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Systematic Review

Are Mechanical Vibrations an Effective Alternative to Accelerate Orthodontic Tooth Movement in Humans? A Systematic Review

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Abstract: The objective of this article was to conduct a systematic review of the literature to contrast the existing evidence on the effect of mechanical vibrations, either high or low frequency, as an alternative to accelerate orthodontic tooth movement in humans. A literature search from 2010 to June 2021 was conducted in the electronic databases: PubMed, NCBI, Google Scholar, EBSCO, Cochrane, and Ovid, using the eligibility criteria to identify the studies. Only randomized clinical trials (RCT) were included. The certainty of the evidence was assessed using the GRADE tool and the risk of bias (RoB) in individual studies was evaluated according to the Cochrane bias risk tool. Fifteen RTCs were included for final review. Overall, the RoB was classified as low (3), moderate (5), and high (7). Three articles with low RoB, four with moderate RoB, and four with high RoB found no significant effect in the use of vibrations on orthodontic movement. Only four articles, three of them with high RoB and one with moderate RoB, found that mechanical vibrations are effective at accelerating orthodontic tooth movement. The results seemed to indicate that there is no evidence that vibratory stimuli can increase the rate of dental movement or reduce neither the time of dental alignment nor canine retraction during orthodontic treatment. It is important to note that a greater number of high-quality randomized controlled trials are urgently needed.

Keywords: orthodontic tooth movement; accelerated orthodontics; high-frequency vibrations; low-frequency vibrations

1. Introduction

Orthodontic treatment requires a remarkable diagnostic judgment, as well as a wide clinical mastery; nevertheless, despite the vast capabilities of the orthodontist, patients will become hesitant to seek care due to the duration of treatment and pain related to it, which are the main dilemmas before accepting a treatment. The duration of orthodontic treatment averages two years or more depending on the severity of the case. The need for surgical treatment and patient cooperation, among other factors, tends to increase the number of appointments required significantly, with a duration of up to 32 months [1].

Thence, decreasing orthodontic treatment time will be a desirable goal not only for the patient but also for the orthodontist because orthodontic tooth movement can be considered as a "controlled trauma" with possible side-effects in prolonged periods [2]. Therefore, a maximum biological response with minimal side-effects in a short time is an ideal objective; for this purpose, there are currently some available methods and techniques. These methods and techniques are divided into surgical: corticotomies and micro-osseoperforations; and those of a physical, biological, or mechanical environment: photobiomodulation, electromagnetic pulses, pharmacotherapy, and, of particular interest for this work, mechanical vibrations; nonetheless, in the case of the last alternative, the research is still unfinished or debatable [2–7].

The study of mechanical vibrations as a method of orthodontic acceleration spans more than 40 years, since Shapiro et al., in 1979, carried out studies on piezoelectricity induced by a pulsed force to stimulate the tooth movement [8–10], and since then, the literature has shown that bone cells are very sensitive and responsive to changes in frequency (number of complete oscillations per second, measured in Hertz), magnitude, and displacement [11–13]. Nevertheless, before discussing the possible effect that mechanical vibrations could have on tooth movement, it is important to remember that orthodontic movement is governed by catabolic and anabolic effects that are carried out sequentially on both the compression and tension side, where the osteoblasts will initiate the production of inflammatory mediators related to bone resorption, such as interleukins (IL-1, IL-6, and IL-8), tumor necrosis factor-a (TNF-a), and activation of the RANKL (receptor activator of NF-κB)/RANK (RANK ligand)/OPG (osteoprotegerin) axis related to the rate of bone resorption. In addition, the tooth movement will be obtained as a result [7].

To regulate the physiological response mentioned above, orthodontics combined with vibrations has been divided into two areas: (1) those of vibration devices operating at $\leq$45 Hz (called low frequency), and (2) the devices operating at $\geq$90 Hz (called high frequency). These vibrational stimuli will produce catabolic or anabolic changes depending on the orthodontic strength applied [11].

There are two vibratory devices commercially available, one focused on low-frequency vibrations: the AcceleDent device (OrthoAccel Technologies, Inc., Bellaire, TX, USA) with a time of use of 20 min a day, and the high-frequency device: VPro5™ (Propel Orthodontics, Ossining, NY, USA) with a wear time of 5 min a day and 120 Hz. These devices have been evaluated in clinical and in vitro studies in order to identify how the mechanical vibrations affect the orthodontic tooth movement [4,13].

In this sense, it has been reported that once the vibrational stimulus is applied, the mechanoreceptors responsible for detecting the stimulus (Pacini and Meissner corpuscles) sends signals to the somatosensory cortex, which can have an effect at the local circulatory system [14–16]. Vibrations at the cellular level can also stimulate the RANK/RANKL pathways and induce signaling molecules such as MAPK (mitogen-activated protein kinase), c-fos, and nitric oxide; and RANKL and OPG that significantly regulate the osteoclast activity, and thus, alveolar bone turnover. On the other hand, the vibrations could produce piezoelectric charges, resulting in an osteogenic reaction [14–16].

