formant F1 and F2 of alveolar fricative consonants "s" and "z", obtained from sentences production. In order to elicit emissions, read the sentences proposed for the Brazilian Portuguese language will be performed. (Table I) All evaluations were made by the authors of the study, assisted by a speech therapist.

The evaluation will be made with the PRAAT 5404 software, developed by Paul Boersma and David Weenink at the University of Amsterdam.

Statistical Analysis

The evaluators repeated 30% of the sample at least 1 month after the first evaluation. Random error evaluation were made using the Dahlberg formula, while the systematic error evaluation was done by the paired t-test, with $p > 0.05$ for statistically significant differences.

Shapiro Wilk tests were used to verify the normal distribution of the variables. Since all had normal distribution, parametric tests were used.

To evaluate the differences between the periods, one-way ANOVA test was used. To evaluate the differences between the retainers, two-way ANOVA test was used, using the value of the difference of T0 to other periods.

All statistical analyses were performed with Statistica software (Statistica for Windows – Release 10.0 - Copyright Statsoft, Inc. Tulsa, Okla), at the $P<0.05$ level of significance.

RESULTS

Random error evaluation was a maximum of 28.13 (formant of the first letter /s/ of "bispos") for F1 and 39.56 (formant of the word "pois") for F2. These values were considered small. Systematic errors were not found ($p>0.05$).

Regarding DDK, no statistically significant differences were found related to the period evaluated or between the different groups. Although numerically T1 and T2 groups were higher than T0, all values were close enough, ranging from 2.200 to 2.413 vocalizations per second (Table II).

For formants evaluation (Table II to IX), each alveolar fricative consonant was analyzed individually. For evaluation among the periods within each retainer, differences in formant values were observed in both F1 and F2 in most of the groups. In some groups values decreased (tables III, V, VII and IX) while in others the values increased (tables IV and VI). In all groups, there was a change in the values from T0 to T1, which tended to decrease in T2.

In F2 for the same consonant, there was a statistically significant difference for all devices studied among the periods. While there was a difference among T0 and the other two periods, there was no difference between T1 and T2. The same situation occurred for the consonant /s/ of the word "Pois", differing only by the fact that for the AHWA there was no difference.

The comparison between the retainers was performed by comparing the differences between T1 and T2 in relation to T0, and a statistically significant difference was observed only in two consonants (Table X). In these groups, CWA presented greater changes than AHWA, with statistically significant values. The other two retainers presented intermediate changes and showed no statistical difference with either CWA or AHWA.

DISCUSSION

This was the first study to evaluate the influence of upper restraints on oral DDC. This analysis has been used to visualize the speech motor ability of an individual. It measure the speed necessary to stop a particular motor impulse and substitute for its opposite.[26] When we pronounce the syllables "pa", "ta", and "ka", we observe three pronunciations where the position of the tongue remains in different places. In the first, there is the encounter between the lips where the tongue and the palate practically do not participate. In the second, the tongue is positioned in anterior region of the palate.

Finally, for the pronunciation of the syllable "ka" the posterior region of the tongue is positioned in the region of the soft palate. In the three syllables, there is a total obstruction of the air passage.

The retainers evaluated by this study had different designs, altering the interaction of soft and hard tissues that promote orofacial functions. In this process, function and morphology are closely linked, so it could be expected that imbalance of this interaction by the presence of the retainers would cause significant differences in orofacial functions. Thus, in the retainers that occupy more volume on the palate, more changes was expected, as the CWA and its modifications (UWA and AHWA). Finally, for VF, little changes were expected, because it did not occupy volume on the palate. Some difficulties were expected mainly in the transition from the syllable "pa" to "ta" and from "ta" to "ka", since the acrylic of retainers occupy exactly the anterior region of the palate and they can influence the syllable "ta". In this study, however, no differences were found in this regard for any appliance at any time.

DDK in the volunteers using the devices was slightly higher than in the T0, factor that was not expected. The reason for this happened is probably due to the greater familiarity of volunteers with the pronunciation after performing it more often. It was recommended that volunteers pronounce the three syllables as fast as possible. Although we have not found any changes in pronunciation speed, there may have been loss of pronunciation quality. Future studies can verify a possible loss of this quality and relate quality to the speed of pronunciation of these three syllables.

