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SYSTEMATIC REVIEW

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Effect of supplemental vibration on tooth movement and treatment time with clear aligners. A systematic review and meta-analysis

Efeito da vibração suplementar no movimento dentário e no tempo de tratamento com alinhadores transparentes. Uma revisão sistemática e meta-análise

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ABSTRACT

Aim: The aim of this systematic review and meta-analysis was to evaluate the effect of supplemental vibrational force on tooth movement and treatment duration in patients undergoing treatment with clear aligners. **Material and Methods:** Electronic searches were carried out without any restriction in PubMed, the Cochrane Library, the Directory of Open Access Journals, LILACS, and Google Scholar. The revised Cochrane risk of bias tool (RoB 2.0) for randomized controlled trials, the Risk of Bias in Nonrandomized Studies of Intervention (ROBINS-I) tool for prospective studies, and the Newcastle-Ottawa Scale for retrospective studies were used. Grading of Recommendations Assessment, Development, and Evaluation (GRADE) was used to assess the quality of evidence. Random effects meta-analysis with standardized mean difference (SMD) was carried out using Review Manager software (Revman 5.4). **Results:** Ten studies met the inclusion criteria for this systematic review. While some studies reported a reduction in aligner change intervals and improved tracking, the overall clinical impact on treatment duration was limited. Meta-analysis demonstrated a statistically significant decrease in aligner exchange rate with the use of supplemental vibration (SMD = -2.36; 95% CI: -4.52 to -0.21; p = 0.03), although no consistent improvement in final tooth alignment or total treatment time was observed. **Conclusion:** There is limited evidence on the effect of supplemental vibration of aligners. The meta-analysis indicates that while supplemental vibration may significantly reduce the aligner exchange rate, it does not result in a statistically significant improvement in incisor alignment or reduction in the total number of aligners required for treatment completion. These findings suggest limited clinical benefit of vibrational force in enhancing overall treatment efficiency with clear aligners.

KEYWORDS

Acceleration; Clear aligner; Orthodontic appliances; Tooth movement; Vibration.

RESUMO

Objetivo: O objetivo dessa revisão sistemática com meta-análise foi avaliar o efeito da força vibracional suplementar no movimento dentário e na duração do tratamento em pacientes submetidos a tratamento com alinhadores transparentes. **Material e Métodos:** Foram realizadas pesquisas eletrónicas sem qualquer restrição no PubMed, na Cochrane Library, no Directory of Open Access Journals, na LILACS e no Google Scholar. Foram utilizadas a ferramenta Cochrane revisada de risco de viés (RoB 2.0) para ensaios controlados aleatórios, a ferramenta Risk of Bias in Nonrandomized Studies of Intervention (ROBINS-I) para estudos prospectivos e a Newcastle-Ottawa Scale para estudos retrospectivos. A classificação de recomendações, desenvolvimento e avaliação (GRADE) foi utilizada para avaliar a qualidade das evidências. A meta-análise de efeitos aleatórios com diferença média padronizada (SMD) foi realizada utilizando o software Review Manager (Revman 5.4). **Resultados:** Dez estudos atenderam aos critérios de inclusão para esta revisão sistemática. Embora alguns estudos tenham relatado uma redução nos intervalos de troca dos alinhadores e um melhor acompanhamento, o impacto clínico geral na duração do tratamento foi limitado.

A meta-análise demonstrou uma diminuição estatisticamente significativa na taxa de troca de alinhadores com o uso de vibração suplementar (SMD = -2,36; IC 95%: -4,52 a -0,21; p = 0,03), embora não tenha sido observada uma melhoria consistente no alinhamento final dos dentes ou no tempo total de tratamento. **Conclusão:** Existem poucas evidências sobre o efeito da vibração suplementar dos alinhadores. A meta-análise indica que, embora a vibração suplementar possa reduzir significativamente a taxa de troca dos alinhadores, ela não resulta em uma melhoria estatisticamente significativa no alinhamento dos incisivos ou na redução do número total de alinhadores necessários para a conclusão do tratamento. Esses resultados sugerem um benefício clínico limitado da força vibratória no aumento da eficiência geral do tratamento com alinhadores transparentes.

PALAVRAS-CHAVE

Aceleração; Alinhador transparente; Aparelhos ortodônticos; Movimento dentário; Vibração.

INTRODUCTION

Orthodontic treatment with clear aligners has gained widespread popularity due to its advantages in aesthetics, patient comfort, removability, and improved oral hygiene. These transparent thermoplastic trays are designed using three-dimensional (3D) computer-aided technology to progressively move teeth into proper alignment. However, despite their many advantages, one major limitation of clear aligners, as with traditional fixed appliances, is the prolonged treatment duration, especially in complex malocclusions or cases requiring high patient compliance [1].

Although clear aligner software often predicts the ideal correction of a malocclusion, clinical results may not always match the virtual treatment plan. In some cases, clinicians must resort to auxiliary techniques such as elastics or interproximal reduction, and additional refinement aligners may be necessary to achieve the desired outcomes. These challenges contribute to extended treatment times and may affect overall predictability. Patients often express concern over the length of treatment, and shorter treatment times are desirable to reduce risks such as enamel decalcification, root resorption, and patient burnout, while also improving satisfaction and compliance [2].