Some authors who have evaluated the effect of high- or low-frequency vibrations have reported increases in the proliferation of osteoblasts, fibroblasts, and the loading-related regulation of gene expression in bone, being higher at high frequencies compared to low frequencies. Meanwhile, studies with vibrations combined with a compressive load factor have not reported an increase in the expression of RANKL mRNA or its protein [4,13].

Therefore, a review of the current state of the art, focused on high- or low-frequency vibrations to accelerate orthodontic tooth movement in humans, is a priority for decision-making in the consultation of orthodontists; for this purpose, we conducted a systematic review of only randomized controlled trials (RCTs) in order to evaluate the gold standard articles for judging the benefits of treatment on the effect of mechanical vibration stimuli during orthodontic treatment to accelerate dental movement in humans.

2. Materials and Methods

This study was conducted according to the recommendations of PRISMA (Preferred Report Elements for Systematic Review and Meta-Analysis) [17,18].

2.1. Search Methods for Identification of Studies

Based on the preferred reporting element guidelines for systematic reviews and meta-analysis (PRISMA), a specific question was developed in accordance with the PICO principle (participants, interventions, control, and results). The question addressed was "Do mechanical vibrations accelerate dental movement during orthodontic treatment in Humans?"

(P) Participants: Humans subjected to an orthodontic treatment.

(I) Types of interventions: Interventions of interest were orthodontic forces (such as alignment, closing of spaces, and grinding distalization) that would be carried out in conjunction with vibration treatment, coupled with a control group that would not have the stimulus.

(C) Control intervention: Teeth that were not subjected to vibratory stimuli were considered as controls.

(O) Outcome: Amount of human dental movement in response to vibration stimuli during orthodontic treatment.

This protocol was registered in PROSPERO: Prospective International Registry of Systematic Reviews with ID number CRD42021245217.

2.2. Sources of Information

To identify relevant studies to the PICO question, we performed an extensive search for studies published from 2010 to June 2021; only articles published in the English language indexed in the following electronic databases: PUBMED, NCBI, OVID, EBSCO, Cochrane Library, and Google Scholar, were included; a manual search in the list of references of the articles used was also performed. The aim of the search was to find studies focused on the effect of mechanical vibrations (high or low) in the orthodontic tooth movement. The main keywords were: (1) Vibration therapy OR AcceleDent OR Vpro5 OR Powered toothbrush OR High frequency OR Low frequency. (2) Acceleration OR Efficiency OR Rate OR Speed. (3) Orthodontics OR Tooth movement OR Alignment OR Retraction. (4) 1 AND 2 AND 3.

2.3. Inclusion Criteria

(1) The study must have evaluated the effectiveness of high- or low-frequency vibratory stimuli in the Orthodontic Tooth Movement (OTM).
(2) Study design: only randomized controlled trials (RCTs) were included in order to evaluate the gold standard articles for judging the benefits of treatments.
(3) Participants: studies where only healthy subjects requiring orthodontic treatment were included.
(4) Type of interventions: subjects must have been assigned to an experimental or control/placebo group in order to receive or not high- or low-frequency vibratory stimuli.
(5) Result type: indicator of tooth movement speed and related treatment parameters.

2.4. Exclusion Criteria

(1) Retrospective design studies, cohort study, case reports, descriptive studies or letters, review articles, and animal studies.
(2) Participants with systematic diseases affecting bone metabolism or orthodontic treatment.

2.5. Search Strategy and Study Selection

Two independent reviewers (M.F.G.V. and M.F.S.O.) searched the databases. In cases of unresolved disagreements, a third author (L.M.L.P-F.) was consulted. The search strategy was created from a combination of input terms and keywords related to the PICO strategy.

Reference manager software was used to save quotations and articles (Mendeley Ltd., London, UK, 2008–2019, Elsevier version 1.19.4). Once the duplicates were deleted, the titles of the articles and summaries were read to select the studies. The relevant studies were analyzed by reading the full text and the final selection was carried out by three researchers (M.F.G.V., M.A.C.S., and B.I.C-C.). If the discrepancies were not resolved, a third investigator (L.M.L.P-F.) was consulted.

2.6. Data Collection Process

Three authors performed the data extraction independently (M.F.G.V., A.D.K., and C.D.R.M.). The following items were considered for data extraction: author, year, type of study, origin, sample size, male/woman, groups, age, vibratory device, vibration frequency, time spent, orthodontic mechanics, motion measurement, results, and conclusions.