Regarding the formant analysis, we found a statistically significant difference for most fricative consonants /s/ and /z/, for all the devices. These findings are in agreement with the other studies that evaluated the influence of speech on upper retainers.[14,27-30] Frequency values in a general way changed significantly from T0 to T1, sometimes increasing their value (Tables III, V, VI and VII) and others decreasing (Tables IV and VII). However, after 21 days of contention use (T2), although the difference for T0 decreased in relation to the T1, the values were not statistically similar to T0 in many cases. In studies that evaluated speech in a subjective way, they showed shorter periods of adaptation, occurring in about 2 weeks.[27,28] However, other studies that performed an objective evaluation indicated a longer period of adaptation, reaching more than 2 months.[14,29]

Speech changes found in this study can be explained by the modification of the oral cavity and palate, consequently the movement of the tongue. Retainers are

strange bodies, causing speech disturbs of vowels and mainly consonants.[27,28] Although studies have indicated alterations in the pronunciation of consonants, alveolar and palatal consonants such as /t/ /d/ e /j/ tend to suffer greater alterations in devices with acrylic in the palatal region.[31] However, when we evaluate the fricative consonants /s/ and /z/, we observe a different behavior, since they require an air passage, and it is highly influenced by occlusion interferences, as well as an increase in the vertical dimension. Thus, in this study the VF demonstrate significant changes in these consonants, in agreement with a previous study.[30]

Following this rationality, we believe that different designs of Hawley or Wrap Around can minimize this disturb on speech. The advantage of the Wrap-around in this factor is to be able to use stainless steel wires that contour the teeth by vestibular and lingual, not interfering in the occlusal, different from the Hawley with Adams clamps. AHWA is a retainer routinely used for anterior open bite treatments, functioning as a tongue position educator. However, with this lower volume of acrylic in the anterior palate region, we believe that the influence on speech could be lower. The idea of change the volume and design modification of acrylic had already been proposed by Erb,[27] who found minor changes on speech using Hawley with roughness in the anterior acrylic region, compared to conventional Hawley. When the retainers evaluated in this study were compared, the worst results were exactly for CWA, and the best were for AHWA, agreeing that the smaller the amount of acrylic in the anterior region, the smaller the change in speech. Some studies compared Hawley and VF,[14,29] and observed greater changes for the acrylic retainer. However, our study did not find this difference. This is due to the fact to different methodologies, design of acrylic retainer (in this study the Wrap-Around was used) or even a difference of the pronunciation of consonants in Brazilian Portuguese in relation to the native language of the studies performed.

CONCLUSION

According to the methodology applied, it is possible to affirm that:

- There was no change in oral motor abilities evaluated by diadochokinesis in any of the evaluated retainers.
- All retainers evaluated promoted significant changes in formants of the fricative consonant /s/ and /z/ after their installation. Although these changes minimized after 21 days, they were lower than without retainer.

• There were few differences between the retainers, represented by a greater alteration of the conventional Wrap-Around, and smaller by the modified anterior hole Wrap-Around.

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FIGURE CAPTIONS

Fig 1. Retainers evaluated **A**, conventional Wrap-Around; **B**, modified horseshoe-shaped Wrap-Around; **C**, modified anterior hole Wrap-Around; **D**, vacuum-formed.

Fig 2. Subgroups randomly distributed according to the retainer, periods of use and days of phonetic evaluations.