Orthodontic treatment duration is influenced by various factors, including the complexity of the malocclusion, patient age, compliance, and bone biology. Therefore, strategies to safely accelerate tooth movement have garnered attention. There are various surgical, mechanical, and biological methods discussed over time to accelerate orthodontic tooth movement, which are now being combined effectively with clear aligner treatment [3]. The treatment time depends on the rate of tooth movement, which in turn depends on the rate of alveolar bone remodeling. Pharmacological agents prescribed for systemic diseases, such as prostaglandins, bisphosphonates, corticosteroids, and salbutamol, have been studied for their effects on orthodontic tooth movement [4,5]. Some drugs have been used favorably to accelerate tooth movement by influencing bone remodeling. An alternate non-systemic approach to accelerating tooth movement is by using device-assisted therapy that includes techniques like photobiomodulation, direct electric currents, pulsed electromagnetic fields, resonance vibration, and low-level lasers [6]. Among several adjunctive options explored, ranging from surgical interventions and pharmacologic agents to device-assisted therapies, non-surgical methods are favored due to their minimal invasiveness. One such mechanical adjunct is the use of vibrational devices.

Mechanical vibration, as a form of cyclic loading, is hypothesized to enhance orthodontic tooth movement (OTM) by stimulating bone remodeling. The proposed biological rationale includes principles such as the bone-bending theory and bioelectric theory, which suggest that mechanical forces generate piezoelectric potentials that promote localized cellular responses. These forces influence osteoblast and osteoclast activity through mechanotransduction pathways [7]. Research on piezoelectricity caused by a pulsed force for accelerating tooth movement was conducted as early as the 1970s [8]. Bioelectrical potential is created when there is application of discontinuous forces, which leads to the idea of trying cyclic forces and vibrational devices. The molecular basis behind the acceleration of orthodontic tooth movement (OTM) using the vibrating devices is stimulating more expression of receptor activator of nuclear factor-κ B ligand (RANKL) and osteoblast formation in the periodontal ligament, thus accelerating bone remodeling [9]. Depending on the orthodontic force used, these vibrating stimulations will result in either catabolic or anabolic alterations [10].

Orthodontic treatment using fixed appliances or aligners can be associated with pain, risk of root resorption, and potential relapse—especially in intrusion mechanics due to forces affecting periodontal and alveolar structures [11]. Other proposed advantages of vibration force include reduction in pain [12], reduction in root resorption during aligner treatment [13], and improved retention due to increased bone density [14].

There are two kinds of vibration devices that operate at frequencies between less than or equal to 45 or more than or equal to 90 Hz, which are referred to as low and high frequency, respectively. Commonly available and researched vibration devices include a low-frequency device, AcceleDent (OrthoAccel Technologies, Bellaire, Tex), providing 0.2 N at 30 Hz vibrational force worn for 20 minutes per day, and a high-frequency VPro5TM (Propel Orthodontics, Ossining, NY) providing vibration at 120 Hz and worn for 5 minutes daily [15]. The Tooth Masseuse device produced a high vibration frequency of 111 Hz and is no longer available [16]. Many vibratory devices are now commercially available with different frequencies; there are custom-made devices, and some electric toothbrushes are also prescribed to provide vibratory stimuli [17].

Several systematic reviews have explored the efficacy of vibrational stimulation with fixed appliances, demonstrating its potential to accelerate tooth movement and reduce treatment duration. They suggest that while it may significantly enhance canine retraction, high heterogeneity and methodological limitations hinder definitive conclusions, with overall weak evidence for its efficacy in alignment and inconclusive effects on pain reduction and root resorption. Despite their theoretical benefits, evidence regarding the clinical efficacy of vibrational devices in clear aligner therapy remains inconclusive [18-20]. The existing evidence on the effect of vibration on acceleration of tooth movement when combined with aligner treatment is unclear due to varied results, with claims of reduced treatment time [21] to no effect [22]. This systematic review and meta-analysis was undertaken to assess whether supplemental low- or high-frequency vibration improves tooth movement efficiency and reduces treatment duration in patients undergoing orthodontic treatment with clear aligners.

MATERIAL AND METHODS

Protocol and registration

Based on the International Prospective Register of Systematic Reviews (PROSPERO), this review was registered preliminarily with number CRD42024538212. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in conducting and reporting the systematic review and meta-analysis [23].

Research question

Do low-or high-frequency vibrational devices have an effect on orthodontic tooth movement and treatment duration when used with aligners?

Eligibility criteria

Studies satisfying the following eligibility criteria were included in the systematic review and meta-analysis:

1. Participants: Orthodontic patients undergoing treatment with clear aligner therapy.
2. Intervention/exposure: Aligner patients exposed to low- or high-frequency vibration devices for accelerating tooth movement.
3. Comparison: Aligner patients without supplemental vibration.
4. Primary Outcome Measures: Tooth movement Difference/acceleration in tooth movement (decrease in treatment duration or aligner wear time).
5. Study design: randomized controlled trial (RCT), controlled clinical trial, and prospective and retrospective studies.

Exclusion criteria

1. Animal studies
2. Case reports, case series, reviews
3. Other language studies
4. Studies using fixed appliances
5. Other method of acceleration combined with vibration

Information sources and search strategy

An electronic search was carried out by two authors independently without any restriction in year of publication in PubMed, Cochrane Library, Directory of Open Access Journals, ScienceDirect, LILACS, and Google Scholar till March 2025. Additional searches were carried out in the clinical trials registry for grey literature and manual hand searches of references of included studies. Keywords related to aligner treatment, vibration, accelerated tooth movement, and aligner change time according to the research question were used in the above databases with Boolean operators (AND, OR) (Table I). Manual searches to identify studies were performed in some orthodontic journals like the American Journal of Orthodontics & Dentofacial Orthopedics, Angle Orthodontist, European Journal of Orthodontics, and Journal of the World Federation of Orthodontists. All references were exported to Zotero software for duplicate elimination. After title and abstract screening, irrelevant articles were excluded, and full texts of remaining articles were downloaded and assessed for eligibility.

