Asian Journal of Periodontics and Orthodontics
2024, Volume 4, Page No: 60-74

Available online at: www.tsdp.net

ISSN: 3062-3499

Review Article

Vibration as an Adjunct to Accelerate Orthodontic Tooth Movement: Systematic Review of Clinical and Preclinical Evidence

Jun Zhou[1], Khalid Adel Omar Bazar[2]*, Wang Bin[1]

[1]Department of Oral Biosciences, University of Hong Kong, Hong Kong, China.
[2]Department of Restorative Dentistry - College of Dental Medicine, University of Sharjah, PO Box 27272, Sharjah, United Arab Emirates.

***E-mail** ✉ khalidadelbazar@outlook.com

Received: 19 April 2024; **Revised:** 09 August 2024; **Accepted:** 16 August 2024

ABSTRACT

This systematic review investigates how high-frequency vibrations (>30 Hz) and low-frequency vibrations (≤30 Hz) influence orthodontic tooth movement (OTM). Articles were collected through a systematic search in MEDLINE and SCOPUS, following PRISMA guidelines and structured around a PICO question. Data from selected studies were extracted, and study quality was evaluated using EPHPP, ROBINS-I, and STAIR assessment tools. From an initial pool of 350 studies, 30 met the inclusion criteria. Overall, low-frequency vibrations did not demonstrate consistent acceleration of OTM in either aligner-based or fixed orthodontic treatments, though isolated studies reported slight improvements. In contrast, high-frequency vibrations were associated with enhanced aligner exchange rates, tooth displacement, and space closure during fixed appliance therapy. In vivo research particularly indicated that vibrations between 60 Hz and 120 Hz stimulate bone biomarkers, promoting alveolar bone remodeling. The evidence suggests that high-frequency mechanical stimulation can effectively accelerate OTM, showing positive outcomes across both experimental and clinical settings. However, broader and more standardized studies are needed to confirm its therapeutic potential in orthodontics.

Keywords: Orthodontics, Orthodontic tooth movement, Vibration, High-frequency vibration, Low-frequency vibration

How to Cite This Article: Zhou J, Bazar KAO, Bin W. Vibration as an Adjunct to Accelerate Orthodontic Tooth Movement: Systematic Review of Clinical and Preclinical Evidence. Asian J Periodont Orthodont. 2024;4:60-74. https://doi.org/10.51847/ZWrGaDObiC

Introduction

Achieving an aesthetically "ideal" smile generally requires collaboration among multiple dental specialties, including orthodontics, prosthodontics, and oral surgery. Prior to achieving this goal, one of the most frequent conditions that must be corrected is malocclusion, a misalignment affecting more than one-quarter of adolescents. This condition not only causes functional limitations but also impacts facial appearance and overall quality of life. To manage malocclusion, clinicians typically employ fixed or removable orthodontic treatments [1–4].

The average duration of orthodontic therapy is approximately 24 months, though it can vary per clinical case [5, 6]. Extended treatment periods can negatively influence patients, as they demand dietary restrictions, increased hygiene efforts, regular appointments, and greater financial investment. Prolonged treatment may also damage the periodontal environment, potentially leading to root resorption or periodontal disease [5, 7–9]. In recent years, minimizing orthodontic treatment time has become a significant concern for both patients and practitioners. Shorter treatments may reduce side effects, lower costs, and enhance patient satisfaction [5, 7, 10, 11]. The rate of orthodontic tooth movement (OTM) is the key determinant of overall treatment duration. To accelerate OTM, biological modification of the alveolar bone and the periodontal ligament (PDL)—the two key structures responsible for tooth support and stability—is required [5, 12, 13]. Remodeling of these tissues occurs through an inflammatory cascade triggered by orthodontic forces, which initiate cellular and molecular alterations characteristic of the OTM process [14, 15]. Osteoclasts and osteoblasts, the main bone cells involved, are

therefore the principal focus of non-surgical approaches aimed at enhancing OTM [1, 16].

Tooth movement occurs through resorption and deposition of alveolar bone in response to compression and tension forces produced by orthodontic devices. These forces compress the PDL, initiating vascular alterations and the release of pro-inflammatory mediators such as interleukin-1β (IL-1β), which in turn stimulates osteoclast and osteoblast differentiation, thus facilitating tooth displacement [17, 18].

Application of vibratory stimulation may enhance OTM by upregulating receptor activator of nuclear factor-kappa B ligand (RANKL) expression in the PDL without causing additional damage, such as root resorption [19, 20]. Quantifying RANKL and osteoprotegerin (OPG) levels can provide insight into the osteoclastogenic response to mechanical vibration [21, 22]. Moreover, vibration may potentiate the effects of prostaglandin E2 (PGE2) and RANKL on human PDL cells, mediated via the cyclooxygenase pathway [23]. It can also activate nuclear factor kappa B (NF-κB), thereby promoting osteoclast differentiation and bone resorption, resulting in faster OTM, especially under continuous force [24, 25]. Additionally, vibration may encourage PDL cell differentiation through increased synthesis of type I collagen, Runx2, and Osterix, all of which are critical for bone formation [23, 26].

Over time, both surgical and non-surgical techniques have been developed to enhance the pace of OTM [27–30]. Among these, vibration therapy represents a non-invasive and patient-friendly method. Two commonly used devices are the AcceleDent® (introduced by MAO in 2006), which delivers low-frequency mechanical vibrations (LFMV) at 30 Hz for 20 minutes daily [31, 32], and the VPro5®, which provides high-frequency mechanical vibrations (HFMV) at 120 Hz for 5 minutes daily [33, 34]. Both devices are portable, simple to operate, and compatible with aligners or fixed braces.

Although numerous studies have explored the effects of vibration on OTM, methodological inconsistencies and contradictory findings make it difficult to reach a definitive conclusion [7].

Thus, a detailed evaluation of vibration's effectiveness in promoting OTM in both animal models and human subjects is warranted. Animal studies allow for controlled testing of vibration intensity, providing clearer evidence of its biological impact, whereas clinical trials often struggle with consistent application, leading to variable outcomes.