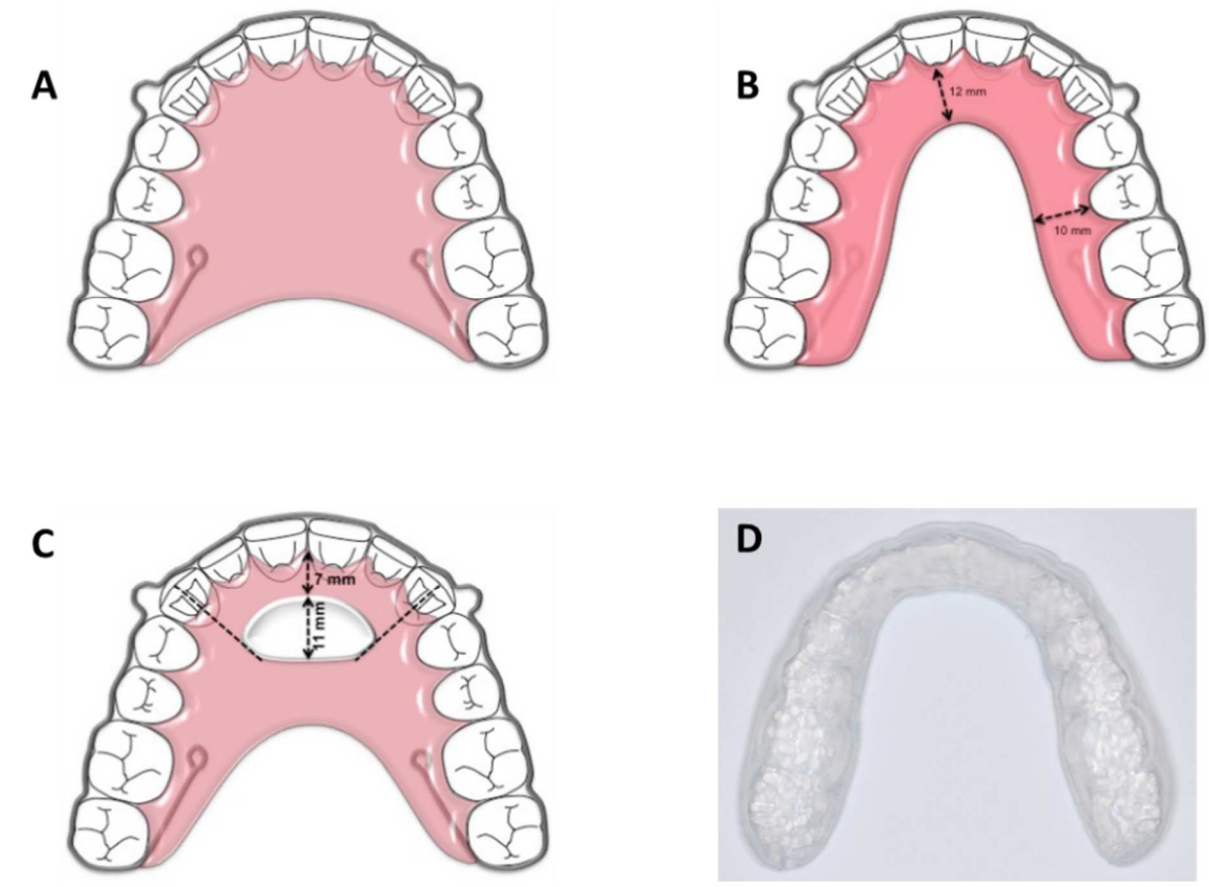

Figure 1

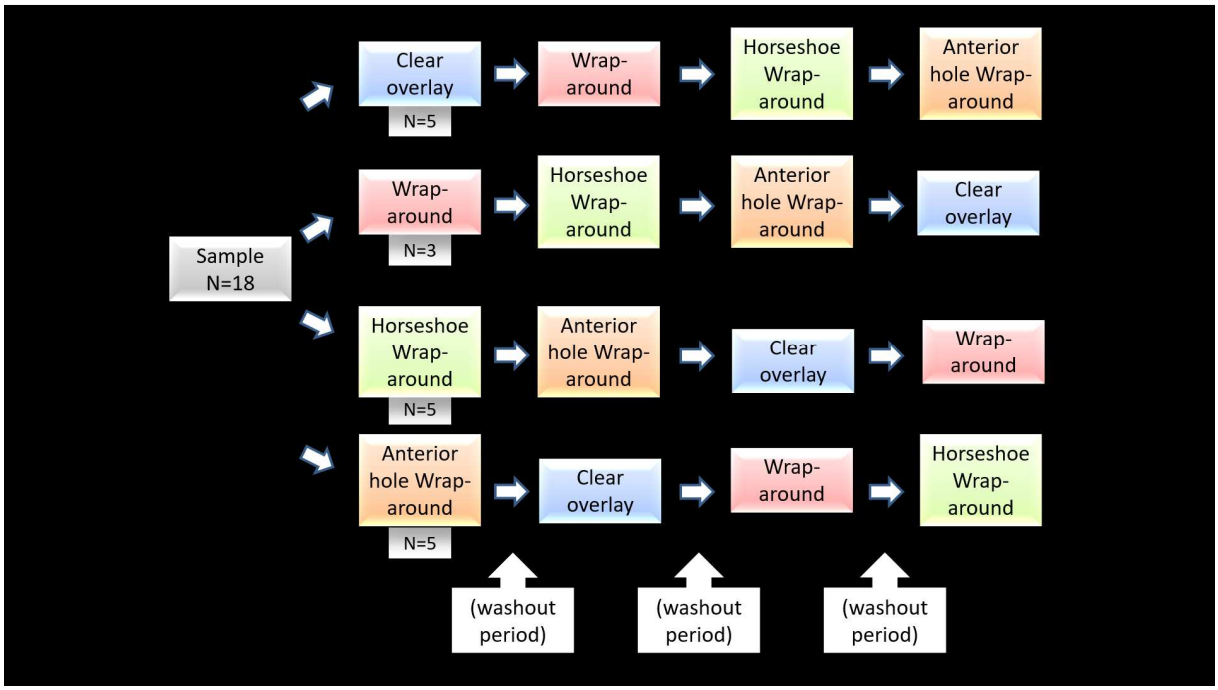
Sample
N=18
Clear overlay
N=5
Wrap-around
N=3
Horseshoe Wrap-around
N=5
Anterior hole Wrap-around
N=5
Wrap-around
Horseshoe Wrap-around
Anterior hole Wrap-around
Clear overlay
Horseshoe Wrap-around
Anterior hole Wrap-around
Clear overlay
Wrap-around
Anterior hole Wrap-around
Clear overlay
Wrap-around
Horseshoe Wrap-around
Clear overlay
Anterior hole Wrap-around
Wrap-around
Horseshoe Wrap-around
(washout period)
(washout period)
(washout period)