Data extraction and synthesis

Three reviewers independently collected data in a tabulated form. The patient demographic data, type of vibration device used, number of aligners, aligner exchange time, total duration of treatment, type of tooth movement assessed, and other outcomes of the studies were collected. Any conflicts in data collection were resolved by discussion with a fourth reviewer until consensus.

Risk of bias of the individual studies

The included articles were evaluated for potential risk of bias and tabulated. The revised Cochrane risk of bias tool (RoB 2.0) was used for randomized controlled trials, and low, some concerns, or high risk of bias was identified [24]. The Risk of Bias in Nonrandomized Studies of Intervention (ROBINS-I) tool was used for prospective studies [25], and the Newcastle-Ottawa Scale was used for retrospective clinical studies [26].

Quality assessment

Quality assessment of the included studies was carried out using the Grading of Recommended Assessment, Development, and Evaluation (GRADE) tool [27].

Summary measures and approach to synthesis

Results of the individual studies were analyzed, and studies with similar interventions were pooled. Results from retrospective studies were interpreted with caution and presented separately when necessary to avoid overgeneralization. Means and standard deviations of the continuous data with 95% confidence intervals (CI) were pooled. Statistical analysis was carried out using review manager (Revman 5.4) software. Statistical significance was established at $p<0.05$. Clinical heterogeneity was assessed based on the study characteristics data, and statistical heterogeneity was calculated using the Tau2 and $I2$ statistics. Random effects meta-analysis and standardized mean difference were used as summary statistics in meta-analysis as the same outcome was measured in a variety of ways in different studies.

Table I - Search strategy

Databases	Search strategy used
MEDLINE searched through PubMed,	("Clear aligner" OR aligner OR "clear aligner treatment")AND(vibrat* OR vibration OR "vibrational forces" OR "vibratory device" OR "sham device" OR "mechanical vibration" OR Acceledent OR "electric toothbrush") AND (tooth movement* OR orthodontic tooth movement* OR "rate of tooth movement" OR "accelerated" OR "aligner change" OR "treatment time").
Directory of open access journal (DOAJ)	Clear aligners and vibration
Cochrane Database of Systematic Reviews searched through The Cochrane Library	("Clear aligners" OR aligner OR "clear aligner treatment")AND(vibrat* OR vibration OR "vibrational forces" OR "vibratory device" OR "sham device" OR "mechanical vibration" OR acceledent)
Google scholar	"clear aligner" and vibration device and "accelerated tooth movement" or "tooth movement"
LILACS	("clear aligner") OR (aligner) AND (vibration) OR ("vibration device")
Science direct	("Clear aligners" OR aligners)AND(vibration OR "vibrational forces") AND ("tooth movement" OR "orthodontic tooth movement")

* indicates truncated search term.

RESULTS

Study selection

The initial database search included 266 articles, out of which 37 were cited as duplicates. Two independent reviewers screened the title and abstract, and 205 articles were excluded as being irrelevant to the systematic review. 24 articles were sought for retrieval. No additional articles were found through hand search or additional search. After screening the full-text articles according to the eligibility criteria, ten articles were included for qualitative analysis and seven articles were included in meta-analysis. The PRISMA flow chart is depicted in Figure 1.