2.7. Risk of Bias in Individual Studies

The risk of bias was evaluated according to the Cochrane bias risk, which evaluates clinical trials and the possible bias in seven areas: random sequence generation, assignment concealment, participant blinding, blindness of evaluation results, incomplete results, selective reporting, and other biases. Bias was judged for each domain. The study was classified as low risk when all the elements were evaluated as low bias; as uncertain risk if one or more elements were evaluated as risk of uncertain bias; and as high risk when one or more elements were evaluated as high risk of bias. Each risk analysis was performed by three reviewers (M.F.G.V., M.A.C.S., and J.E.S.S.), and in the case of mismatching, a third reviewer was consulted (E.R.C.) [19].

2.8. Evidence Level

The certainty of scientific evidence of the results was assessed through the Grading of Recommendations Assessment, Development and Evaluation (GRADE). The RoB of the articles involving the dental movement during arc alignment and canine retraction were evaluated considering their RoB design, consistency, candor, and accuracy [20,21].

3. Results

3.1. Selection of Studies

The electronic search brought up a total of 435 articles. PubMed (n = 216), NCBI (n = 16), EBSCO (n = 24), OVID (n = 2), Google Scholar (n = 165), Cochrane (n = 12), and 2 additional references were also identified by manual search. After removing the duplicates, the title and abstract of 425 articles were read; nevertheless, 404 articles were deleted by irrelevance and, finally, 21 articles were potentially appropriate for the full text read. According to eligibility criteria, it was decided to exclude six of them. Fifteen RCT studies were included in the synthesis review [22–36]. The process of identifying, selecting, and excluding studies are shown in a flow chart according to the PRISMA statement (Figure 1).

3.2. Characteristics of the Studies

Ten studies used low-frequency vibrations [23,24,26–28,32–36], and five studies analyzed the high-frequency vibrations [22,25,29–31]. The devices used to generate the vibrations were as follows: AcceleDent (OrthoAccel Technologies, Inc., Bellaire, TX, USA) device [23,24,26,27,32,34,36], VPro5 (Propel Orthodontics, Ossining, NY, USA) [30], five studies applied the mechanical vibration with toothbrushes [25,28,29,31,33], one custom-made vibratory device [29], and one performed it with a dental massager whose brand was not specified [22].

The dental movement rate was measured by a digital caliper and by clinical inspections [23,28,32], measurements on plaster models [22,24–26,29,31], digitized plaster models [27,33,35], or intraoral scanning [30,34,36].

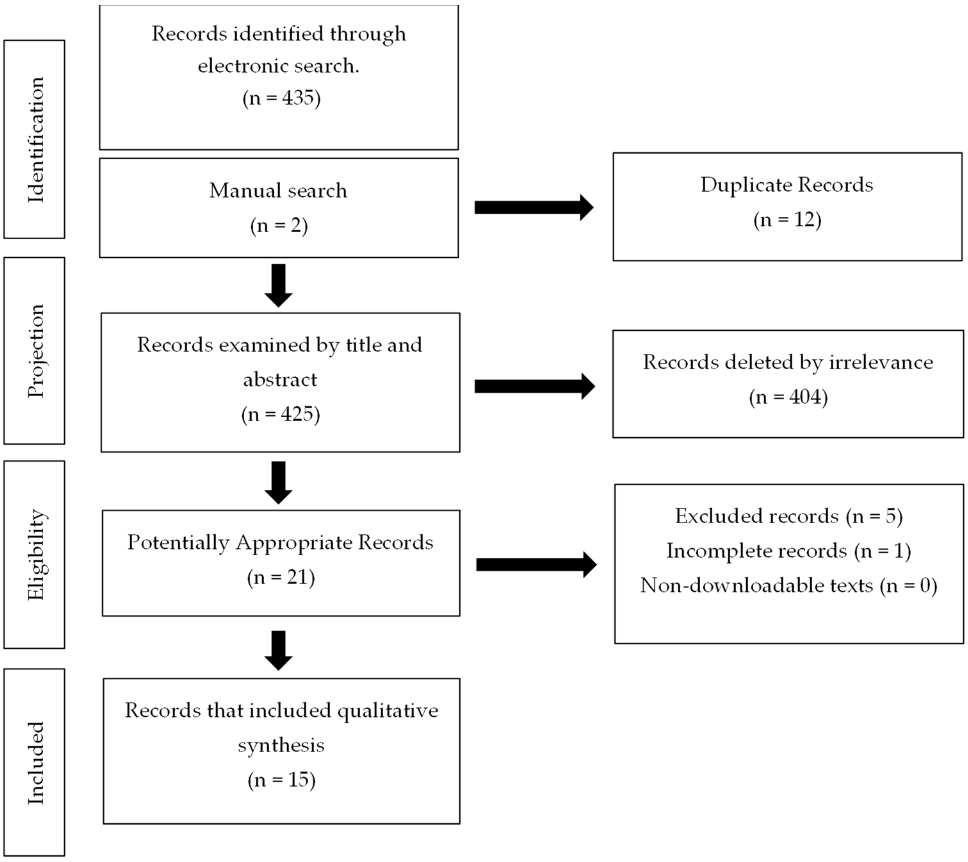

Figure 1. PRISMA flow diagram of record processing and elimination.