Figure 2

Table I: Sentences proposed for evaluation of fricative consonants

Specific Adjustments	**Segments**	**Sentences**
Lip, lingual (tip and body) and velopharyngeal adjustments (nasal and audible nasal escape)	Alveolar fricative consonants [s] and [z]	**S**oube que a Ca**s**a dos Bi**s**po**s** é visitada por turistas todos os dias e que o roteiro de visita dura cerca de duas horas para ser percorrido.
	Alveolar fricative consonants [s] and [z]	Dete**s**to ir à casa dele, pois fica do outro lado da cidade e o acesso é difícil.
Adjustments of lingual (tip and body) and velopharyngeal (nasal)	Alveolar fricative consonants [s] and [z]	Não men**c**ionei anteriormente, mas minha mãe morou muito anos em Santos, numa mansão à beira mar.

Table II: Vocalizations per second (DDK test)

Group	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	2.200 (0.23)	2.324 (0.23)	2.349 (0.26)
HWA	2.200 (0.23)	2.319 (0.31)	2.375 (0.30)
AHWA	2.200 (0.23)	2.337 (0.32)	2.404 (0.26)
VF	2.200 (0.23)	2.295 (0.24)	2.413 (0.32)

*Statistically significant at $p < 0.05$

Table III: Descriptive statistics of the frequency (Hz) of the consonant /s/ of the word "**S**oube" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	880,97 (26,73) [A]	827,42 (46,53) [B]	832,46 (37,05) [B]	2077,17 (101,11) [A]	1980,04 (63,13) [B]	2030,69 (97,78) [AB]
HWA	880,97 (26,73) [A]	843,03 (47,10) [B]	826,52 (36,30) [B]	2077,17 (101,11)	2034,62 (117,24)	1990,80 (94,44)
AHWA	880,97 (26,73)	881,57 (50,50)	862,99 (50,16)	2077,17 (101,11)	2017,95 (66,59)	2048,98 (106,05)
VF	880,97 (26,73)	872,89 (56,51)	870,10 (78,52)	2077,17 (101,11) [A]	1990,22 (86,05) [B]	1978,42 (81,91) [B]

*Statistically significant at p <0.05

Table IV: Descriptive statistics of the frequency (Hz) of the consonant /z/ of the word "Ca**s**a" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	526,9917 (64,4513) [A]	569,1183 (44,5490) [B]	573,2900 (40,1739) [B]	1472,054 (152,2594)	1386,377 (138,8911)	1395,687 (118,1010)
UWA	526,9917 (64,4513) [A]	549,3744 (29,9717) [B]	574,9700 (34,8362) [B]	1472,054 (152,2594) [A]	1357,785 (131,1260) [B]	1397,628 (111,0633) [AB]
AHWA	526,9917 (64,4513) [A]	573,3517 (39,4624) [B]	573,2128 (38,8443) [B]	1472,054 (152,2594)	1444,209 (90,1430)	1395,956 (103,1699)
COR	526,9917 (64,4513) [A]	577,2633 (32,8143) [B]	562,0417 (34,4296) [AB]	1472,054 (152,2594) [A]	1348,137 (147,3018) [B]	1380,153 (116,4764) [AB]