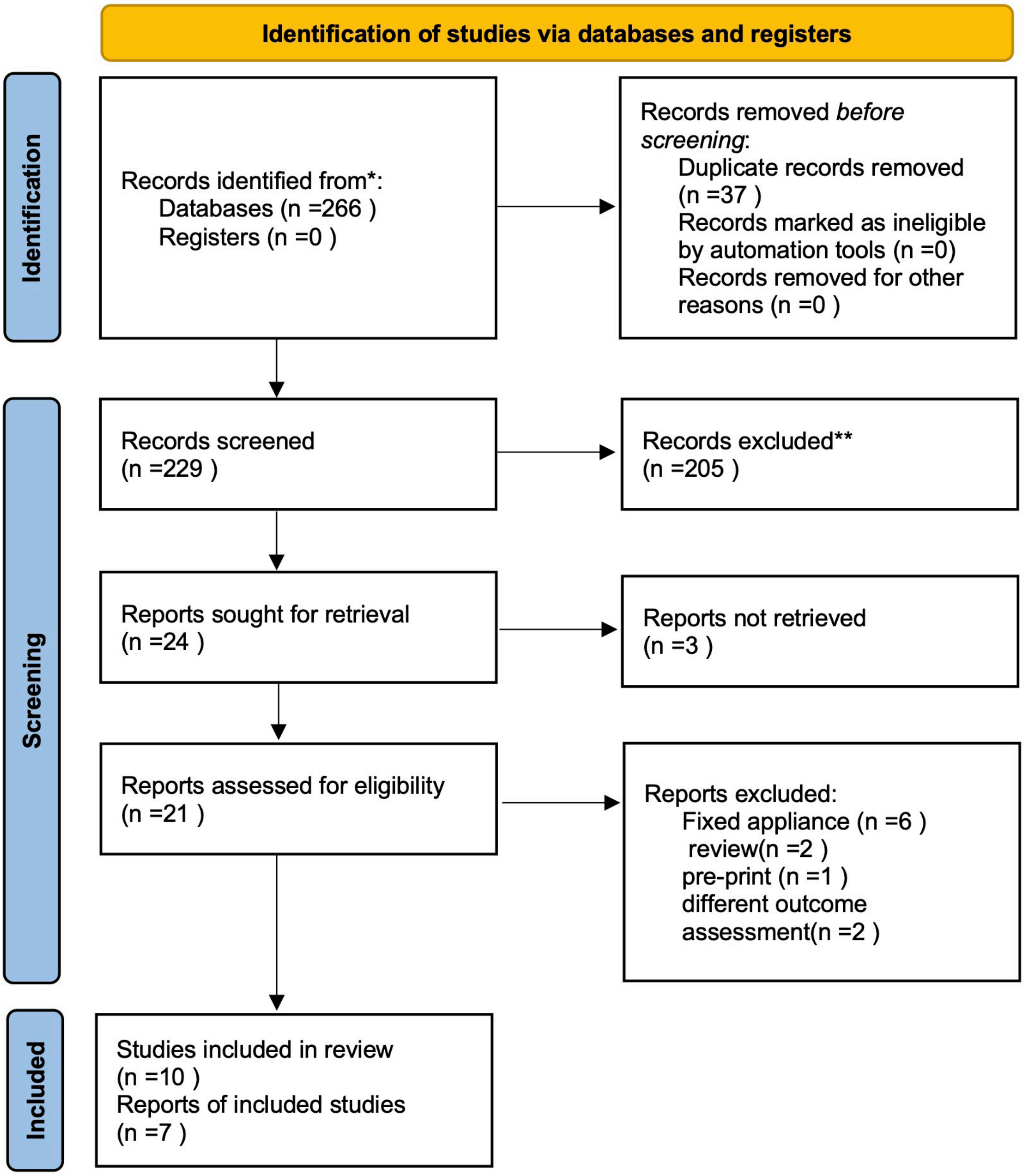

Figure 1 - PRISMA Flowchart.

Study characteristics

Ten studies were included in the systematic review [12,14,22,28-34]. The characteristics of the individual studies are presented in Table II. Five randomized controlled trials (RCT) [22,28,29,32,33], one controlled clinical trial [34], one prospective study presented in two parts with the data combined [12,31], and two retrospective studies were seen [14,30]. There were a total of 328 participants, and they were patients in the age group of 14 years to 45 years. There was significant methodological variability seen in the included studies. Five studies used the low-frequency vibration device AcceleDent Aura for 20 minutes per day [12,29,31-34]. Four studies used high-frequency vibration VPro+ for 5 minutes per day [14,22,28,30]. The control groups were either prescription sham devices [14,28,29] or no usage of any devices and only aligners [12,22,30-34]. The study period included a specific set of aligner numbers or the end of treatment. The aligner exchange rate varied from 14 days to 5 days. Given the limited number of clinical studies available on supplemental vibration in clear aligner therapy, a broader inclusion criterion was adopted to capture the current scope of evidence. This systematic review included studies employing both low- and high-frequency devices and various study designs (RCTs, CCTs, and prospective studies). While this approach may introduce clinical and methodological heterogeneity, it was necessary to comprehensively evaluate the existing literature on this topic.

Risk of bias within individual studies

Three RCTs showed low risk of bias, two showed some concerns/unclear risk of bias, and one CCT showed unclear risk of bias. Shortcomings in deviations from intended interventions, missing outcomes, and selection of reported results were seen. (Figure 2) The two prospective studies showed a high risk of bias (Figure 3), and two retrospective studies showed a low risk of bias (Table III).

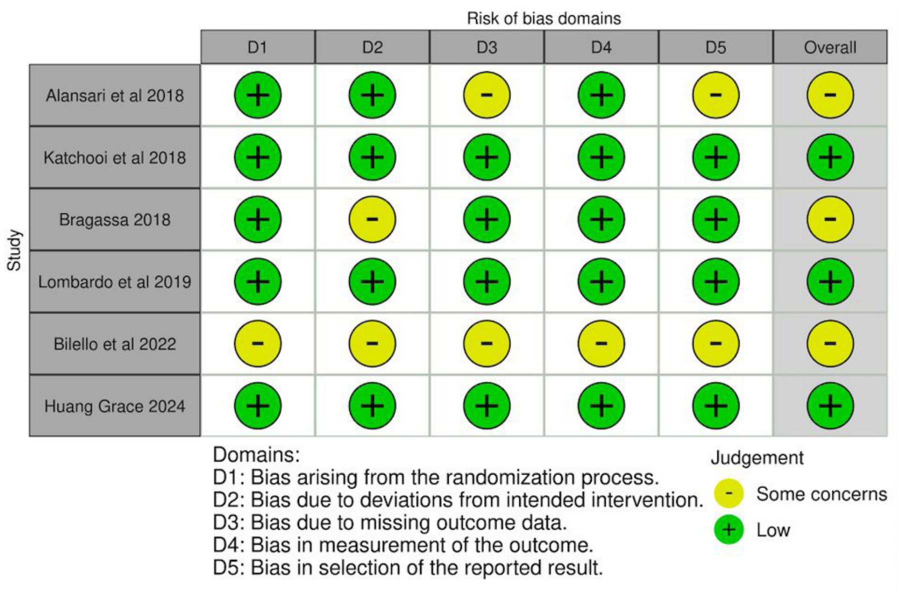

Figure 2 - Evaluation of Risk of Bias using Revised Cochrane risk of bias tool (RoB 2.0) for Randomized controlled trials.

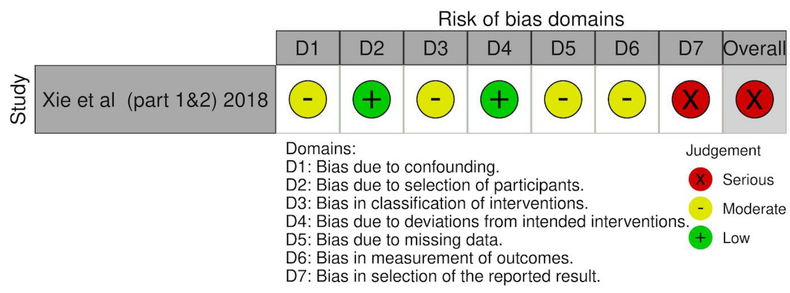

Figure 3 - Evaluation of Risk of Bias of the non-randomized studies using the ROBINS-I tool.

