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Vibration devices and clinical effect of vibration on the acceleration of orthodontic tooth movement with aligners.

A scoping review

Levana Suzanne Monique Elbaz

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

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Trabalho realizado sob a Orientação de Mestre Selma Pascoal

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Eu, acima identificado, declaro ter atuado com absoluta integridade na elaboração deste trabalho, confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio (ato pelo qual um indivíduo, mesmo por omissão, assume a autoria do trabalho intelectual pertencente a outrem, na sua totalidade ou em partes dele). Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

Comunicação Científica apresentada nas XXIX Jornada Científicas de Ciências Dentárias do IUCS-CESPU, na forma de Poster

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RESUMO

Introdução: Em ortodôntia, cada vez mais se procura a estética mas também,a diminuição do tempo de tratamento que acarreta muitas vezes problemas periodontais e cáries. Numa tentativa da redução do tempo de tratamento surgiram técnicas não invasivas como por exemplo a vibração, que se associam ao tratamento ortodôntico. Dos dispositivos existentes no mercado, os mais referidos na literatura são o AcceleDent® e o VPro® que estimulam a diferenciação e maturação celular acelerando a movimentação dos dentes.

Objetivos : O objetivo da presente revisão é perceber como a vibração tem um efeito na aceleração do movimento dentário ortodôntico com alinhadores.

Materiais e Métodos : Pesquisa bibliográfica na base de dados PUBMED, incluindo artigos compreendidos entre 2008 e 2020 em inglês, usando as palavras-chave: Orthodontic OR "orthodontic movement" OR "Accelerated tooth movement" OR "tooth movement" AND Vibration OR "Vibration device" OR AcceleDent OR VPro OR "electric Toothbrushes".

Resultados : A pesquisa na literatura identificou 8 artigos. Destes 8 estudos, quatro usaram AcceleDent® e quatro VPro®.

Discussão : Os dispositivos de vibração estimulam a diferenciação e maturação celular acelerando a remodelação óssea durante o movimento ortodôntico. A sua aplicação diária em conjunto com o aparelho ortodôntico, aumenta a eficácia do tratamento, estimulando as citocinas e os fatores de remodelação óssea no ligamento periodontal, as vibrações estimulam a atividade estoclástica devido ao aumento da libertação de RANKL e não existe aumento de dor.

Conclusão : A utilização dos dispositivos de vibração durante o tratamento ortodôntico permite a aceleração considerável do movimento dentário, no caso de tratamento com alinhadores permitiu trocas de alinhador num período mais curto de tempo, melhoria na densidade óssea e uma redução do tempo do tratamento.

PALAVRAS-CHAVE : Orthodontic OR "orthodontic movement" OR "Accelerated tooth movement" OR "tooth movement" AND Vibration OR "Vibration device" OR AcceleDent OR VPro OR "electric Toothbrushes".

ABSTRACT

Background: In orthodontics, aesthetics are increasingly sought but also, the reduction of treatment time, which often causes periodontal problems and cavities. In an attempt to reduce the treatment time, non-invasive techniques emerged, such as vibration, which are associated with orthodontic treatment. Of the devices on the market, the most referred to in the literature are AcceleDent® and VPro® that stimulate cell differentiation and maturation by accelerating tooth movement.

Objectives: The aim of the present scoping review is to understand how does vibration have an effect on the acceleration of orthodontic tooth movement with aligners.

Material and Methods: A bibliographic search in the Pubmed database from 2008 to 2020 of articles in English was performed using the following key words: Orthodontic OR "orthodontic movement" OR "Accelerated tooth movement" OR "tooth movement" AND Vibration OR "Vibration device" OR AcceleDent OR VPro OR "electric Toothbrushes".

Results: Literature search identified 8 articles. Of these 8 studies,four used AcceleDent® and four used VPro®.

Discussion: Vibration devices stimulate cell differentiation and maturation by accelerating bone remodeling during orthodontic movement. Its daily application in conjunction with the orthodontic appliance, increases the effectiveness of the treatment, stimulating cytokines and bone remodeling factors in the periodontal ligament, vibrations stimulate stochastic activity due to the increased release of RANKL and there is no increase in pain.