*Statistically significant at p <0.05

Table V: Descriptive statistics of the frequency (Hz) of the consonant /s/ of the word "Bi**s**pos" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	**T1 mean (SD)**	**T2 mean (SD)**	**T0 mean (SD)**	**T1 mean (SD)**	**T2 mean (SD)**
CWA	363,3544 (38,0670)	368,0356 (43,6344)	381,9867 (40,0323)	1983,486 (111,4988)	1878,219 (85,5965)	1930,193 (109,8771)
UWA	363,3544 (38,0670)	372,9639 (44,1838)	392,0139 (39,7132)	1983,486 (111,4988)	1923,140 (98,4788)	1928,407 (59,5417)
AHWA	363,3544 (38,0670)	390,4983 (48,9154)	398,7772 (47,2105)	1983,486 (111,4988)	1964,243 (87,5992)	1966,235 (96,7447)
COR	363,3544 (38,0670)	366,0100 (42,0325)	397,5106 (57,2672)	1983,486 (111,4988)	1953,027 (105,7254)	1896,217 (104,6029)

*Statistically significant at $p < 0.05$

Table VI: Descriptive statistics of the frequency (Hz) of the consonant /s/ of the word "Bispo**s**" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	478,0367 (77,2834) [A]	408,3944 (40,5082) [B]	412,4433 (46,8640) [B]	1865,800 (133,5967) [A]	1684,463 (66,4594) [B]	1693,978 (90,7386) [B]
UWA	478,0367 (77,2834) [A]	423,0533 (46,8489) [B]	426,1422 (37,9708) [B]	1865,800 (133,5967) [A]	1729,927 (92,9582) [B]	1698,825 (109,7170) [B]
AHWA	478,0367 (77,2834) [A]	423,5817 (50,1229) [B]	436,0911 (52,5282) [AB]	1865,800 (133,5967) [B]	1648,722 (114,6296) [A]	1726,157 (80,9932) [A]
COR	478,0367 (77,2834)	431,9028 (41,3789)	433,0306 (46,8692)	1865,800 (133,5967) [B]	1696,999 (122,0202) [A]	1686,423 (88,1755) [A]

*Statistically significant at p <0.05

Table VII: Descriptive statistics of the frequency (Hz) of the consonant /s/ of the word "Deste**s**to" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	543,9683 (31,6385)	529,6117 (33,0444)	547,4383 (38,1043)	1805,268 (95,9704)	1771,451 (112,2768)	1727,153 (107,6539)
UWA	543,9683 (31,6385)	523,5328 (36,5884)	543,5122 (38,1756)	1805,268 (95,9704)	1745,881 (107,0633)	1769,781 (143,4165)
AHWA	543,9683 (31,6385)	534,5517 (45,9014)	546,1711 (34,4802)	1805,268 (95,9704)	1796,724 (116,0062)	1755,558 (73,5751)
COR	543,9683 (31,6385)	535,3394 (38,8984)	564,1211 (36,2202)	1805,268 (95,9704)	1758,826 (74,2151)	1744,900 (91,6799)

*Statistically significant at $p < 0.05$

Table VIII: Descriptive statistics of the frequency (Hz) of the consonant /s/ of the word "Poi**s**" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	431,4189 (33,9287) ^{AB}	408,0467 (28,5227) ^{A}	436,4428 (40,3579) ^{B}	2030,459 (94,6432) ^{A}	1872,032 (84,9301) ^{B}	1867,133 (115,5755) ^{B}
UWA	431,4189 (33,9287)	420,6889 (49,5513)	439,1139 (42,7323)	2030,459 (94,6432) ^{A}	1851,053 (104,9394) ^{B}	1912,821 (97,4112) ^{B}
AHWA	431,4189 (33,9287)	425,4711 (46,6588)	433,8461 (40,4435)	2030,459 (94,6432) ^{A}	1916,970 (110,8204) ^{A}	1905,111 (114,0701) ^{B}
COR	431,4189 (33,9287)	417,9733 (43,3541)	429,1100 (38,7552)	2030,459 (94,6432) ^{A}	1861,401 (99,1955) ^{B}	1917,540 (90,5942) ^{B}