Table II - Characteristics of the included studies

Author and year	Study design	Sample characteristics	Groups Intervention	Vibration device used	Outcomes measured	Time point of assessment	Author's conclusion	Quality assessment
Alansari et al., 2018 [28]	RCT	n= 75 male and female Age: 18 to 45 years	7-day sham (n=15) 7-day vibration (n=15) 5-day sham (n=15) 5-day vibration (n=15) Control no vibration(n=15)	VPro5 appliance- 5 minutes per day	i) Pain perception- numerical rating scale ii)Gingival crevicular fluid (GCF) markers iii) percentage of tooth movement in comparison with the predicted movement (Aligner tracking)	Baseline and after 4 aligners Pain day 1 and 3	Vibration devices showed significant reduction in the time intervals. High levels of cytokines and bone remodeling markers in the GCF and lower levels of pain and discomfort was seen.	moderate
Katchooi et al., 2018 [29]	RCT	n= 27 (1 discontinued) 12Male & 14 Female Adults (18 years or older)	Group A Active Device with (n=13)3 non completer Group B Control device with no vibration (n=13) 2 non completer	experimental AcceleDent device -20 minutes per day	i)Change in maxillary and mandibular incisor irregularity in completers ii)pain levels- numerical rating scale and quality of life (Qol) questionnaire	Baseline and after completion of initial aligners(<25) Pain baseline and midpoint	Authors found no significant effect on final alignment, orthodontic pain or oral health related quality of life.	high
Shipley, 2018 [30]	Retrospective study	n= 16 Age 14-45 (5 Male & 11Female)	Experimental n = 8 vibration device Control n = 8 no vibration	VPro5 appliance- 5 minutes per day	i) treatment time ii) number of aligners iii) aligner exchange rate in days iv) number of case refinements v)additional aligners required to complete treatment.	Baseline and end of treatment	Significant decrease in both treatment time and number of aligners required to complete treatment was observed by high frequency vibration subjects	low
Xie et al. (part 1), 2018 [31]	Prospective study	n=30	n=10 without vibrating device n= 10 with vibration device n=10 Orthopulse group	AcceleDent device -20 minutes per day	Part 1-Difference between expected and actual tooth movement Part-2-Oral health-related quality of life (OHIP questionnaire) numerical Pain scale	Pre-treatment, aligner 10, aligner 20	No statistically significant difference in tooth movement was observed Reduced pain with new pair of aligners and during treatment in the Acceledent group was seen.	low
Bragassa, 2018 [32]	RCT	n=33 age 32.3±9.85 64% female, 36% male	G1- n=10 control no vibration G2-n= 12 4 day aligner wear without vibration G3-n= 11 4 day aligner wear with vibration	AcceleDent device -20 minutes per day	i)Efficiency and accuracy of incisor alignment ii) accuracy of overbite(OB) correction iii) discomfort- numeric analog scale	Baseline (T_o) 12-weeks of treatment (T_{final}) discomfort- (T4-days, T2-weeks, T6-weeks, Tfinal)	vibration resulted in a slight increase (3%) in the accuracy of the achieved incisor alignment and reduced some pain but not statistically significant. Vibration therapy has no effect on the efficiency and accuracy of incisor alignment, accuracy of OB correction nor the discomfort associated with aligner treatment.	moderate

RCT- Randomized control trial, CCT- Controlled clinical trial.

Table II - Continued...

Author and year	Study design	Sample characteristics	Groups Intervention	Vibration device used	Outcomes measured	Time point of assessment	Author's conclusion	Quality assessment
Shipley et al., 2019 [14]	Retrospective study	n=30 (19 female/11 male) meanage24±10years control mean age 28 ± 11 years	n=15 high frequency vibration n=15 chewies(sham)	VPro+ for 5 minutes per day	i)Aligner change or treatment time ii)Bone density	baseline (T1) and between the groups at initiation of retention (T2)	High-frequency vibration adjunctive to clear aligners led to shorter treatment time in minimum-moderate crowded cases	low
Lombardo et al., 2019 [33]	RCT	n=45 20 males and 25 females of mean age 27.1 ± 9.0 years	Group A n=15 control 14 days Group B n=15 14 days low-frequency vibration device Group C n=15 7 days low-frequency vibration device	AcceleDent device -20 minutes per day	accuracy of tooth movement versus the prescription	Pre and post treatment	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.	high
Bilello et al. 2022 [34]	CCT	n=24 (4 excluded) age 35.0 ± 10.3 years 5 male, 15 female	Group A n=10 aligner with AcceleDent device Group B n=10 control aligner	AcceleDent device for 20 min per day,	The number of aligners needed and treatment duration patients' perception of pain	Pre and post treatment	Vibration usage successfully complete an aligner treatment with a significant saving of time when compared to a standard 14-days change regimen. Use of this device allowed reduction in pain perception during the treatment.	moderate
Huang, 2024 [22]	RCT	n=48 age 30 to 45 years 18 males and 30 females	Group 1 n=12: 22-hour tray wear time, no VPro+ Group 2 n=12: 22-hour tray wear time, VPro+ Group 3 n=12: 12-hour tray wear time, no VPro+ Group 4 n=12: 12-hour tray wear time, VPro+	VPro+ for 5 minutes per day	Total number of days for 10 trays, averages days per tray	Initial and 10 trays completion	there were no significant differences in aligner progression between non-VPro+ Groups 1 and 3 and VPro+ Groups 2 and 4.	high

RCT- Randomized control trial, CCT- Controlled clinical trial.