Conclusion: The use of vibration devices during orthodontic treatment allows for considerable acceleration of tooth movement, in the case of treatment with aligners it allowed aligner changes in a shorter period of time, improved bone density and reduced treatment time.

KEYWORDS - Orthodontic OR "orthodontic movement" OR "Accelerated tooth movement" OR "tooth movement" AND Vibration OR "Vibration device" OR AcceleDent OR VPro OR "electric Toothbrushes".

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List of abbreviations

LFV = Low frequency vibration
HFA = High frequency acceleration
HFV = High frequency vibration
OT = Orthodontic treatment
OTM = Orthodontic tooth movement
Y = Years

1. INTRODUCTION

Orthodontic treatment (OT) is in much demand and is practiced in every country. With the evolution of orthodontic techniques, clinicians started to give more relevance to the functional aspect and the optimization of the treatment. The most revolutionary of orthodontic advance in the last decade has been the introduction of digitally fabricated aligners to move the teeth in small, progressive sequences(1). Currently, the most used is Invisalign®.

It is still very challenging to reduce the duration of OT. Long term treatment is often associate to irritation, increasing risks of caries, gingival recession, and root resorption (2). Accelerating orthodontic tooth movement (OTM) has long been desired for its multiple benefits, including shorter treatment duration, reduced side effects, differential tooth movement and improved post treatment stability.

In recent years, numerous surgical (corticotomy, corticision, piezocision) and nonsurgical (laser terapy, electric current, pulsed electromagnetic fields, photobiomodulation) and pharmacological methods (PGE, vitamin D, parathyroid hormone) adjunctive procedures to accelerate OTM have been introduced.(3)(4)

Vibration is a non-invasive method that can be applied in conjunction with OT to increase the rate of tooth movement. A number of vibratory devices are commercially available, such as AcceleDent® and Tooth Masseuse or VPro®. (5)(6)

Tooth movement by orthodontic force application is characterized by remodeling changes in dental and periodontal tissues, including dental pulp, periodontal ligament (PDL) and alveolar bone. This dynamic involves a coordinated action of osteoclasts and osteoblasts

in response to mechanical load. Moreover, inflammatory mediators are released after mechanical stimulus or injury, triggering the biologic process associated with orthodontic tooth movement(7).

It is reported that vibration may stimulate differentiation of osteoclasts from hematopoietic cells by increasing blood flow. These signals may be mediated in response to direct effects on the cell membrane, changes in ion transport, activation of stretch-activated channels, activator changes in the attachments between skeletal bones and extracellular matrix, or modification of intracellular signals that regulate gene expression to promote bone remodeling (Figure 1).

Vibration may enhance orthodontic tooth movement via a mechanism related to induction of inflammatory mediators. (3)

However, it is unclear what kind of information is available in literature about how vibration can stimulate bone remodeling and accelerate orthodontic tooth movement in aligner treatment.

Therefore, the aim of the present scoping review is to assess the influence on the acceleration of orthodontic tooth movement with aligners under vibration stimulus.