The objective of this review is to evaluate the influence of high (>30 Hz) and low (≤30 Hz) frequency vibratory stimuli on orthodontic tooth movement acceleration in both human and animal studies involving applied orthodontic forces.

Materials and Methods

This systematic review followed the 2015 PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols) [35]. The review protocol was registered and approved in PROSPERO under the number CRD42024535048.

The research question was structured using the PICO approach, a model designed to improve the precision and focus of systematic reviews. The PICO elements for this study were defined as follows:

- P (Population): Human or animal subjects undergoing orthodontic treatment with applied orthodontic force.
- I (Intervention/Exposure): Use of vibrational stimuli, either high frequency (>30 Hz) or low frequency (≤30 Hz).
- C (Comparison): Orthodontic patients or animals receiving treatment with versus without vibration exposure.
- O (Outcome): Measurement of orthodontic tooth movement (OTM) by assessing distance changes at defined time intervals.

Search strategy and selection process

An electronic search was conducted using the following MeSH terms:

((orthodontics OR "orthodontic tooth movement" OR "tooth movement") AND (vibration OR "high frequency vibration" OR "low frequency vibration"))

Searches were performed in the MEDLINE and SCOPUS databases in April 2024.

Eligibility criteria

Inclusion parameters

- Clinical and in vivo investigations.
- Studies applying vibration simultaneously with orthodontic forces.
- Orthodontic treatments performed with aligners or fixed braces.

Exclusion parameters

- Reviews, meta-analyses, case reports, and conference papers.
- In vitro experiments.
- Articles not published in English.
- Studies combining vibration with surgical or other stimulation techniques.
- Simulation or numerical modeling research.

Data extraction process

Two independent reviewers (S.P. and S.O.) screened all articles by titles and abstracts. Publications that failed to meet the inclusion rules were discarded. Any inconsistencies between reviewers were settled through discussion. Eligible full-text papers were subsequently assessed in detail.

All relevant data were extracted and verified for consistency. The recorded variables included:

- Authors and publication year,
- Study design and sample details,
- Grouping method,
- Orthodontic appliance type,
- Targeted tooth and movement direction,
- Vibration protocol specifics,
- Key outcomes and conclusions.

Evaluation of study quality

Each selected article underwent quality evaluation using appropriate assessment frameworks. For randomized clinical trials, the Effective Public Health Practice Project (EPHPP) tool [36] was applied. For non-randomized studies, the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool [37] was used. Animal studies were assessed following the Stroke Therapy Academic Industry Roundtable (STAIR) guidelines [38].

Results and Discussion

Search outcome

A total of 350 records were retrieved from database searches. After removing 92 duplicates, 258 unique papers remained. Title and abstract screening identified 112 publications for full-text assessment. Following eligibility evaluation, 78 were excluded based on the selection criteria, leaving 30 studies for inclusion. Among these, 25 were clinical investigations and 5 were in vivo experiments.

The step-by-step selection process is illustrated in **Figure 1** (PRISMA flow diagram).

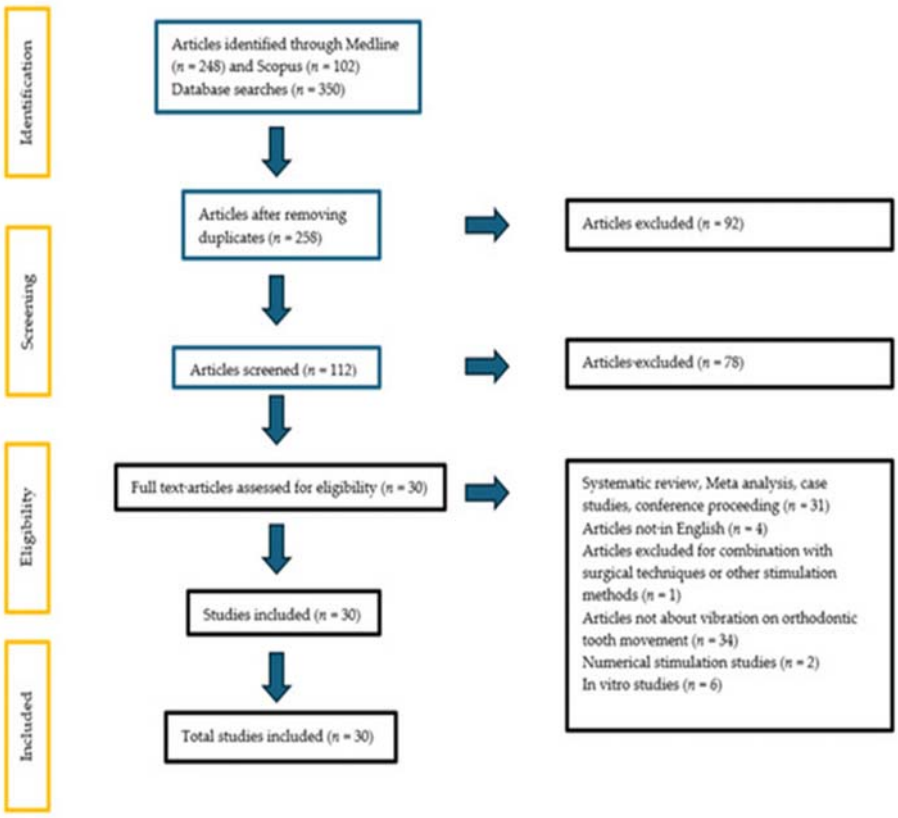

Figure 1. PRISMA flow diagram.

Quality assessment

The evaluation outcomes are summarized in the following tables:

Table 1. Assessment of animal research quality according to the STAIR preclinical recommendations [38].