The follow-up periods ranged from 5 days [30], 60 days [29], 10 weeks [22,26], to the total treatment [24,27,32,36]. Only one study evaluated the first month after stimulus application [28], one article evaluated only two months [25], three articles evaluated the effect for 3 months [31,33,34], and two articles evaluated the time until space closure [23,35]. None of the articles evaluated the post-orthodontic treatment stage. Eight studies measured the rate of tooth movement during canine retraction [23,25,28,29,31,33–35], while seven studies evaluated the dental alignment phase [22,24,26,27,30,32,36].

3.3. Risk of Bias in Studies

Three RCTs were classified with a low RoB [24,35,36], five were classified with a moderate RoB [22,23,27,31,32], and seven with a high RoB [25,26,28–30,33,34]. The main reasons of the RoB outcomes were methodology factors, study blinding, and blinding during result measurement. The RoB assessments of the included studies are shown in Figure 2.

3.4. Results of Individual Studies

From the fifteen analyzed articles, seven studies had a high RoB [25,26,28–30,33,34]; the reason why it is important is to mainly describe the results in the orthodontic movement of those articles with low or moderate RoB. Three RCTs with a low RoB [24,35,36] and four with a moderate RoB [22,27,31,32] did not show a significant effect on the range of orthodontic movement with the use of high- or low-frequency vibrations, while only a moderate RoB article had a higher movement rate [23].

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and researchers (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Miles (2012)	?	?	?	+	+	+	+
Pavlin (2015)	+	+	+	+	+	+	?
Woodhouse (2015)	+	+	+	+	+	+	+
Leethanakul (2016)	?	-	?	+	-	+	-
DiBiase (2018)	+	+	+	+	+	+	?
Miles (2016)	+	+	+	+	+	+	-
Liao (2017)	+	-	-	-	+	?	-
Lombardo (2018)	+	+	?	+	+	+	?
Alansari (2018)	+	?	-	+	-	?	?
Katchooi (2018)	+	+	+	+	+	+	+
Kannan (2019)	+	?	?	?	+	+	?
Azeem (2019)	+	?	?	?	+	+	-
Siriphan (2019)	+	-	?	+	+	+	?
Taha (2019)	+	?	-	?	-	-	-
Kumar (2020)	+	+	+	+	+	+	+

Figure 2. Risk of bias summary for each of the included RCT studies (n = 15). The green color with a plus sign indicates low risk of bias; the yellow color with a question mark indicates an unclear risk of bias, and the red color with a minus sign indicates high risk of bias.

The characteristics of the low- and high-frequency vibrations studies are included in Tables 1 and 2, respectively.

Table 1. Summary of characteristics of the low-frequency vibration articles.

Author/ Origin	Sample	Groups	Vibration/ Time	Orthodontic Mechanics	Movement Measurement	Results	Conclusions
Pavlin (2015) United States	n = 45 Age: 12–40	EG: n = 23 CG: n = 22	AcceleDent (30 Hz, 0.25 N) Until closing space	Canine retraction	Digital caliper in the mouth	The average movement rate was significantly higher for the AcceleDents group at 1.16 mm.	An increase in movement was presented when vibrations were applied as a complement to orthodontic treatment.
Woodhouse (2015) United Kingdom, Germany	n = 81; F:41; M:40 Age: 14.06 ± 1.7	EG: n = 29 NFD = 25 CG: n = 27	AcceleDent (30 Hz, 0.25 N) 20 min a day for 209 ± 65 days	Alignment of the jaw arch	Plaster Models measured by digital caliper	There were no significant differences.	No evidence that vibrating force can increase alignment rate or reduce the time.
Miles (2016) Australia	n = 40 F:26; M:14 Age: 12–13	EG: n = 20, M:6; F:14 CG: n = 20, M:8; F:12	AcceleDent (30 Hz, 0.25 N) 20 min a day for 10 weeks	Alignment of jaw front teeth	Plaster models	There were no significant differences.	The device had no effect on increasing the perimeter of the previous arcade, or on reducing irregularity or discomfort.