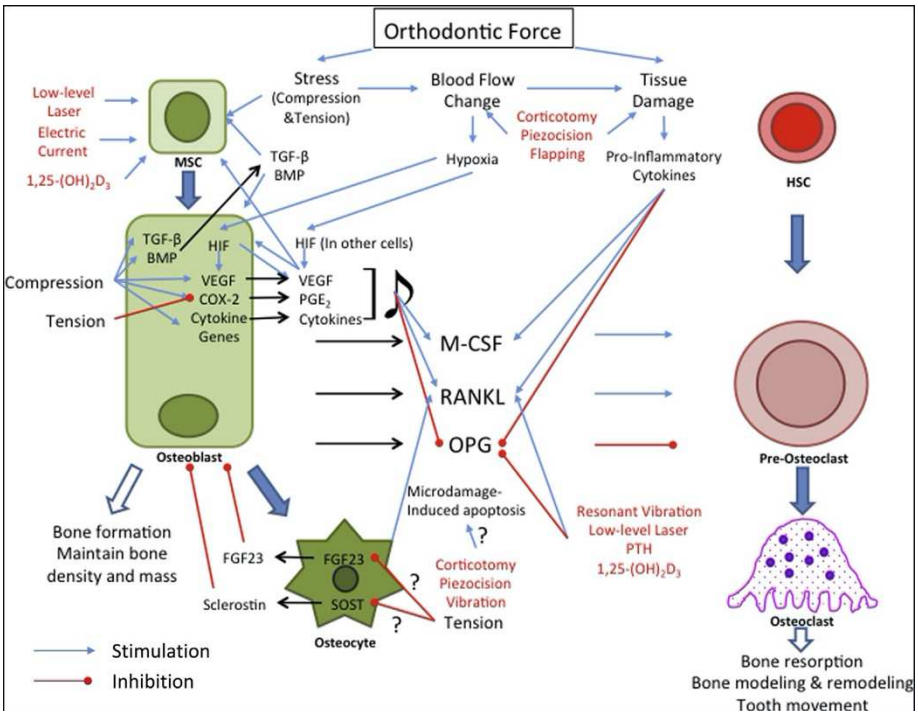

Figure 1: Summary of cellular and molecular mechanisms underlying accelerated orthodontic tooth movement. *Adapted from Hechang Huang et al., 2014* (8)

2. MATERIAL AND METHODS

2.1 Protocol and registration

This scoping review protocol was drafted using the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (Prisma) extension for Scoping Reviews (Prisma-ScR).(9)

2.2 Formulation of Research Question

A PICO [Patient Population (P), Intervention (I), Comparison (C), and Outcomes (O)] approach was used to structure and respond to a research question. It was found that higher precision can be achieved through the use of PICO templates and the relevance of search results can therefore also be improved . (10)

PICO criteria for research question was: "Does Vibration (I) accelerate tooth movement (O) in patients undergoing orthodontic treatment (P) compared with aligners convencional technique (C)?

2.3 Search strategy

The electronic database PubMed was searched to identify original clinical studies that assessed the clinical effect of vibration on the acceleration of orthodontic tooth movement with aligners. Searches were performed from database inception up to 1st February 2021 and the search strategy is presented in Supplementary Table 1.

Table 1: Detailed search strategies

Data base	Research equation	Identified articles	Selected articles
Pubmed	Orthodontic OR "orthodontic movement" OR "Accelerated tooth movement" OR "tooth movement" AND Vibration OR "Vibration device" OR AcceleDent OR VPro OR "electric Toothbrushes".	432	8

2.4 Study selection

All records were exported to an Excel file (Microsoft® Office) and the duplicates were removed by the software filter and then manually verified. Two authors (E.L and P.S) independently screened the titles and abstracts of all identified studies. The full texts of the most relevant studies were evaluated by the same authors to assess their eligibility. The inclusion criteria were as follows: 1) Articles published between 2008 and 2020; 2) Clinical studies; 3) Studies that use vibration devices; 4) Studies that use aligners. The exclusion criteria comprised: 1) Systematic reviews; 2) Studies not written in English; 3) Studies that

combine vibration stimulation with surgical techniques or others stimulation method; 4) Studies *in vitro* or *in vivo*; 5) Studies that used fixed appliances (Table 2).

Table 2: Eligibility criteria

Inclusion criteria	Exclusion criteria
Articles published between 2008 and 2020	Articles not published in English
Clinical studies	Systematic review
Studies use vibrations devices	Others surgical or stimulation techniques
Patients enrolled with Invisalign® clear aligners	Studies *in vitro* or *in vivo*
	Used of fixed appliances

2.5 Data collection and extraction

All data related to study characteristics and outcomes from the included studies were extracted to an excel spreadsheet. Data related to the study characteristics were collected: authors, subjects, study design, aim, measured variables, inclusion and exclusion criteria, limitations, general remarks and mechanical stimulation parameters (device type, frequency, irradiation time, application technique).

2.6 Critical appraisal of individual sources of evidence

The quality of the knowledge synthesis methods was appraised using "Oxford Centre for Evidence-based Medicine". The included articles were classified according to the level / degree of scientific evidence by type of study - "Oxford Center for Evidence-based Medicine": 4 level 2b (Randomized Clinical Trial), 2 level 3b (Case Report), 2 level 4 c (Lower quality Case report) .