Authors/Year	Determination of Sample Size	Selection Criteria	Random Assignment Method	Concealment of Group Allocation	Documentation of Excluded Subjects	Masked Outcome Evaluation	Reporting of Funding and Conflicts
Nishimura *et al.* (2008) [19]	Fair	Limited	Limited	Limited	Not Applicable	Limited	Fair

Kalajzic *et al.* (2014) [39]	Fair	Limited	Limited	Limited	Not Applicable	Limited	Fair
Yadav *et al.* (2015) [40]	Fair	Limited	Robust	Limited	Not Applicable	Limited	Fair
Takano-Yamamoto *et al.* (2017) [41]	Limited	Limited	Robust	Limited	Not Applicable	Fair	Robust
Alikhani *et al.* (2018) [42]	Limited	Limited	Limited	Limited	Fair	Robust	Fair

NA = Not applicable.

Table 2. Quality grading of clinical studies using the EPHPP tool [18].

Authors/Year	Participant Selection Bias	Research Design Quality	Control of Confounding Factors	Outcome Masking	Data Gathering Approach	Participant Retention	Overall Study Rating
Leethanakul *et al*., (2016) [17]	Fair	Robust	Robust	Fair	Robust	Robust	Robust
Azeem *et al*., (2019) [43]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Reiss *et al*., (2020) [44]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Miles *et al*., (2012) [45]	Fair	Robust	Robust	Fair	Robust	Robust	Robust
Khera *et al*., (2022) [46]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Woodhouse *et al*., (2015) [47]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Liao *et al*., (2017) [48]	Robust	Robust	Robust	Limited	Robust	Robust	Fair
Katchooi *et al*., (2018) [49]	Robust	Robust	Robust	Robust	Robust	Robust	Robust
Miles, (2018) [50]	Robust	Robust	Robust	Limited	Robust	Robust	Fair
Siriphan *et al*., (2019) [21]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Kumar *et al*., (2020) [51]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Teletar *et al*., (2021) [52]	Robust	Robust	Robust	Limited	Robust	Robust	Fair
Lombardo *et al*., (2019) [53]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
DiBiase *et al*., (2018) [54]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Taha *et al*., (2020) [55]	Robust	Robust	Robust	Limited	Robust	Robust	Fair
Mayama *et al*., (2022) [56]	Robust	Robust	Robust	Fair	Robust	Robust	Robust
Yildiz *et al*., (2023) [57]	Robust	Robust	Fair	Fair	Robust	Robust	Robust
ElMotaleb *et al*., (2024) [58]	Robust	Robust	Robust	Fair	Robust	Robust	Robust

Table 3. Risk of bias analysis in non-randomized studies based on the ROBINS-I framework [37].

Study Authors/Year	Chance of Bias from Randomization	Potential Bias from Intervention Deviations	Likelihood of Bias from Missing Data	Bias Risk in Outcome Evaluation	Risk of Selective Outcome Reporting	Cumulative Bias Assessment
Akbar *et al*., (2022) [59]	Minimal	Minimal	Minimal	Some issues	Minimal	Some issues
Bowman, (2014) [60]	Minimal	Elevated	Elevated	Minimal	Minimal	Elevated
Orton-Gibbs *et al*., (2015) [61]	Elevated	Elevated	Elevated	Elevated	Elevated	Elevated
Bowman, (2016) [62]	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal
Shipley, (2018) [63]	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal
Shipley *et al*., (2019) [33]	Minimal	Some issues	Minimal	Minimal	Minimal	Some issues
Bilello *et al*., (2022) [64]	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal

According to the STAIR assessment, results varied across evaluation domains. For sample size, about 60% of the experiments received an intermediate rating, while 40% were judged as weak. In terms of inclusion/exclusion definitions and allocation concealment, every study (100%) obtained a weak rating. When considering randomization, 60% were classified as weak and the remaining 40% as strong. Only one report mentioned animals excluded from analysis, which earned a moderate grade. Regarding blinding of outcome assessment, 60% of the works were weak, 20% moderate, and 20% strong. For declaration of funding and potential conflicts of interest, 80% achieved moderate, and 20% were strong.

Among 18 randomized controlled trials, 14 (78%) were rated as high quality, and 4 (22%) as medium quality. For the seven non-randomized investigations analyzed using ROBINS-I, three (43%) showed low bias risk, two (29%) presented some concerns, and the remaining two (29%) displayed high risk.

In vivo experiments

An outline of the animal studies included is displayed in **Table 4**.

Table 4. Results summary for selected in vivo investigations [37].

Study Authors (Year)	Study Population	Orthodontic Device	Study Aims	Vibration Settings	Key Outcomes	Study Conclusions
Nishimura *et al*. (2008) [19]	N = 12 male Wistar rats, 6 weeks old. Groups: CG (expansive spring on upper first molars), EG (spring + vibration on first molars)	Fixed appliances: 0.012-inch nickel-titanium expansive spring	Assess impact of resonance vibration on tooth movement	Vibration at 61.02 ± 8.375 Hz, 8 min on days 0, 7, 14 over 21 days with expansive spring	EG: 15% greater tooth movement by day 21, increased osteoclasts. Mean displacement 0.0014 ± 0.002 mm, velocity 0.27 ± 0.018 mm/s. RANKL expression higher on compression side. Root resorption observed in both groups.	Resonance vibration enhances tooth movement and RANKL in PDL without increasing periodontal damage like root resorption.
Kalajzic *et al*. (2014) [39]	N = 26 female Sprague-Dawley rats, 7 weeks old. Groups: CG1 (unloaded), CG2 (vibration only), CG3 (orthodontic spring), EG (spring + vibration)	Fixed appliances: nickel-titanium coil spring (25 g force)	Evaluate cyclical vibratory force effects on tooth movement, PDL integrity, and bone remodeling	Cyclical force at 0.4 N, 30 Hz, 10 min, 2x/week	Tooth movement: CG3 (0.486 ± 0.178 mm) vs. CG1, CG2, EG; EG (0.242 ± 0.139 mm) vs. CG2, CG3. Fewer osteoclasts in CG1/CG2, significant in CG3 (7.50 ± 1.98) vs. CG1 (1.75 ± 2.06), CG2 (1.75 ± 1.50). Bone volume fraction decreased in CG3. EG showed disrupted collagen morphology.	Cyclical forces at 30 Hz inhibited tooth movement and disrupted PDL collagen structure.
Yadav *et al*. (2015) [40]	N = 64 male CD1 mice, 12 weeks old. Groups: CGs (baseline, no spring + 5/10/20 Hz), EGs (spring + no vibration, spring + 5/10/20 Hz)	Nickel-titanium coil springs: 10 g force, 2 weeks	Investigate low-frequency vibration effects on tooth movement rate, bone volume fraction, tissue density, and PDL integrity	Low-frequency mechanical vibration (LFMV) at 5, 10, or 20 Hz, 15 min	LFMV did not enhance tooth movement. Microfocus X-ray showed increased bone volume fraction and tissue density with LFMV. Sclerostin decreased at 10/20 Hz. Picrosirius staining indicated LFMV preserved PDL collagen thickness.	LFMV (5, 10, 20 Hz) did not accelerate tooth movement but maintained PDL integrity and thickness without deleterious effects.
Takano-Yamamoto *et al*. (2017) [41]	N = 70 male Wistar rats, 25 weeks old (410 g). Groups: C (control), TM (Ni-Ti appliance), V (vibration	Fixed appliances: 0.014-inch nickel-titanium wire for palatal movement of	Examine if vibration with Ni-Ti appliance accelerates tooth movement, identifying optimal	Vibration at 3 gf, 70 Hz, for 3, 6, 10, or 30 min weekly over 21 days	EG3 (3 gf, 70 Hz, 3 min/week) optimal for accelerating tooth movement. Vibration alone did not move teeth. No correlation with exposure duration.	Optimal high-frequency vibration (3 gf, 70 Hz, 3 min/week) with static force enhances osteoclastogenesis and tooth movement