Table 1. *Cont.*

Author/ Origin	Sample	Groups	Vibration/ Time	Orthodontic Mechanics	Movement Measurement	Results	Conclusions
Liao (2017) Australia	n = 13 Age 12–15	Split-mouth design	Oral B Hamming Bird Vibrating Unit 50 Hz 10 min a day for 28 days	Canine retraction	Digital caliper in the mouth	Canine distalization on the side of vibration was significant	Suggested that the mechanism for OTM acceleration may be more biologically based than mechanically based.
Lombardo (2018) Italy	n = 45; F:25; M:20 Age: 14–45	EG[1]: n = 15; M:8; F:7 EG[2]: n = 15; M:4; F:11 CG: n = 15; M:8; F:7	AcceleDent (30 Hz, 0.25 N) 20 min a day	Aligner treatment	Digital models	There were no significant differences	There were no differences in accuracy between replacing aligners accompanied by low-frequency vibration every 7 days and replacing it every 14 days without vibration.
DiBiase (2018) United Kingdom	n = 81 Age: <20	EG: n = 22; M:11; F:11 NFD: n = 19; M:8; F:11 CG: n = 20; M:11 F:9	AcceleDent (30 Hz, 0.25 N) 20 min a day throughout treatment	Aligner treatment	Gypsum models	There were no significant differences	Vibratory stimulus combined with fixed appliances does not affect the closure of space, duration of treatment, or occlusal result.
Katchooi (2018) U.S.A.	n = 27; F:15; M:12 Age: <18	EG: n = 13; M:6; F:7 NFD: n = 13; M:6; F:7	AcceleDent (30 Hz, 0.25 N) 20 min a day for 25 weeks	Aligner treatment	Switching time from aligner to 1 week.	There were no significant differences	The device does not influence the ability to complete a series of aligners.
Siriphan (2019) Thailand	n = 60; F:47; M:13 Age: 18–25	EG (30 Hz): n = M:3; F:17 EG (60 Hz): n = 20; M:5; F:15 CG: n = 20; M:5; F:15.	30 Hz and 60 Hz in modified toothbrushes. 20 min a day for 3 months.	Canine distalization	Digital models	There were no significant differences	3 months with vibration of 30 or 60 Hz does not accelerate the movement rate of the canine.
Taha (2019) Tokyo	n = 21; F:14; M:7 Age: 11–17	EG: n = 10; M:3; F:7 CG: n = 11; M:4; F:7	AcceleDent (30 Hz, 0.25 N) 20 min a day at 7 p.m. for 12 weeks	Canine retraction	Intraoral scanning	There were no significant differences	No statistically significant differences in canine retraction between experimental and control groups.
Kumar (2020) India	n = 65; F:35; M:30 Age: 16–17	LFS: n = 20; M:10; F:10 LFC: n = 20; M:8; F:12 CG: n = 25 M:12; F:13	30 Hz custom-made device by researchers. 20 min a day during space closure	Canine retraction	Digital models	There were no significant differences	Low-frequency vibrations do not increase the rate of dental movement in adolescent patients with early bicuspid extraction or in combination with passive self-linked brackets.

Abbreviations: EG, experimental group; CG, control group; M, male; F, female; NFD, nonfunctional device; EG[1], experimental group aligner substitution 14 days; EG[2], experimental group aligner substitution 7 days; LFS, low-frequency vibration and self-ligation; LFC low-frequency vibration and conventional ligation.

Table 2. Summary of characteristics of the high-frequency vibration articles.

Author/ Origin	Sample	Groups	Vibration/ Time	Orthodontic Mechanics	Movement Measurement	Results	Conclusions
Miles (2012) Auatralia	n = 66; F:40; M:26 Age: 11–15	EG: n = 33, M:12; F:21 CG: n = 33 M:4 F:19	Dental massage device (111 Hz, 0.06 N). 20 min a day for 10 weeks	Alignment of the six jaw anterior teeth	Plaster model	EG = reduction of 65% at 10 weeks, while CG showed a 69% reduction in the same period.	There seems to not be any clinical advantage in the use of the vibratory devices for the early resolution of crowding during initial alignment.
Leethanakul (2016) Thailand	n = 15; F:11; M:4 Age: 19–25	Split-mouth design, (right or left) it was determined randomly	Vibratory Electronic Toothbrush (Colgate) (125 Hz). 15 min a day for 2 months	Retraction of maxillary canines	Plaster Models measured by digital caliper	The amount of movement was greater for the experimental canine than for control, $p = 0.001$.	Orthodontic force along with vibratory stimuli increased IL-1beta secretion in the gingival crevicular fluid and accelerated movement.
Alansari (2018) U.S.A.	n = 60; F:34; M:24 Age: 18–45	EG[2]: n = 13; M:5; F:8 EG[3]: n = 13; M:4; F:9 EG[4]: n = 13; M:7 F:6 EG[5]: n = 5; M:2; F:3 CG: n = 13; M:5; F:8	Vpro5™ (120 Hz)/ 5 min a day. 5 min a day for four aligners.	Anteroposterior movement rate of a lower anterior	Digital intraoral scans.	There were no significant differences.	Vibration treatment resulted in the significant shortening of time for correction of jaw incisors with transparent aligners.
Kannan (2019) India	n = 23; Age: 18–25	Split-mouth design	Oral B CrossAction Electric Toothbrush ® Dual Power Clean 100–105 Hz. Three times a day for 5 min/ 3 months	Individual retraction of canines with mini-implants	Gypsum models and digital caliper.	There were no significant differences.	More RCTs are needed to determine whether vibratory devices result in a significant reduction in the duration of orthodontic treatment.
Azeem (2019) Pakistan	n = 28; F:10; M:18 Age: 18–24	Split-mouth design	Oral B Triumph (125 Hz). 20 min day for 60 days.	Canine retraction using a helical spring. Canine distalization	Gypsum models and digital caliper.	There were no significant differences	The application of vibratory stimuli using an electric brush does not accelerate orthodontic tooth movement.