Table III - Risk of Bias assessment using New castle Ottawa scale for retrospective studies

Studies	SELECTION (maximum 4 stars)				COMPARABILITY (maximum 2 stars)	OUTCOME (maximum 3 star)			total stars (9)	Risk of Bias
Cohort studies	Representativeness of the exposed cohorts	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at the start of the study	Comparability of cohorts on basis of design or analysis	Assessment of outcome	Was follow-up long enough for outcome to occur	Adequacy of follow up of cohorts		
	a) Truly representative of the average in the target population* (all subjects or random sampling); b) Somewhat representative of the average in the target population* (nonrandom sampling); c)Selected group of patients; d)No description of the sampling strategy.	a) drawn from the same community as the target population *; b) drawn from a different source. c)no description of the derivation of the comparison population.	a) secure record (eg surgical records)* b) structured interview * c) written self-report d) no description	a) yes* b) no	The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled. a)The study controls for age, sex*; b) The study controls for malocclusion characteristics. * c) Cohorts are not comparable on the basis of design or analysis is controlled for confounders	a)Independent blind assessment*; b)Record linkage*; c)Self-report; d)No description.	a) yes * b) no	a) complete follow up - all subjects accounted for* b) subjects lost to follow up unlikely to introduce bias - small number lost (follow up, or description provided of those lost) * c) follow up rate and no description of those lost d) no statement		
Shipley, 2018 [30]	c	a*	a*	a*	b*	b*	a*	a*	7	low
Shipley et al., 2019 [14]	c	a*	a*	a*	b*	b*	a*	a*	7	low

*awarding a point for each answer that is marked with an asterisk.

Results of individual studies and data synthesis

Results of individual studies are tabulated in Table IV. Random effect model meta-analysis was done for 7 of the 10 included studies, and standardized mean difference (SMD) was calculated for three parameters: incisor irregularity, aligner exchange rate, and total number of aligners for treatment completion. Publication bias was negated by including data from unpublished literature. Heterogeneity was acknowledged and addressed through qualitative synthesis and subgroup interpretation where possible.

A forest plot comparing the change in maxillary and mandibular incisor irregularity in aligners only and aligners combined with vibrational force showed that there was very minimal increase in incisor alignment with vibration (SMD -0.18, CI -0.62, 0.25) and was not statistically significant. (p=0.41), and subgroup analysis showed no difference in maxillary and mandibular alignment (Figure 4).

A forest plot comparing the aligner exchange rate in aligners only and aligners combined with vibrational force showed a significant decrease in aligner exchange rate or days per aligner usage with supplemental vibration (SMD -2.36, CI -4.52, -0.21) (p=0.03) (Figure 5). The forest plot comparing the total number of aligners required for treatment completion in aligners only and aligners combined with vibrational force is almost similar (SMD -0.38, CI -1.32, 0.56) and shows no significant difference between the groups (p=0.43) (Figure 6).

Quality of evidence

The GRADE approach (Table II) showed that the quality assessment was high for four studies.

Study or Subgroup	Aligner+vibrational force Mean	SD	Total	Only aligner Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
4.1.1 Maxillary incior irregularity								
Katchooi et al 2018	−3.56	0.9	10	−3.36	1.8	11	25.8%	−0.13 [−0.99, 0.72]
Xie et al (part 1) 2018	1.07	0.97	10	1.8	1.94	10	23.9%	−0.46 [−1.35, 0.43]
Subtotal (95% CI)			**20**			**21**	**49.7%**	**−0.29 [−0.91, 0.33]**
Heterogeneity: Tau² = 0.00; Chi² = 0.26, df = 1 (P = 0.61); I² = 0%								
Test for overall effect: Z = 0.91 (P = 0.36)								
4.1.2 mandibular incisor irregularity								
Katchooi et al 2018	−3.56	2.2	10	−3.74	2.1	11	25.8%	0.08 [−0.78, 0.94]
Xie et al (part 1) 2018	0.87	1.54	10	1.21	1.05	10	24.5%	−0.25 [−1.13, 0.63]
Subtotal (95% CI)			**20**			**21**	**50.3%**	**−0.08 [−0.69, 0.54]**
Heterogeneity: Tau² = 0.00; Chi² = 0.27, df = 1 (P = 0.60); I² = 0%								
Test for overall effect: Z = 0.25 (P = 0.80)								
Total (95% CI)			**40**			**42**	**100.0%**	**−0.18 [−0.62, 0.25]**
Heterogeneity: Tau² = 0.00; Chi² = 0.76, df = 3 (P = 0.86); I² = 0%								
Test for overall effect: Z = 0.82 (P = 0.41)								
Test for subgroup differences: Chi² = 0.22, df = 1 (P = 0.64), I² = 0%								

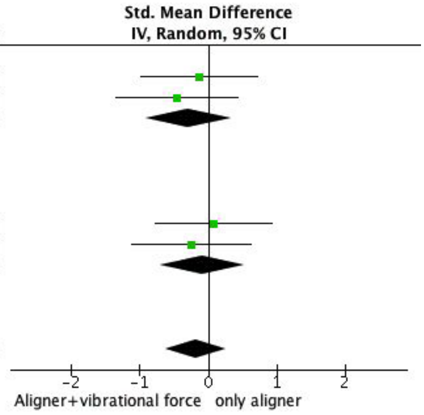

Figure 4 - Forest plot comparing the change in maxillary and mandibular incisor irregularity in aligners only and aligner combined with vibrational force.