*Statistically significant at $p < 0.05$

Table IX: Descriptive statistics of the frequency (Hz) of the consonant /s/ of the word "Men**c**ionei" in the different retainers and in each period (T0, T1 and T2). SD = Standard Deviation

GROUP	F1			F2		
	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)	T0 mean (SD)	T1 mean (SD)	T2 mean (SD)
CWA	384,3111 (53,5545) A	463,0806 (58,7286) B	481,1800 (47,3515) B	2004,307 (267,3707)	1928,257 (171,7628)	1927,308 (170,1220)
UWA	384,3111 (53,5545) A	479,1794 (56,4092) B	451,1400 (49,2785) B	2004,307 (267,3707)	1950,849 (166,9286)	1922,661 (133,9884)
AHWA	384,3111 (53,5545) A	459,6944 (49,4373) B	494,0033 (39,8699) B	2004,307 (267,3707)	1977,194 (243,0903)	1947,458 (214,9999)
COR	384,3111 (53,5545) A	468,8944 (61,5961) B	484,7811 (58,4595) B	2004,307 (267,3707) A	1866,702 (181,3618) B	1880,939 (204,0335) B

*Statistically significant at $p < 0.05$

Table X: Comparison of the difference of formant values (Hz) in T1 and T2 in relation to T0 of the different contentions (ANOVA at two criteria DP = Standard Deviation)

		SS	Degr. Of Freedom	MS	F	P (>0.05)
	Formante F1					
Soube	Contenção	48154,1	3	16051,4	4,92662	0,002796*
	Tempo	5517,4	1	5517,4	1,69344	0,195348
	Cont/Tempo	7799,7	3	2599,9	0,79798	0,497032
Casa	Contenção	3,0	1	3,0	0,00070	0,978893
	Tempo	294,0	3	98,0	0,02318	0,995199
	Cont/Tempo	3146,3	3	1048,8	0,24809	0,862581
Bispos	Contenção	11918,3	1	11918,3	4,61652	0,033437*
	Tempo	7205,7	3	2401,89	0,93037	0,427971
	Cont/Tempo	2647,0	3	882,33	0,34177	0,795155
Bispos	Contenção	9634,1	3	3211,4	0,47991	0,696778
	Tempo	755,3	1	755,3	0,11288	0,737395
	Cont/Tempo	788,9	3	263,0	0,03930	0,989560
Detesto	Contenção	1012,1	3	337,361	0,133936	0,939691
	Tempo	7604,5	1	7604,499	3,019073	0,084505
	Cont/Tempo	828,9	3	276,290	0,109690	0,954318
Pois	Contenção	5763,4	3	1921,147	0,675514	0,568448
	Tempo	5489,0	1	5488,986	1,930039	0,166976
	Cont/Tempo	6136,0	3	2045,339	0,719183	0,542135
Mencionei	Contenção	32659	3	10886	0,7726	0,511222
	Tempo	22711	1	22711	1,6117	0,206378
	Cont/Tempo	40899	3	13633	0,9675	0,410050
	Formante F2					
Soube	Contenção	44449	3	14816,3	0,84801	0,469940
	Tempo	1528	1	1528	0,08747	0,767864
	Cont/Tempo	48763	3	16254,3	0,93031	0,427999
Casa	Contenção	61678	3	20559	2,01463	0,114814
	Tempo	2438	1	2438	0,23889	0,625796
	Cont/Tempo	42810	3	14270	1,39834	0,246050
Bispos	Contenção	65017	3	21672,3	1,23708	0,298683
	Tempo	64	1	64	0,00365	0,951905
	Cont/Tempo	48317	3	16105,6	0,91933	0,433345
Bispos	Contenção	16390	3	5463	0,2834	0,837350
	Tempo	6486	1	6486	0,3364	0,562864
	Cont/Tempo	57352	3	19117	0,9915	0,398808
Detesto	Contenção	18952	3	6317,5	0,53357	0,660012
	Tempo	16388	1	16388	1,38411	0,241413
	Cont/Tempo	26728	3	8909,2	0,75246	0,522697
Pois	Contenção	32659	3	10886	0,7726	0,511222
	Tempo	22711	1	22711	1,6117	0,206378
	Cont/Tempo	40899	3	13633	0,9675	0,410050
Mencionei	Contenção	149703	3	49900,9	2,01652	0,114542
	Tempo	4483	1	4483	0,18114	0,671067
	Cont/Tempo	12459	3	4152,9	0,16782	0,917930

3 Discussion

3 DISCUSSION

For this study, two types of evaluations were chosen. First, the perceptual auditory analysis of speech, which consists of a subjective evaluation. The subjective analysis was used in the first studies that investigated speech alterations by orthodontic retainers, (ERB, 1967; HAYDAR et al., 1996) and today is usually used to evaluate the consonants. In this study, however, we chose to use subjective analysis because there are no studies in the literature evaluating the perception of laypersons, i.e., individuals who are not related to speech therapy or dentistry.