	only), TMV (Ni-Ti + vibration)	upper right first molar	magnitude, frequency, and duration		No root resorption. Increased osteoblast, osteoclast, osteocyte activation, and tooth socket size in TMV.	without affecting root resorption.
Alikhani *et al*. (2018) [42]	N = 206 male Sprague-Dawley rats, 120 days old (400 g). Groups: CG1 (no spring/no HFV), CG2 (inactive spring), CG3 (orthodontic movement), EG (orthodontic + HFA regimens)	Fixed appliances: Sentalloy closing coils, 10 cN or 25 cN force, 1 mm activation	Assess high-frequency acceleration (HFA) effects on tooth movement rate, alveolar bone, and underlying mechanisms	HFA at 0.01 g, 0.05 g, or 0.1 g; frequencies of 30, 60, or 120 Hz; 5 or 10 min duration	HFA increased tooth movement rate with higher acceleration. Non-linear frequency/time effects. HFA and orthodontic forces both PDL-dependent, enhancing cytokine release and osteoclast activity. 60/120 Hz increased movement more than 30 Hz or controls.	HFA enhances tooth movement in catabolic phase and supports retention in anabolic phase, with 60/120 Hz most effective.

Abbreviations: N = sample size; CG = control group; EG = experimental group; PDL = periodontal ligament; HFA = high-frequency acceleration; RANKL = receptor activator of nuclear factor kappa-B ligand; LFMV = low-frequency mechanical vibration.

Animal research investigating the use of vibration to accelerate orthodontic tooth movement (OTM) generally showed neutral findings, except for one report [42], which indicated that vibration may improve OTM during the catabolic stage.

Frequencies up to 30 Hz [39, 40, 42] produced no statistically relevant change in movement speed, while 60 Hz, 70 Hz, and 120 Hz vibrations resulted in enhanced OTM rates [19, 41, 42] and higher bone biomarker activity [19, 41]. The vibration exposure times ranged between 3 and 30 minutes.

Only two studies [19, 41] assessed root resorption, both confirming that high-frequency vibration had no detrimental effect on root integrity.

Of the five animal-based studies, three involved rats: two [40, 41] used the Wistar strain (50%), two [39, 42] used Sprague Dawley (33%), and one [40] worked with CD1 rats (17%).

Two studies analyzed root conditions with fixed orthodontic appliances—one using HFMV [56, 65] and another LFMV [58]—and both concluded that vibration did not affect root morphology.

All included investigations focused on maxillary first molar movement to assess the rate of tooth displacement.

Clinical research

Details for the clinical component are presented in **Table 5**.

Table 5. Summary of clinical trials included [38].

Author (Year)	Type of Study	Population	Orthodontic Appliance	Treatment Objectives / Methods	Vibration Parameters	Results	Conclusion
Miles *et al*., (2012) [45]	Randomized clinical trial	N = 66, aged 11–15 years. Groups: CG: no stimulation, EG: Tooth Masseuse®	Fixed appliances	Evaluate tooth movement rate and patient discomfort. Irregularity measured at T0, T1 (5 weeks), T2 (8 weeks), T3 (10 weeks). Pain assessed after placement, 6–8 h, 1 day, 3 days, and 7 days.	111 Hz, 0.06 N, ≥20 min/day	CG: T0 4.9 mm → T3 1.6 mm, T0–T2: 3.1 mm, T0–T3: 3.4 mm. EG: T0 6.2 mm → T3 2.1 mm, T0–T3: 4.0 mm	No significant difference in irregularity reduction or pain between groups
Bowman (2014) [60]	Non-randomized clinical trial	N = 117, ♂47 ♀70. Groups: EG: AcceleDent®, CG1: fixed appliances, CG2: historical controls	Fixed appliances	Assess impact of vibration on lower arch leveling and alignment in Class II non-extraction cases undergoing upper molar distalization	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Alignment time: EG 93 days < CG1 120 < CG2 131. Next archwire (0.017×0.025") placed 27 days earlier than CG1 and 38 days earlier than CG2. Levelling: EG ~5 months, CG ~7 months	AcceleDent® reduced alignment and levelling time by ~30–40%
Woodhouse *et al*., (2015) [47]	Randomized controlled trial	N = 81, ♂40 ♀41, mean 14.1 y. Groups:	Fixed appliances	Evaluate effect of vibration on initial alignment speed	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Baseline irregularity: 8.5 ± 3.8 mm. Initial alignment: 2.7 ± 2.8 mm. Time from initial	No evidence that vibration accelerates