Study or Subgroup	aligner+Vibrational force Mean	SD	Total	only aligner Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Bilello et al 2022	9	1	10	15.4	1.2	10	27.9%	−5.55 [−7.66, −3.44]
Huang Grace 2024	4.31	0.37	12	4.5	0.65	12	36.2%	−0.35 [−1.15, 0.46]
Shipley et al 2019	5.2	2.2	15	8.7	1.2	15	35.8%	−1.92 [−2.81, −1.04]
Total (95% CI)			**37**			**37**	**100.0%**	**−2.36 [−4.52, −0.21]**
Heterogeneity: Tau² = 3.16; Chi² = 22.73, df = 2 (P < 0.0001); I² = 91%								
Test for overall effect: Z = 2.15 (P = 0.03)								

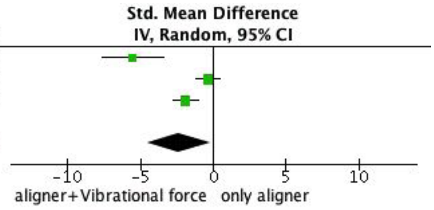

Figure 5 - Forest plot comparing the aligner exchange rate in aligners only and aligner combined with vibrational force.

Study or Subgroup	aligner+vibrational force Mean	SD	Total	Only aligner Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Bilello et al 2022	41.1	22.4	10	33.1	15.5	10	26.0%	0.40 [−0.49, 1.29]
Bragassa 2018	32.6	7.04	11	30.5	6.59	10	26.3%	0.30 [−0.57, 1.16]
Katchooi et al 2018	18.6	3.8	13	20.1	3.5	13	27.4%	−0.40 [−1.18, 0.38]
T.Shipley 2018	25.63	5.78	8	45	10.18	8	20.3%	−2.21 [−3.53, −0.89]
Total (95% CI)			**42**			**41**	**100.0%**	**−0.38 [−1.32, 0.56]**
Heterogeneity: Tau² = 0.68; Chi² = 12.20, df = 3 (P = 0.007); I² = 75%								
Test for overall effect: Z = 0.79 (P = 0.43)								

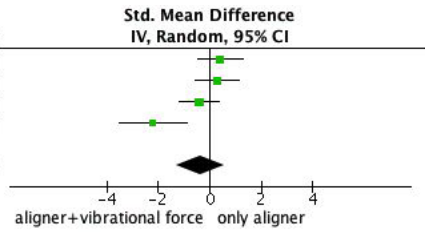

Figure 6 - Forest plot comparing the total number of aligners required for treatment completion in aligners only and aligner combined with vibrational force.

Table IV - Results of the individual studies

Author and year	Tooth movement		Aligner exchange rate	Total number of aligner	Treatment duration
Alansari et al., 2018 [28]	Percentage of tracking (mean ± SD) Aligner+ no vibration: 84 ±13* (p=0.022) 7 days aligner+ sham: 70± 16 7 days aligner+HFA: 90 ± 14*(p=0.003) 5 days aligner +HFA: 84 ± 12 *p=0.022)		Aligner+ no vibration: 14 days 7 sham, 7 HFA- 7 days 5 sham, 5 HFA- 5 days change	4 aligners studied	
Katchooi et al., 2018 [29]	Change in Maxillary Incisor irregularity Aligner +LFV: -3.56±0.9 Group B: -3.36±1.8 (p=0.74)	Change in Mandibular Incisor irregularity Group A: -3.56±2.2 Group B: -3.74±2.1 (p=0.85)	one week aligner change	Total aligners: Group A: 18.6±3.8 Group B: 20.1±3.5 Total: 19.5±3.7	
Shipley, 2018 [30]	Upper crowding initial Aligner: 0.95±4.45 Aligner+HFA: 0.74±3.47 (p=0.412) Final 0.0mm	lower crowding initial Aligner: 0.6±2.24 Aligner+HFA: 1.86±2.76(p=0.332) Final 0.0mm	Aligner+HFA: 4.75±0.70)p=0.001* Aligner - 14 days exchange	Aligner: 45±10.18 Aligner+HFA: 25.63±5.78 (p=0.001*)	Aligner: 96.75±18.76 Weeks Aligner+HFA: 19.25±3.88 Weeks (p=0.005*)
Xie et al. (part 1&2) 2018 [12,31]	Change in Maxillary Incisor irregularity 20th aligner Aligner: 1.8±1.94 Aligner +LFV: 1.07±0.97	Change in Mandibular Incisor irregularity 20th aligner Aligner: 1.21±1.05 Aligner +LFV: 0.87±1.54	Aligner: 7 days Aligner +LFV: 6 days	Total 20 aligners studied	
Bragassa, 2018 [32]	Percentage of irregularity reduction G1: 18.9%, G3:29.1% (p=0.003)* Accuracy: (G1- 48.3%), (G2- 36.1%), (G3- 37.7%)		G1- 14 days aligner change G2,G3- 4 days aligner change	mean number of aligners (G1:30.5±6.59, G2:32.3±8.05 and G3:32.6±7.04)	
Shipley et al., 2019 [14]			change aligners as soon as they become loose HFV group: 5.2 ± 2.2 days Control 8.7 ± 1.2 days (p=0.0001*)	Total aligners mean: HFV group: 26 Control: 29	Duration total days: HFV group: 135±27 Control 252±59 days (p=0.002*)
Lombardo et al., 2019 [33]	mean total imprecision was 2.1 ± 0.9 degrees mean prescription of 5.7 ± 2.2 degrees		Group A, B-conventional aligners replaced every 14 days Group C- aligners replaced every 7 days	Total aligners Group A: upper 13.5 ± 4.7, lower 12.6 ± 4.9 Group B: upper 11.7 ± 4.2, lower 11.5 ± 3.4 Group C: upper 11.5 ± 3.9, lower 12.3 ± 3.8	
Bilello et al., 2022 [34]			Group A changed the aligners every 7 days Group B changed the aligners every 14 days Average days per aligner: Group A: 9 ± 1.0 Group B: 15.4 ± 1.2 P < 0.0001*	Total aligners Group A: 41.1 ± 22.4 Group B: 33.1 ± 15.5 (P = 0.36)	Duration total days: Group A: 366.6 ± 187.4 Group B: 509.3 ± 243.5 (*P* = 0.16)
Huang, 2024 [22]			aligner change instructions from Dental Monitoring app Number of days per tray (full time aligner wear) Group 1: 4.50± 0.65 Group 2: 4.31± 0.37 (p=0.655)	10 trays studied	Total days for 10 trays (full time aligner wear) Group 1: 40.50± 5.81 Group 2: 38.83± 3.30 (p=0.655)