3. RESULTS

The literature search identified a total of 432 articles in MEDLINE/Pubmed, as shown in Figure 2. After reading the titles and abstracts of the articles, 388 were excluded. Of the remaining 42 potentially relevant studies, 34 were excluded because they did not meet the inclusion criteria. Thus 8 studies were included in this review.

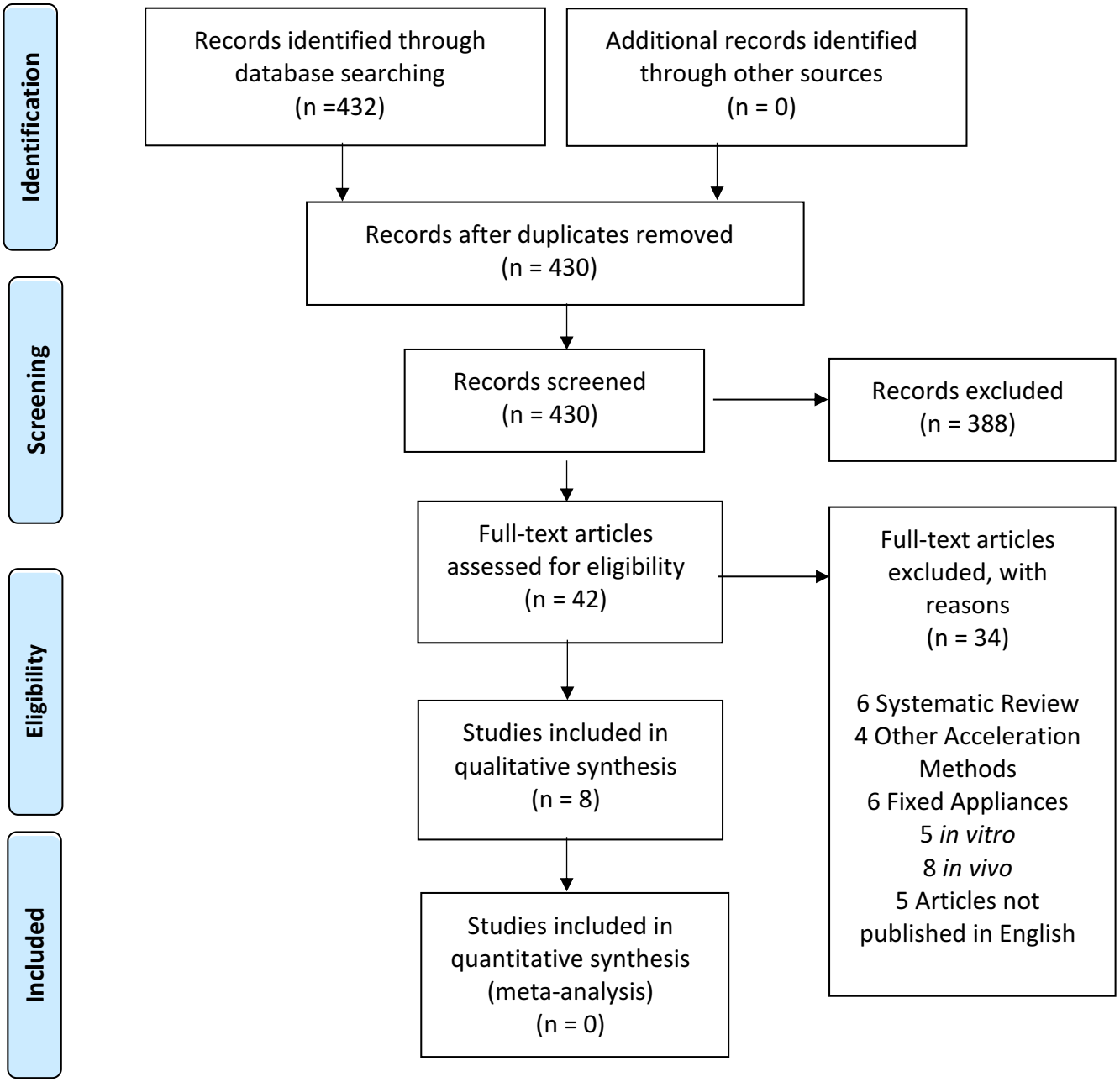

Figure 2. **Flow diagram of the search strategy used in this study.**

After retaining articles following scanning of title, abstract and full text, height studies were successfully found and included in the review as Study 1- Shipley T *et al.* (2019), Study 2- Katchooi M *et al.* (2016), Study 3- Lombardo L *et al.* (2018), Study 4 Aldrees AM (2016),Study 5 - Shipley TS (2018) , Study 6 - El-Bialy T (2020) , Study 7- Alpan D *et al.* (2017), Study 8 El-Bialy T (2020).