		EG1: fixed appliance + AcceleDent®, CG1: sham device, CG2: fixed appliance only				→ final: 150 ± 62.5 days; baseline → final: 209 ± 65 days. Rate increase per mm: initial 0.01 mm/day, overall 0.004 mm/day	initial or total alignment
Orton-Gibbs *et al*., (2015) [61]	Non-randomized clinical trial	N = 117, mean 31 y, 76% adults, ♀66% ♂44%	Ceramic (52), Metal (19), Lingual (19), Aligners (16), Expansion appliances (11)	Assess treatment duration with AcceleDent®	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Fixed appliances + AcceleDent®: 12.4 months (38.2% faster than predicted 20 months). Aligners + AcceleDent®: 7–10 day exchange, 37.2% faster than estimate	AcceleDent® reduces treatment duration with fixed appliances or aligners
Bowman (2016) [62]	Non-randomized clinical trial	N = 30, mean age EG 13.1, CG 12.9, ♂13 ♀17 per group	Fixed appliances	Effects on molar distalization	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	2nd-molar eruption: significant EG vs CG. Crown movement: EG 1.1 mm/month vs CG 0.9 mm/month; root apex: EG 2.9 mm/month vs CG 1.7 mm/month	~30% faster mandibular levelling, up to 3× monthly maxillary movement, 150–200% reduction in time
Leethanakul *et al*., (2016) [17]	Randomized controlled trial	N = 15, mean 22.9 y. EG: one canine + 60 g + vibration; CG: contralateral canine only	Fixed appliances	Assess effect of electric toothbrush vibration on IL-1β during canine distalization	Colgate® Motion-Multi Action, 125 Hz, 15 min/day, 2 months; T0–T3	IL-1β levels higher at pressure/tension sites with vibration; T2–T3 canine movement doubled in EG vs CG	Vibration + orthodontic force ↑IL-1β, ↑bone resorption, ↑tooth movement
Liao *et al*., (2017) [48]	Randomized controlled trial	N = 13, mean 13.6 y. Vibration vs non-vibration side	Fixed appliances	Evaluate biomechanics of single-tooth vibration	Oral B® Hamming Bird, 50 Hz, 0.2 N, 10 min/day	Distalization greater with vibration. PDL VHS amplified: 9.2% mesio-distal, 10.8% linguo-buccal. Tissue response: 7.3–13.5%	Vibration ↑space closure and canine distalization
Lombardo *et al*., (2019) [53]	Randomized controlled trial	N = 45, mean 27.1 y, ♀25 ♂20. Groups: CG: aligner every 14d, EG B: 14d + AcceleDent®, EG C: 7d + AcceleDent®	Aligners	Compare tooth movement accuracy with vibration and aligner replacement	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Rotation upper incisors: B> A (0.72>0.62). Canine vestibulo-lingual: B> C (0.67>0.54). Canine mesio-distal: B> C (0.65>0.49). Upper molars vestibulo-lingual: B> C (0.71>0.55)	No difference between 7-day vibration aligners and 14-day without vibration
Katchooi *et al*., (2018) [49]	Randomized controlled trial	N = 27, mean 33 y, ♂12 ♀15. EG: AcceleDent® + aligners; CG: sham + aligners	Aligners	Evaluate AcceleDent® with Invisalign®	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Compliance similar; irregularity index: no difference. Pain lower with active AcceleDent® on day 3	No effect on final alignment or pain reduction
DiBiase *et al*., (2018) [54]	Randomized clinical trial	N = 61, mean 13.9 y, ♂30 ♀31	Fixed appliances	Evaluate additional vibration on space closure	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Mandibular arch closure median 0.89 mm/month; no differences for secondary outcomes, overall rate 0.74 mm/month, median	Vibration did not improve space closure, treatment duration, or outcome; no

						18.57 months, visits 12, breakages 2	increased breakage
Miles, (2018) [50]	Randomized controlled trial	N = 40, mean 12.8 y, ♀26 ♂14	Fixed appliances	Compare time to working wire stage with AcceleDent®	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Upper arch: 139 (EG) vs 132 (CG) days. Lower: 143 (EG) vs 139 (CG) days	No significant time difference
Shipley, (2018) [63]	Non-randomized clinical trial	N = 16, EG 27.6 y, CG 18.9 y, ♀11 ♂5	Aligners	Effect of HFA on aligner exchange interval & treatment duration	VPro5®, 120 Hz, 5 min/day	Crowding post-treatment 0.0 mm. Aligners used: EG 5 vs CG 14 (~66% reduction). Treatment time shorter in EG	HFA ↑aligner change rate, ↓number of aligners, ↓treatment time
Azeem *et al.*, (2019) [43]	Randomized controlled trial	N = 28, mean 20.8 y, ♀18 ♂10. EG: vibration + 100 g canine, CG: no vibration	Fixed appliances	Effect of electric toothbrush vibration on canine retraction	Oral-B Triumph®, 125 Hz, 20 min/day	Canine movement similar first 3 months; plaque minimal; no discomfort	Vibration + light force does not accelerate movement
Siriphan *et al.*, (2019) [21]	Randomized controlled trial	N = 60, mean 21.5 y, ♀47 ♂13. EG1: 60 cN + 30 Hz, EG2: 60 cN + 60 Hz, CG: 60 cN only	Fixed appliances	Effects on canine distalization, OPG, RANKL	30 or 60 Hz, 20 min/day; T1–T4	RANKL differed at compression side; movement rates: 30 Hz 0.82, 60 Hz 0.87, CG 0.83 mm/month	30/60 Hz vibration has no effect on canine movement or RANKL/OPG
Shipley *et al.*, (2019) [33]	Non-randomized clinical trial	N = 30, ♀19 ♂11	Aligners	Effect of HFV on tooth movement & bone density	VPro5®, 120 Hz, 5 min/day	Aligners exchange: EG 5.2 ± 2.2 vs CG 8.7 ± 1.2 days; total treatment: EG 135 ± 27 vs CG 252 ± 59 days; bone density ↑ in EG	HFV ↑aligner change, ↑tooth movement, ↑bone density
Kumar *et al.*, (2020) [51]	–	N = 65, mean 17.1 y, ♀35 ♂30. EG1: passive self-ligating + vibration, EG2: MBT + vibration, CG: MBT only	Fixed appliances	Evaluate low-frequency vibration with different brackets	30 Hz, 20 min/day	Space closure: EG1: 0.61 max R/L, 0.51 mand R/L; EG2: 0.54/0.54 max, 0.46/0.46 mand; CG: 0.57/0.61 max, 0.53/0.53 mand	Low-frequency vibration did not significantly increase tooth movement
Taha *et al.*, (2020) [55]	Randomized-controlled trial	N = 21, mean 15.48 y, ♀14 ♂7. EG: mechanical vibration + fixed appliance, CG: fixed appliance	Fixed appliances	Canine retraction, pain perception	AcceleDent®, 30 Hz, 0.25 N, 20 min/day; T0–T3	Tooth movement T1–T3 similar (EG: 1.39, 2.49, 3.37 mm; CG: 1.12, 2.59, 3.54 mm). Pain slightly higher EG first day, similar day 2–6	No significant differences in retraction rate or pain
Reiss *et al.*, (2020) [44]	Randomized controlled trial	N = 40, mean 20.4 y, ♀20 ♂20	Fixed appliances	Effect of vibration on bone remodeling biomarkers, irregularity, and compliance	AcceleDent®, 30 Hz, 0.25 N, 20 min/day; T0–T3	Irregularity: T0 7.24 vs 8.96, T1 4.26 vs 5.24, T2 2.33 vs 2.96, T3 0.97 vs 1.22. Biomarker changes not different	No effect on bone remodeling biomarkers, irregularity, or compliance
Telatar *et al.*, (2021) [52]	Randomized controlled trial	N = 20, ♀10 ♂10. EG: AcceleDent®, CG: control	Fixed appliances	Effect on canine distalization	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	EG: lower 1.09, upper 1.24 mm/month; CG: lower 1.06, upper 1.06 mm/month	No statistical difference in canine retraction rate