*p ≤0.05. HFA- High frequency acceleration, HFV- High frequency vibration.

Downgrading was done in a few RCTs to moderate due to methodological quality and risk of bias. Prospective and retrospective studies were of low quality.

DISCUSSION

Orthodontic treatment generally involves a prolonged duration, and the need to reduce treatment time without compromising results has become a central focus in modern orthodontics. Among various acceleration modalities, supplemental vibration has emerged as a non-invasive, patient-friendly adjunct. Unlike invasive techniques such as corticotomy or pharmacologic agents, vibrational devices are considered safe and well-tolerated by patients, as reflected in the studies included in this review [30].

The biological mechanism behind vibrational force involves cyclic loading that stimulates bone remodeling by enhancing osteoclastic and osteoblastic activity through mechanotransduction. Alansari et al. [28] demonstrated increased cytokine expression in GCF with high-frequency vibration, indicating an upregulated bone remodeling response [28]. However, this biological plausibility did not consistently translate to clinical significance across all included studies.

Some studies reported improved outcomes with vibration; for instance, Alansari et al. found statistically significant improvement in tracking of aligners ($p=0.03$) when high-frequency vibration was used and aligners were changed every week [28]. Bragasa in 2018 described a statistically significant irregularity reduction with vibration and aligners ($p=0.003$) [32]. Conversely, others like Katchooi et al. [29] and Lombardo et al. [33] found no added benefit. This discrepancy could be attributed to heterogeneity in device frequency (low vs. high), differences in aligner exchange protocols (ranging from 5 to 14 days), case complexity, and variations in outcome measurement. For example, studies using a 7-day aligner change protocol may naturally observe faster movement compared to those with a 14-day interval, confounding the effect of vibration.

Shipley stated that high-frequency vibration accelerated tooth movement with reduced treatment duration and a faster aligner exchange rate. The treatment duration was 19.25 ± 3.88 weeks with high-frequency vibration compared to 96.75 ± 18.76 with no vibration, and fewer aligners were required for completion of treatment with vibration [30]. Shipley et al. [14] also stated a faster aligner exchange rate and decreased treatment time with high-frequency vibration. Bilello et al. [34] showed that the average day per aligner was significantly less with vibration, while there was no difference in the number of aligners or treatment duration between two groups. Huang [22] showed that there was no effect of vibrational force on the rate of aligner change.

The meta-analysis indicated a statistically significant reduction in aligner exchange rate (SMD = -2.36), but this minimal reduction may not have substantial clinical impact. Similarly, no significant difference was observed in overall tooth alignment or total number of aligners needed. These findings suggest that while vibration may offer marginal efficiency gains, its clinical benefit may be context-dependent and not universally applicable.

Risk of bias also plays a crucial role in interpreting these findings. While most RCTs were rated as low or moderate risk using the RoB 2.0 tool, the prospective study assessed with ROBINS-I showed serious risk due to confounding and selection bias. Retrospective studies, although methodologically weaker, showed low risk based on Newcastle-Ottawa criteria but lacked control over treatment standardization. These limitations reduce the strength of the overall evidence and underscore the need for high-quality, protocol-consistent RCTs.

Heterogeneity was another major limitation. This review included studies with different vibrational devices, frequencies, patient compliance levels, and endpoint definitions. Such variability complicates data synthesis and weakens the generalizability of pooled results. Although a random-effects model and subgroup interpretation were employed, the clinical diversity across studies remains a challenge.

Various vibratory devices are commercially available, and the definitive action of these devices is still being researched [35]. Furthermore, while some studies reported improved tracking or reduced exchange intervals, none evaluated long-term stability or post-treatment relapse. The role of vibration in retention and relapse prevention remains unexplored and should be investigated in future studies.

LIMITATIONS

Patient compliance was assessed in very few studies, and this could affect the results of the studies. There is a difference in the type of vibration (low- and high-frequency vibration) in the assessed studies, and the exact effect of each is not clear. The aligner change interval was different in different studies, and no common aligner change rate was used; hence, the significance of the aligner exchange rate should be weighed carefully. There is a need for further trials focused on the most effective protocol of the type of vibration and time of aligner change.

CONCLUSIONS

Within the limitations of the given study, the following conclusion could be derived:

1. There is no significant difference in tooth alignment with supplemental vibration with aligners.
2. There is minimal reduction in the aligner exchange rate with supplemental vibrational force.

Author's Contributions

RG: Conceptualization. RG, JR, SS, SK: Data Curation. RG, JR, SS, SK: Formal Analysis. RG, JR, SS, SK: Investigation. RG: Methodology. RG: Resources. RG: Software. SMM: Supervision. RG, JR, SS, SK: Validation. SMM: Visualization. RG: Writing – Original Draft Preparation. JR, SS, SK, SMM: Writing – Review & Editing.

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

This review was carried out using a systematic search of electronic databases. Since it is based entirely on previously published studies, no additional ethical approval was needed.

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