Abbreviations: EG, experimental group; CG, control group; M, male; F, female; EG[2], experimental group aligner substitution 7 days; EG[3], changed aligners every 7 days, no vibration treatment, EG[4], experimental group aligner substitution 5 days; EG[5], changed aligners every 5 days, no vibration treatment.

3.5. Assessment of the GRADE Test Certainty

The evaluation of the evidence according to GRADE is described in Table 3. The quality of evidence was rated as low for tooth movement rate during alignment [22,24,26,30] and tooth movement rate during canine retraction [23,25,28,29,31,33,34] due to inconsistency and imprecision of the studies, as well as risk of bias. Four articles were not included in the Grade analysis, due to the impossibility of placing them in one of the two groups because they evaluated different mechanics such as anteroposterior movement or noncanine distalization, or the completion of the sequence of aligners [30,35,36].

Table 3. Population: Patients with orthodontic treatment. Intervention: Vibratory stimuli.

Evaluation Period	Study Design	Limitations	Number of Patients	Inconsistency of Results	Indirect Evidence	Other Considerations	Evidence Quality	Feedback
Tooth movement rate during alignment phase	RCT	Serious limitations. [1,2]	Studies 7 (380)	Serious. [5]	Not serious.	Serious considerations. [6]	- -+- Low [7]	There seems not to be any clinical advantage in the use of the vibratory apparatus.
Tooth movement rate during canine retraction	RCT	Serious limitations. [3,4]	Studio 8 (270)	Serious. [5]	Not serious.	Serious considerations. [6]	- -+- Low [7]	The amount of movement was the same with the use of the vibratory apparatus.

Alignment: Miles 2012, Woodhose 2015, Miles 2016, Alansari 2018, Lombardo 2018, Dibiase 2018, Katchooi 2018. Canine retraction: Pavlin 2015, Letthankul 2016, Liao 2017, Kannan 2019, Azeem 2019, Siriphan 2019, Taha 2020, Kumar 2020. [1] Unclear risk in random sequence generation, assignment concealment, participant blinding, incomplete information, and other biases. [2] Seven studies with a limited sample size were included (n = 380). [3] High risk of bias in the randomization, blinding, and other biases. [4] Eight studies with a limited sample size were included (n = 270). [5] Considerable heterogeneity. [6] Orthodontic technique, vibrational stimulus varied between studies. [7] Confidence in the estimation of the effect and its magnitude could change with new studies.

4. Discussion

Adjunctive vibration has gained popularity among clinicians and patients as they are not an invasive treatment and have not been shown to have adverse effects. However, the efficacy of the procedure is still controversial. The literature has questioned how vibratory therapy works, if there really exists a biological stimulation of bone metabolism or if the mechanical stimulus simply helps to improve the settlement as in the case of aligners [30]. In this sense, accelerated orthodontic devices were created in response to the growing desire for faster treatment times; nevertheless, valid questions remain on the impacts of mechanical vibrations on bone metabolism. This systematic review contrasted current literature regarding the effectiveness of these devices in accelerating orthodontic tooth movement. The results of this work showed that there is a lack of quality-randomized clinical studies without potential risks of bias that evaluate either high- or low-frequency vibrations effects on orthodontic tooth movement, being even fewer than the number of studies found at high frequency [22,25,29–31]. In addition, 17% of the studies evaluated in this article employed a treatment with aligners, leaving aside conventional treatment such as brackets [27,30,36]. Furthermore, because of the heterogeneity of methodology across the included studies (different types of devices, orthodontic mechanics, and appliances), a meta-analysis could not be performed.