Mayama *et al*., (2022) [56]	Randomized controlled trial	N = 25, mean 20.2 y, ♀21 ♂4. EG: vibration upper arch one side, CG: other side	Fixed appliances	Effect and safety of supplemental vibration	102.2 ± 2.6 Hz, 5.2 ± 0.5 g, 3 min/day	Canine movement: CG 0.89 ± 0.55 mm, EG 1.21 ± 0.60 mm; visits: CG 6.38 ± 3.10, EG 4.61 ± 2.15; no pain; crown/root ratio unchanged	Vibration ↑canine movement, ↓number of visits, no pain or root issues
Akbar *et al*., (2022) [59]	Non-randomized clinical trial	N = 30, ♀20 ♂10. EG: left upper arch vibration, CG: right side only	Fixed appliances	Local vibration on canine retraction & anchorage loss	Oral B®, 240 Hz, 15 min/day	No discomfort; canine retraction and anchorage loss similar after 12 weeks	Vibration had no significant effect on canine movement or anchorage loss
Bilello *et al*., (2022) [64]	Non-randomized clinical trial	N = 20, mean 35 y, ♀75%. EG: 7-day aligner + AcceleDent®, CG: 14-day aligner	Aligners	Evaluate AcceleDent® efficacy with aligners	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Aligners needed: EG 41.1 ± 22.4, CG 33.1 ± 15.5. Treatment duration: EG 366 ± 187.4, CG 509.3 ± 243.5 days. Wear per aligner: EG 9.0 ± 1, CG 15.4 ± 1.2. Pain: EG 2.4 ± 1, CG 4.4 ± 1.4	AcceleDent® led to faster, comfortable treatment, with reduced pain; acceleration due to device vs aligner regimen unclear
Khera *et al*., (2022) [46]	Randomized controlled trial	N = 30, aged 18–25. EG: vibration side, CG: control	Fixed appliances	Low-frequency vibration on canine retraction	Customized device, 30 Hz, 0.25 N, 20 min/day; T0–T4	Rate of canine retraction not significantly different between groups	30 Hz vibration did not accelerate canine retraction
Yildiz *et al*., (2023) [57]	Randomized controlled trial	N = 24, ♀8 ♂16, mean 15.07. CG: split-mouth force only; EG: split-mouth + AcceleDent®	Fixed appliances with Hycon	Synergistic effect of Hycon + AcceleDent® on orthodontic movement and root resorption	AcceleDent®, 30 Hz, 0.25 N, 20 min/day	Intermittent force accelerated canine distalization; vibration did not affect movement	Intermittent force effective, vibration did not add acceleration
ElMotaleb *et al*., (2024) [58]	Randomized controlled trial	N = 32 (64 canines), ♀, age 15–21. EG: vibration + fixed appliance, CG: fixed appliance	Fixed appliances	Effectiveness of AcceleDent® on canine retraction	AcceleDent®, 30 Hz, 0.25 N, 20 min/day, 4 months	No difference in total canine movement, monthly rate, pain, or root condition	AcceleDent® did not accelerate movement, reduce pain, or affect roots

Abbreviations: N = number of participants; CG = control group; EG = experimental group; IL = interleukin; GCF = gingival crevicular fluid; PDL = periodontal ligament; VHS = volume-average hydrostatic stress; HFV = high-frequency vibration; RANKL = receptor activator of nuclear factor kappa-B ligand; OPG = osteoprotegerin; RMAA = rate of mandibular anterior alignment.

Of the 25 clinical investigations, 18 [17, 21, 43–47, 48, 50–58, 66] were randomized controlled, and 7 [33, 59–64] were non-randomized. A split-mouth design was adopted in six [17, 43, 46, 48, 57, 59]. Altogether, the studies evaluated 1,053 orthodontic cases.

A total of 19 [17, 21, 43–46, 48, 50–52, 54–60, 62, 66] used fixed braces, five [33, 49, 53, 63, 64] relied on aligners, and one [61] tested both systems.