These studies are categorized as randomized clinical trial, retrospective study, case report and pilot study and included patients under OT with aligners combined with vibration. The list and a summary description of all the height studies including their characteristics viz-a-viz quality analysis are placed at Table 3.

Of the 8 studies selected, 4 (50%) use AcceleDent® device and 4 (50%) use VPro® device. 6 (75%) authors work with Invisalign® technique, 1 (12,5%) with Suresmile® technique and 1 (12,5%) is not reported. In 1 (12,5%) study, subjects are adolescents whereas in the other 6 (87,5%) studies it is mixed. 1 (12,5%) study treats of class II malocclusion and 1 (12,5%) treats of class III malocclusion.

The results of the evidence degree of included studies (Oxford Center for Evidence-based Medicine) is low, restricted to clinical case reports (level 3 or 4) and randomized clinical trial (level 2b).

Table 3: Characteristics of included studies

Legends :

Alg = Aligner
D = Days
F = Female
Gp = Group
HFA = High frequency acceleration
LFV = Low frequency vibration
M = Male
N/R = Not reported
P = Patients
S = Second
Y = Years

Authors / Years	Shipley T, Farouk K, El-Bialy T./2019	Katchooi M *et al.* /2016	Lombardo L *et al./2018*	Aldrees AM./ 2016	Shipley TS./2018	El-Bialy T./2020	Alpan D, Daher S, Bowman SJ./2017	El-Bialy T./2020
Device type	VPro®	AcceleDent®	AcceleDent®	AcceleDent®	VPro®	VPro®	AcceleDent®	VPro®
Frequency (Hz)	120 Hz	30 Hz	30 Hz	30 Hz	120 Hz	120 Hz	30 Hz	120 Hz
Irradiation time (s)	300 s	20 min/Day	20 min/Day	20 min/Day	5min/Day	5min/Day	20 min/Day	300 s
Application technique	Invisalign®	Invisalign ®	Invisalign®	Suresmile®	Invisalign®	Invisalign®	N/A	Invisalign®
Subjects	30 patients (19 female/11 male)	Gp A (n=14 P) Gp B (n=13 P)	Gp A = conventional protocol + Alg replaced every 14 D .Gp B= LFV device for 20 min / D Gp C = LFV device+ Alg replaced every 7 D	N/R	Gp 1 = Alg + daily HFA +exchangeAlg every 5 D. Gp 2 = Alg without HFA + exchanged Alg every 14 D.	Case 1 : F, 28Y Case 2 : M, 47Y Case 3 : F, 14Y Case 4 : F , 14Y	Adolescents	Female 45 Y
Study design	Retrospective study	Randomized Clinical Trial	Randomized controlled clinical trial	Case Report	Pilot Study	Case Report	A single-blind randomized clinical trial	Case Report

Inclusion criteria	Class I malocclusion good oral hygiene, complete permanent dentition, except third molars and initial anterior crownding	Adult orthodontic subjects with malocclusions whose treatment involved < 25 sets of aligners	Permanent dentition Age between 14 and 50 Y Complete dentition No supernumerary teeth No tooth shape anomalies , No tooth rotation >35°, No diastems >5 mm	Simple malocclusion	Age 14-45 , Class I , Crowding mild to moderate , Completed aligner series Post treatment digital Vivera retainer scan.	Class II skeletal patterns	N/R	Skeletal Class III malocclusion, open bite and bimaxillary dentoalveolar protrusion
Exclusion criteria	Patients with any signs of alveolar bone defects Patients requiring any refinement after the end of their treatment	Systematic diseases or syndromes,use of bisphosphonates ,, generalized moderate to severe periodontitis, or active oral hard or soft tissue lesion	Systemic pathologies Pharmaco-treatment Active periodontal disease	N/R	Subjects with caries, Chronic NSAID, or steroid therapy Bisphosphonate Therapy , Pregnancy	N/R	N/R	N/R