4.1. High-Frequency Studies

In the RCTs evaluated, it was found that in one of the first articles not only of high frequency but also of vibrations as an adjuvant in orthodontic treatment in the study of Miles et al., they reported the use of conventional brackets (Victory Series, 3M Unitek, Monrovia, CA, USA), and they used a device that provides a dental massage at 111 Hz, 0.06 N, for 20 min a day for 10 weeks; however, it showed no statistically significant difference for the resolution of crowding during the initial stage compared to the control group [22].

On the other hand, these results are opposite to those obtained by Leethanakul et al. who, although using high-frequency vibrations (125 Hz), performed them with a battery-powered electronic vibrating toothbrush (Colgate® Motion-Multi Action electric toothbrush) and conventional brackets (3M Gemini brackets; 3M Unitek Corporation, Monrovia, Calif). They observed a significant increase in canine movement in the experimental group compared to the control group ($p < 0.001$) [25].

Azeem et al. also used an electric toothbrush with an orthodontic head specially designed (Oral-B Triumph, OD17; Procter & Gamble, Cincinnati, OH, USA) as a vibration device (125 Hz), and they used MBT prescription brackets (3M Gemini brackets; 3M Unitek Corporation, Monrovia, Calif). The study was carried out on 28 patients of both sexes in a period of

90 days, in which the degree of canine movement was evaluated. However, unlike the study by Leethanakul et al., the results showed no increase in dental movement ($p > 0.05$) [29].

It is important to highlight that, of all the devices used in the high-frequency studies, the Vpro5 (Propel Orthodontics, Ossining, New York) (120 Hz) is the only high-frequency device commercially available that specifically offers to accelerate the orthodontic tooth movement, unlike the other devices previously mentioned, which were not specifically designed to accelerate tooth movement during orthodontic treatment. In this sense, Alansari et al. evaluated the effectiveness of the vibratory stimulus by using the device 5 min a day in 75 patients divided into five groups treated with Invisalign® (Align Technology, Inc., Santa Clara, CA, USA). Under these conditions, they measured the rate of anteroposterior movement of a lower anterior tooth, and the results showed that Vpro5 can reduce the time interval between aligner changes without affecting the treatment efficacy, as equal magnitudes of tooth movement are shown in subjects treated with aligner changes every 14 days or in those who had aligners changed every 7 days ($p < 0.003$) [30]. Nevertheless, as it presents a different appliance, and a short period of evaluation, it is not possible to discern if this benefit will be obtained during the entire treatment, as well as if it is applicable to all types of orthodontics, or if it only works mechanically, allowing a greater adjustment of the aligners.

Finally, Kannan et al. designed a split-mouth study in 23 patients with MBT prescription brackets (3M Gemini Series™ MBT); as these patients required canine distalization, attachments such as Miniscrew implant (tomas® Dentaurum) were used, and the electric toothbrush Oral B CrossAction® Power Dual Clean was used as a supplementary vibration device of 100–105 Hz, for 5 min, three times a day on the experimental side. The three-months results showed no statistically significant difference when the experimental and control sides were compared ($p = 0.70$) [31]. It should be noted that this study did not mention having checked the frequency of its device, as it was based on the Cochrane Review of manual versus electric toothbrushing for oral health.

An interesting finding is that the previously mentioned articles were evaluated in this systematic review with a moderate or high risk of bias, and it is even more important that the only two articles that reported a positive effect of the use of vibrations showed a high risk of bias. Nevertheless, despite this finding, the evidence is still limited to conclude whether or not vibrations, particularly those of high frequency, have a biological effect.

4.2. Low-Frequency Studies

The only articles with low RoB were performed using low-frequency vibrations; nonetheless, only three articles [24,35,36] obtained this evaluation; this result is probably due to the greater number of articles found that evaluated low frequencies.

Eight [24,26,27,32–36] of the ten articles using low-frequency vibrations during orthodontic treatment did not show a statistically significant increase in orthodontic tooth movement, while only two articles, one with high RoB [28] and one with moderate RoB [23], showed the opposite.

It is important to highlight that, among the articles that do not present evidence that low-frequency vibrations have an effect on dental movement, they have in common that most of them used the AcceleDent device (OrthoAccel Technologies, Bellaire, TX, USA) to exert the vibratory stimulus [24,26,27,32,34,36]. In addition, the articles that did not present encouraging results evaluated vibration stimuli in modified toothbrushes [33] or in a device developed by the researchers [35].

Pavlin et al. and Liao et al., who did show positive results, evaluated canine retraction as a stage of treatment and low-frequency vibration, using different devices: the AcceleDent (OrthoAccel Technologies, Bellaire, TX, USA) [23] and the Oral B (USA) Humming Bird vibrating toothbrush [28]. Nevertheless, the evidence suggests that vibratory stimuli could act in a frequency-dependent manner with bone cells more sensitive to higher frequencies [12].