For vibration equipment, 14 investigations [44, 49, 50, 52–55, 57, 58, 60–62, 64, 66] implemented AcceleDent®, two [33, 63] used VPro5®, four [17, 21, 43, 48] used an electric toothbrush, and five [45, 46, 51, 56, 59] employed custom-built units. All studies required daily use.

Those applying low-frequency stimulation [21, 44, 46, 49–55, 57, 58, 60–62, 64, 66] operated at 30 Hz for 20 minutes per day, whereas high-frequency settings [17, 21, 33, 43, 45, 48, 56, 59, 63] ranged from 50 to 125 Hz. Only one paper [21] examined both frequencies.

Regarding outcomes measured:

- 13 reports [17, 21, 43, 46, 48, 51, 52, 54–59] analyzed tooth retraction,
- 4 [45, 60, 62, 66] studied anterior alignment,
- 3 [33, 50, 61] evaluated treatment duration,
- 4 [49, 53, 63, 64] focused on aligner exchange,
- 4 [17, 21, 33, 45] investigated bone-remodeling biomarkers,

- and 6 [45, 49, 55, 56, 58, 64] monitored pain.

In total, 17 out of 25 [21, 43–46, 49–55, 57–59, 64, 66] found no significant enhancement in tooth movement due to vibration.

Only three low-frequency studies [60–62] indicated noticeable improvement in movement rate and alignment. Among nine high-frequency trials [17, 21, 33, 43, 45, 48, 56, 59, 63], four [21, 43, 45, 59] observed no acceleration effect. However, two investigations [33, 63] operating at 120 Hz reported faster aligner turnover and fewer aligners required to finish therapy. Additionally, one study at 50 Hz [48] and another at 102 Hz [56] found greater total space closure and canine distalization.

The orthodontist's primary responsibility is to deliver functional and aesthetic results efficiently, and treatment duration has become an increasingly critical factor. In this context, non-surgical adjunctive techniques, particularly those that patients can apply at home under supervision—such as mechanical vibrations at low or high frequencies—have gained interest in recent years [66]. This method, which employs vibrational forces, aims to accelerate orthodontic tooth movement (OTM) by stimulating periodontal and alveolar bone remodeling [17].

Influence of low-frequency vibrations on orthodontic tooth movement in humans

Within the analyzed literature, only three investigations explored the use of aligners in conjunction with vibration. Both Katchooi *et al*. (2018) [49] and Lombardo *et al*. (2019) [53] utilized AcceleDent® according to the manufacturer's instructions and reported no measurable improvement in aligner change intervals or total treatment duration. In contrast, Bilello *et al*. (2022) [64] could not clearly determine whether any reduction in treatment time was due to AcceleDent® use or to modifications in aligner exchange frequency.

For fixed appliances, the majority of reports indicated no statistically significant benefit from low-frequency vibration in terms of mandibular space closure, overall treatment duration, or final outcomes [51, 54]. Several authors also documented no difference in the retraction speed of maxillary canines between vibration and control groups [21, 46, 55, 57, 58]. Supporting these findings, Telatar *et al*. (2021) [52] measured the monthly retraction rate of lower canines as 1.09 mm with vibration versus 1.06 mm without, and upper canines as 1.24 mm and 1.06 mm, respectively—showing negligible variation between groups.

Conversely, Orton-Gibbs (2015) [61] and Bowman (2016) [62] observed that applying AcceleDent® with fixed appliances resulted in enhanced tooth movement and shorter treatment durations. Bowman (2014) [60] found that incorporating low-frequency mechanical vibration (LFMV) shortened treatment time by approximately 30%, while a subsequent trial [62] confirmed a reduced number of days to reach Class I molar relationships. Similarly, Orton-Gibbs (2015) [61] noted a significant decrease in treatment duration using AcceleDent®. However, Miles (2018) [50] failed to detect any meaningful reduction in total treatment time between vibrational and control groups.

Mechanical analysis of the AcceleDent® mouthpiece revealed that its vibration distribution is uneven, with greater stimulation on anterior teeth and less on posterior ones due to design and occlusal variation [67]. The mouthpiece stiffness, fit accuracy, and individual tooth angulation influence how vibration transmits across the arch. Consequently, misalignment or poor adaptation may prevent adequate stimulation of some teeth, explaining the inconsistent clinical results observed across studies.

In terms of pain perception, ElMotaleb *et al*. (2024) [58], Taha *et al*. (2020) [55], and Katchooi *et al*. (2018) [49] all reported no significant reduction in discomfort when low-frequency vibration was added to orthodontic treatment.

On a biological level, Siriphan *et al*. (2019) [21] found that vibration did not enhance tooth movement rate or cytokine release. Similarly, salivary biomarker analysis revealed increased IL-11 and MMP-9 levels in the control group, but not in those using AcceleDent®, indicating that vibration might dampen inflammatory signaling, potentially slowing movement [44]. Overall, although some studies suggest limited benefits, others indicate that patient-specific and mechanical variables, such as initial crowding and biological response, strongly affect the results.

In summary, low-frequency vibration (≤30 Hz) generally does not accelerate orthodontic tooth movement, despite occasional minor improvements noted in certain reports.

Effects of high-frequency vibrations on tooth movement in humans

A limited number of studies [33, 63] demonstrated that high-frequency mechanical vibration (HFMV) can enhance tooth movement when used with aligners. Shipley *et al*. (2019) [33] found an increase in aligner turnover and displacement with the VPro5® device, and in a related trial, Shipley (2018) [63] observed a 66% rise in aligner change rate and a corresponding increase in the number of aligners required to complete treatment.

Other investigations [17, 48, 56] confirmed similar acceleration when HFMV was applied with fixed appliances. For example, Liao *et al*. (2017) [48] and Mayama *et al*. (2022) [56], using frequencies of 59 Hz and 102 Hz, respectively, documented greater total space closure and enhanced canine distalization, implying that localized high-frequency stimulation may facilitate faster tooth movement. However, treatment timing—particularly archwire progression decisions—may also influence the observed effect.