Aim	Significant difference in the rate of tooth movement/aligner progression and difference in bone density changes after orthodontic treatment between the HFV and control groups	Significant difference in the rate of tooth movement/aligner progression and difference in bone density changes after orthodontic treatment between the HFV and control groups	To determine if there is any difference in the accuracy of tooth movement with a conventional protocol when LFV are associated with aligners replaced every 14 and 7 days.	To determine if the use of HFA reduces the duration of treatment	The use of the HFA device in conjunction with aligner orthodontic treatment could resulted in a significant decrease in the length of treatment	The Use of High Frequency Vibration with Clear Aligners to correct Class II malocclusion	Determine if there is any effect on the rate of tooth movement with HFV	The Use of High Frequency Vibration and Clear Aligners to correct Class III malocclusion
Measured variables	Alveolar Bone density	Incisor Irregularity	The accuracy/ imprecision of dental movements	N/R	Baseline ABO Discrepancy	Facial convexity Bone formation labial	Arch perimeter expansion	Bone formation and density
Limitations	the CBCT gray values Measured the alveolar bone density only in the anterior region . Exchange aligners once passive.	The sample size Aligner wear	The trial registration The control group	the lack of randomization, the small sample size	The small sample size	No control cases the small sample size	Time of study	Root parallelism

General remarcks	The use of a 120Hz high-frequency vibration device accelerated aligner change and corresponding tooth movements and significantly improved bone density.	No evidence that AcceleDent® impacts the ability to complete a series of aligners with a one-week change regimen or the final alignment achieved. AcceleDent® had no effect on end of treatment alignment achieved when used in conjunction with Invisalign®.	There was no difference in accuracy between replacing the aligners accompanied by low-frequency vibration every 7 days and replacing them every 14 days without vibration. Moreover, low-frequency vibration seemed to improve the accuracy of a conventional protocol in terms of upper incisor rotation.	Suresmile® patients were treated faster than the conventionally treated patients, and their results were also of better quality.	Use of an HFA device allowed 66% faster aligner exchanges than control. HFA subjects required significantly fewer aligners to complete treatment than controls	The use of HFV concurrent with Invisalign aligners allowed : Achievement of complex tooth movement Mandibular rotation/projection facilitates complex orthodontic tooth movement including posterior teeth intrusion Increasing bone formation labial	The used of the device nearly every day : Increased rates of dental alignment, leveling, and molar distalization	The use of HFV can be an important treatment : to minimize orthodontic treatment time to help bone formation where gingival recession was initially present due to the severely proclined incisors

4. DISCUSSION

Many attempts have been made in order to reduce orthodontic treatment time as the use of low level laser therapy, self-ligating brackets and flap corticotomy techniques. All these techniques present some disadvantages.On the other hand, no side effects have been yet reported with the application of vibration devices (6) . The purpose of these vibration devices is to stimulate cell differentiation and maturation, which will accelerate bone remodeling and, consequently, the tooth movement.

This movement acceleration was explained by enhanced RANKL expression in the periodontal ligament without damage to periodontal tissues, such as root resorption. Recently , clinical studies and investigations at the cellular level have found that vibration may enhance orthodontic tooth movement via an induction of inflammatory mediators activation mechanism(3). Leethanakul *et al.* (2016) reported increased levels of interleukin (IL)-1β in gingival crevicular fluid on the pressure side of the canine that received vibration when compared to the canine receiving orthodontic force alone , suggesting that IL-1ß could promotes osteoclastogenesis.(11) (IL) -1ß is secreted by osteoclasts as an immediate response to mechanical stress during the initial phase of orthodontic treatment and in the later stages by macrophages, which accumulate in compressed areas. The survival, fusion and activation of osteoclasts are correlated with the level of IL-1ß, which also determines the amount of tooth movement, regulating the remodeling of the alveolar bone.