In addition to the subjective analysis, the objective evaluation through acoustic analysis of the formants and evaluation of the mean DDK rate were used. The analysis of the formants has recently been used to evaluate changes in speech caused by orthodontic appliances (KULAK KAYIKCI et al., 2012; ATIK et al., 2017; WAN et al., 2017). This is due to the fact that the spectrogram.

However, in this study some similar and different results were found using the two analyzes. Firstly, both analyzes found alterations in speech when comparing the T1 and T2 in relation to T0. This is in agreement with all the studies that evaluated changes in speech. (ERB, 1967; STRATTON; BURKLAND, 1993; HAYDAR et al., 1996; KULAK KAYIKCI et al., 2012; ATIK et al., 2017; WAN et al., 2017).

However, when the comparison among the devices was made, in the subjective evaluation the retainer that presented the greatest changes was the VF, whereas in the acoustic analysis the greatest ones tended to be for the CWA.

Both retainers present reasons to influence speech in a most notable way. Retainers made from acrylic cause a considerable modification of the oral cavity and palate, consequently the movement of the tongue. Retainers are strange bodies, causing speech disturbs of vowels and mainly consonants.(ERB, 1967; HAYDAR et al., 1996) Although studies have indicated alterations in the pronunciation of consonants, alveolar and palatal consonants such as /t/ /d/ e /j/ tend to suffer greater alterations in devices with acrylic in the palatal region.(CHEN; WAN; YOU, 2018) Following this rationality, we believe that different designs of Hawley or Wrap Around

can minimize this disturb on speech. With this lower volume of acrylic in the anterior palate region, we believe that the influence on speech could be lower.

On the other hand, although VF does not present acrylic on the palate, theoretically resulting in an improvement in speech changes, it significantly interferes with occlusion, also increasing the vertical dimension of the patient.(SAUGET et al., 1997; CHEN; WAN; YOU, 2018) These factors may have influenced the smaller scores for this device in the subjective evaluation.

Finally, for the two analyzes the AHWA presented favorable results. Probably this device minimizes both the influence of the acrylic on the palate, by reducing its quantity precisely in the portion where speech is more affected (anterior portion of the palate) and occlusal interference that may affect the pronunciation of certain words.

Nevertheless, it is necessary to continue to develop methodologies to evaluate the influence of speech in orthodontic appliances, as well as to continue developing modifications that allow a better adaptation of the patient to the removable retainers. This study assists in the choice of orthodontist in relation to the retention protocol, however other factors should be considered, especially considering that the patient may have preference for a certain type of device.

4 FINAL CONSIDERATIONS

4 FINAL CONSIDERATIONS

According to the methodology applied, it is possible to affirm that all retainers change speech after it is installed. These changes, however, tend to decline after a few days. The device that had the least change in speech and presented better adaptation after 21 days was the modified anterior hole wrap-around. In relation to the device that most affected speech, in the subjective analysis performed by laypersons the vacuum-formed showed the lowest scores, while in the objective analysis there was a greater, if not very marked, change for the conventional wrap-around.

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APPENDIXES

APPENDIX A – Declaration of exclusive use of the article 1 in thesis

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN THESIS

We hereby declare that we are aware of the article "Perception of laypersons on speech changes promoted by upper orthodontic retainers" will be included in Thesis of the student Rodrigo Hitoshi Higa and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, March 05th of 2018

Rodrigo Hitoshi Higa — Signature

Guilherme Janson — Signature

José Fernando Castanha Henriques — Signature

APPENDIX B – Declaration of exclusive use of the article 2 in thesis

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN THESIS

We hereby declare that we are aware of the article "Influence of upper orthodontic retainers on speech: an acoustic analysis" will be included in Thesis of the student Rodrigo Hitoshi Higa and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, March 05th of 2018

Rodrigo Hitoshi Higa — Signature

Guilherme Janson — Signature

José Fernando Castanha Henriques — Signature