Contrary to these results, Azeem *et al*. (2019) [43], Siriphan *et al*. (2019) [21], and Akbar *et al*. (2022) [59] detected no meaningful change in canine retraction with vibration when toothbrush-based devices were used. In such cases, vibration was delivered at a single contact point, which may have reduced efficiency. The direction and distribution of vibration likely play a key role, as in fixed appliance systems, the archwire transmits forces along multiple teeth, causing dissipation of energy. Conversely, during aligner therapy, vibration is applied without any metallic arch, limiting dispersion and concentrating stimulation to specific teeth. The overall effect in fixed systems also depends on bracket design and wire characteristics, which influence how vibration energy propagates through the dental arch.

Two studies [45, 56] observed that patients treated with fixed appliances in combination with high-frequency vibration reported pain during orthodontic therapy, with no significant reduction in discomfort levels compared to controls.

Biological mechanisms and cellular response to high-frequency vibration

From a biological standpoint, Leethanakul *et al*. (2016) [17] investigated the composition of gingival crevicular fluid (GCF) to evaluate tissue response to HFMV generated by an electric toothbrush. The researchers noted that vibratory stimulation can elevate the concentration of several GCF components, including interleukin-1β (IL-1β). This cytokine plays a pivotal role in bone resorption, as it upregulates RANKL expression in osteoblasts and periodontal ligament (PDL) cells, thereby enhancing osteoclast precursor differentiation. In their findings, IL-1β levels were approximately threefold higher in the group exposed to vibration compared with orthodontic force alone. This indicated that the addition of a vibratory element produces a measurable biological effect, intensifying bone turnover and consequently accelerating tooth movement.

Overall, the evidence suggests that high-frequency mechanical vibration promotes orthodontic tooth movement (OTM), although the studies analyzed here were limited by small sample sizes.

Effects of supplemental vibration in in vivo models

In contrast to clinical trials, animal experiments tend to produce more consistent findings, largely due to the ability to control vibrational intensity and direction precisely. In these settings, vibration is applied directly to the tooth, allowing for uniform mechanical stimulation and accurate measurement of biological response.

Nishimura *et al*. (2008) [19] tested a range of resonant frequencies averaging 61 Hz on rats and observed that the first molars moved approximately 0.0014 mm at a velocity of 0.27 mm/second. The experimental group showed a 15% greater tooth displacement than controls. Histological analysis revealed a higher number of multinucleated osteoclasts in the alveolar bone, suggesting a correlation between osteoclast proliferation and movement rate. Vibrational exposure appeared to promote differentiation of monocytes/macrophages and elevate RANKL expression in both PDL fibroblasts and osteoclasts, thereby facilitating bone remodeling.

Similarly, Takano-Yamamoto *et al*. (2017) [41] found that resonant vibration stimulated faster tooth movement without detrimental tissue changes. Their research indicated that HFMV enhances NF-κB pathway activation in osteocytes, osteoblasts, and osteoclasts, which increases osteoclastogenesis and cell activity, thereby expediting bone resorption and tooth displacement.

Further, Alikhani *et al*. (2018) [42] analyzed how anti-inflammatory medication affects HFMV-driven acceleration and investigated PDL involvement during remodeling. They reported that high-frequency vibration enhanced tooth movement during the catabolic phase and contributed to stabilization in the anabolic phase, suggesting that the release of inflammatory mediators within the ligament was a major contributor to accelerated movement.

Collectively, these studies [19, 41, 42] indicate that frequencies between 60 Hz and 120 Hz are effective in stimulating bone turnover and accelerating orthodontic tooth movement in vivo.

Conversely, Kalajzic *et al*. (2014) [39] and Yadav *et al*. (2015) [40] obtained different outcomes for low-frequency mechanical vibration (LFMV). Kalajzic and colleagues found reduced molar separation in the vibration group, suggesting that LFMV might impede movement. Likewise, Yadav *et al*. observed no enhancement in molar displacement or osteoclast formation when LFMV was applied to teeth not subjected to orthodontic forces. They hypothesized that PDL fiber orientation on the tension side might be disrupted by low-frequency input, impairing osteoclast activation and thus limiting movement progression. Both studies tested vibrations between 5 and 30 Hz, supporting the view that low-frequency stimuli are less effective or even inhibitory in some cases.

Study strengths and limitations

Several limitations should be considered when interpreting these findings. The included studies varied in sample size, which may have influenced comparability and statistical reliability. Moreover, different vibration devices and parameters were used across studies, resulting in inconsistent stimulation intensities and frequencies, thus limiting the ability to draw firm conclusions.

A further constraint relates to patient compliance, since most devices are self-administered. The actual exposure depends heavily on the patient's adherence and accuracy of use. Only one investigation [44] measured compliance, revealing an average adherence rate of 53%, with a

noticeable decline over time. Additionally, the small number of in vivo experiments weakens the overall evidence base, and many clinical studies suffer from small cohorts, reducing their statistical power.

Nevertheless, this systematic review offers a comprehensive overview of both animal and clinical studies, enabling a broader understanding of how vibration influences orthodontic tooth movement. The evidence indicates that high-frequency mechanical vibration (HFMV) tends to yield more favorable outcomes compared to low-frequency mechanical vibration (LFMV), which often produces inconsistent or negligible effects. These findings can inform the design of future trials aiming to optimize the use of vibrational therapy in orthodontics.

Conclusion

Vibration therapy represents a non-invasive and modern adjunct to orthodontic treatment, applicable with both fixed appliances and clear aligners. Whether below 30 Hz (LFMV) or above this threshold (HFMV), vibrational input can be adapted to individual cases. The current analysis indicates that HFMV demonstrates stronger evidence of accelerating tooth movement across both in vivo and clinical settings compared with LFMV. However, due to variations in study design, sample size, and device parameters, the results remain inconclusive.

To establish clearer protocols, future research should incorporate larger cohorts, standardized vibration frequencies, and controlled dosage/time parameters. Moreover, investigations should explore optimized vibration protocols—including application duration, frequency, and directionality—to target specific tooth movements. The development of customized, programmable devices capable of delivering precise directional vibration could significantly enhance the efficacy and predictability of orthodontic tooth movement.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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