4.3. Studies Carried Out with Electric Toothbrushes

From the fifteen articles included for this systematic review, five used electric toothbrushes as a vibration device. Leethanakul et al. used the Colgate® Motion-Multi Action electric toothbrush (125 Hz) [25], Liao et al. used the Oral B (USA) Humming Bird Vibrating toothbrush (50 Hz) and brackets (3M Unitek, Monrovia, CA, US) [28], Kanan et al. used the Oral B CrossAction ® Dual Power Clean electric toothbrush (100–105 Hz) [31], Azeem et al. used the Oral B Triumph toothbrush (125 Hz) [29], and Sririphan et al. used vibration devices that were fabricated from toothbrushes (30–60 Hz) [33]. Three of the five articles found no evidence that these devices produce an increase in dental movement [29,31,33], but it is worth mentioning that two of them had a high RoB [29,33] and one had a moderate Rob [31]. There are only two articles that showed a significant result in tooth movement during the application of vibrations by means of vibrating toothbrushes [25,28]. Nevertheless, this article presented a high RoB; therefore, their results do not represent reliable evidence.

4.4. Studies That Evaluated the Canine Retraction

The articles that evaluated the canine retraction have in common the use of the AcceleDent device (OrthoAccel Technologies, Bellaire, TX, USA) [23,34,35] and toothbrushes of commercial or modified brands [25,28,29,31,33]; most of them did not obtain a significant increase in tooth movement [29,31,33–35]. Only three articles [23,25,28] reported significant evidence; however, they were evaluated with a high risk of bias, so they cannot be taken as a reference to establish a beneficial effect on tooth movement. In addition, the use of different devices: Acceledent [23] and vibrating toothbrush [25,28], makes it impossible to compare them with each other as the vibration of these devices was applied in a localized way (toothbrush) or in the entire arch simultaneously due to their design (AcceleDent device, OrthoAccel Technologies, Bellaire, TX, USA).

4.5. Studies That Evaluated the Alignment Phase

Seven articles evaluated the rate of tooth movement during the alignment phase (total n = 380 patients) [22,24,26,27,30,32,36]. The articles evaluated did not show significant evidence of the effectiveness of the mechanical vibrations on reducing the alignment phase, either in studies of low frequency [24,26,27,30,32,36] or in the only article that used high frequency [22]. As in canine retraction studies, the most important variables that could influence the results obtained were the use of diverse vibratory devices and the appliances in the orthodontic mechanics.

5. Excluded Studies

Some articles were excluded for this systematic review even though, despite using mechanical vibrations during orthodontic treatment, they did not evaluate the acceleration of orthodontic tooth movement. The article of Dibiase et al. was excluded because they analyzed root reabsorption [37]. The study of Celebi et al. was excluded because they evaluated the relationship of orthodontic treatment with pain and mechanical vibrations as a principal outcome [38]. The studies of Shipley et al., Bowman et al., and Farouk et al. were excluded because they were retrospective studies [2,9,11]. On the other hand, Akan et al. used an electromyography, a very different device that does not use vibrations.

Strengths and Limitations of This Systematic Review

Although one of the important limitations of this systematic review was to have included articles with high or moderate risk of bias, these articles were RCTs, considered as the gold standard articles for judging the benefits of treatments. On the other hand, it is important to highlight the complexity of reporting a systematic review where there is an extensive heterogeneity in mechanical vibratory devices, the vibration frequencies, and the orthodontic appliances used, making the results difficult to compare in those studies where conventional orthodontic treatment (brackets) or aligners were used. Furthermore, the objectives and experimental times evaluated were diverse too. Nevertheless, despite the heterogeneity of the reported literature, this article integrates all current clinical articles regarding the mechanical vibrations and its influence in the orthodontic tooth movement.

6. Conclusions

Most of the studies analyzed in this systematic review had a high RoB (7) or moderate RoB (5). Only four articles, three of them with high RoB and one with moderate RoB, found that mechanical vibrations are effective to accelerate orthodontic tooth movement. The results seem to indicate that there is no evidence that vibratory stimuli can increase the rate of dental movement or reduce the time of dental alignment or canine retraction during orthodontic treatment. Nevertheless, the different vibration application methods, the different types of vibrations used, the different types of dental movements evaluated, and the short follow-up time make the evidence shown not sufficiently representative. Thus, the results can only be taken as trends and not as a definitive conclusion.

Therefore, it is important to generate high-quality clinical trials that follow the orthodontic treatment to the end, with lower heterogeneity in the orthodontic mechanical appliances and the vibratory device used; this fact is of particular relevance in the application of high-frequency vibrations, as the number of articles regarding this kind of vibratory stimulus was small. The performance of clinical studies with greater standardization will allow us to obtain more robust data in the future from which clinical conclusions can be obtained regarding the use of vibrations as a method to accelerate orthodontic movement.

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