Some authors argue that the use of a vibrating device accelerates orthodontic movement influencing bone remodeling.(12)(16)

Acceledent® is a vibration device who is used like dental movement accelerator. Today it

is the market leader. It can be used for 20 minutes 1x / day as a treatment supplement with transparent and thermoformed Invisalign® aligners. This device produces micro-pulses located in the teeth and bones, allowing the teeth to move more freely. It has a frequency of 30 Hz or 120 Hz and a strength of 0.25 N.

VPro® is a high frequency device that has the advantage of requiring only 5 minutes of use 1x /day. It has a frequency of 120 Hz and a force of 0.36 N.

According to Thomas S. Shipley(6) , the use of a high-frequency vibrating device made it possible to speed up tooth movements with alignment therapy, allowing for a faster change of aligners than in the control group, saving time approximately 66%. These patients using a high frequency vibration device needed 43% less leaks. In addition, the duration of treatment was significantly reduced, with the control group having an actual treatment duration of 96.75 weeks compared to 19.25 weeks for the high frequency vibration group.

Tarek El-Bialy (12) comes to the same conclusion , the results demonstrated subjects using high-frequency vibration were able to advance aligners 40% faster than controls.

In both studies, VPro® was used 5 minutes por days and the faster rate of aligner change could be due to the fact that using VPro® 5 minutes por day may provide better mechanic through consistent aligner setting throughout the dentition, and subsequently more consistent force delivery throughout treatment duration. Furthermore, it is recognized that high frequency vibration (HFV) can provide pain relief from dental origin and therefore patients may have experienced greater compliance with their aligners. Thirdly, the rate-limiting biological response may have been directly amplified by the HFV device, resulting faster rate of tooth movement. (6)(12)

According to Bowman SJ (13), it's possible to have the same results by using AcceleDent®

device 20 minutes por day.

Aldrees AM (14), use AcceleDent® device with Suresmile® instead of Invisalign® and had the same outcomes. Suresmile® patients with vibration were treated faster than the control patients, and their results were also of better quality.

On the other hand, according to Katchooi M (15) , no difference was found using supplemental vibration in conjunction with aligners. Subjects in both groups were able to complete the aligner series with one week change regime.

Shipley T (6) and El Bialy T (10)(16) showed the advantage of using HFV to improve bone formation. In these studies, the number of patients and their ages were all different and all used VPro® 5 minutes por day, suggesting that the use of high frequency vibration device significantly improved bone density from pre-treatment levels which could provide clinically meaningful benefits for pre-restorative set-ups, retention, and post orthodontic stability.

Previous reports showed that the increased bone density effect of HFV is mediated through its upregulation of osteogenic transcription factors. (12)(16)

Moreover,it was demonstrated that the use of HFV helped to improve patients profiles whether with class II or class III malocclusions.

El Bialy T(12) showed that the use of HFV assists complex orthodontic tooth movement including posterior teeth intrusion and incisor decompensation. In other study (16) he showed the correction of the anterior open bite and bimaxillary dentoalveolar protrusion. According to his studies, the hypothesis that the use of HFV minimize orthodontic treatment time and faster aligner change was also verified.

There are important limitations to be considered when interpreting the results of this studies. The small sample size who was found on the majority of included articles. Larger groups would

have provided more generalizable results. However, more details to statistically determine an appropriate sample size should be planned in the future.

In some studies, no control group was found unabling to demonstrate the performance in the absence of the stimulus.

Alveolar bone density was only accessed in the anterior region, laking evaluation around the teeth in posterior regions, suggesting further investigation on this issue.

The replacement of aligners it's also an important limitation because in all of the studies no universal indications are given. Patients were instructed to replace aligners once passive. The replacement interval is variable depending on the patient.

The evidence degree of included studies (Oxford Center for Evidence-based Medicine) is low, restricted to clinical case reports (level 3 or 4), randomized clinical trial (level 2 b), wich could explain the low popularity of vibration devices in orthodontical practice.

We suggest that could be important evaluated the misfit of the aligner during difficult movements when applied with vibration compared to control group.

5. CONCLUSION

Within the limitation of these study, vibration seems to improve bone remodeling and consequently orthodontic tooth movement with aligners.

More multicenter randomized controlled clinical trials and prospective studies are deemed essential to gather valid evidence before confirmed effectiveness of vibratory stimulus on tooth movement acceleration.

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