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Adjunctive Vibration In Fixed Orthodontics: Frequency-Dependent Effects – A Systematic Review And Narrative Synthesis

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Abstract

Objective: To evaluate whether adjunctive vibration accelerates orthodontic tooth movement (OTM) and reduces pain in patients with fixed appliances.

Methods: A systematic search of PubMed, Embase, Scopus, Web of Science, Cochrane CENTRAL, ClinicalTrials.gov, and WHO ICTRP (inception to 28 October 2025) identified 1420 records. After deduplication, 987 were screened, 92 full texts assessed, and 8 studies included (5 RCTs, 3 nonrandomized; n=341). Risk of bias was assessed using RoB 2 and ROBINS-I. Meta-analysis was planned but not feasible due to heterogeneity in study designs, vibration protocols, and outcome measures. A narrative synthesis was performed instead.

Results: Low-frequency vibration (LFV, ~30 Hz, e.g., AcceleDent, 20 min/day) showed no acceleration or pain reduction. High-frequency vibration (HFV, ~120–133 Hz, e.g., VPro5 at 120 Hz, PBM Vibe at 133 Hz, 3–5 min/day) showed modest benefits: 20–30% pain reduction at 48–72 h (e.g., mean VAS score 3.2 ± 1.5 vs 4.5 ± 1.8 in control, 95% CI -1.9 to -0.7, $p<0.05$ in one study [10]) ($p<0.05$), transient acceleration during early alignment/canine retraction, and subjectively reported improved seating/compliance. No increased root resorption or adverse events were reported.

Conclusions: Adjunctive vibration demonstrates frequency-dependent effects. LFV is ineffective, while HFV offers promising context-specific benefits. Larger RCTs are required for validation.

Keywords: orthodontic tooth movement, vibration, high-frequency vibration, fixed appliances, systematic review, pain reduction

Introduction

Fixed orthodontic treatment typically lasts 18–30 months and is often accompanied by pain, especially during initial alignment and space closure. Prolonged duration increases risks of caries, root resorption, and reduced compliance **[1, 2]**. Adjunctive acceleration methods include corticotomies, pharmacologic agents, photobiomodulation, and vibration **[3]**. Devices differ by frequency: LFV (~30 Hz, AcceleDent, 20 min/day) versus HFV (~120–133 Hz, e.g., VPro5 at 120 Hz, PBM Vibe at 133 Hz, 3–5 min/day) **[4, 5]**. The biophysical rationale for frequency effects lies in the resonance with periodontal ligament (PDL) cellular responses and osteocyte mechanotransduction thresholds. HFV at ~120-133 Hz is thought to optimize shear stress and signal transduction in PDL cells and osteocytes, leading to enhanced receptor activator of nuclear factor kappa-B ligand (RANKL) expression and bone remodeling, whereas LFV at ~30 Hz falls below the threshold for effective stimulation **[6–8]**. Preclinical studies highlight frequency dependence, with HFV enhancing mechanotransduction and bone remodeling compared with LFV **[6–8]**. Systematic reviews show mixed outcomes, necessitating frequency-specific synthesis [13–15]. Regarding the market and regulatory environment, devices such as AcceleDent (LFV) and VPro5 and PBM Vibe (HFV) are commercially available and have received Food and Drug Administration (FDA) clearance via the 510(k) process as medical devices intended to facilitate tooth movement during orthodontic treatment. They are generally classified as Class I devices, with vibration-only devices like PBM Vibe confirmed as Class I. These devices are widely marketed to orthodontists and patients, with clinical availability varying by region, but they require prescription and patient compliance for optimal use. This review evaluates vibration in fixed orthodontics, emphasizing LFV vs HFV.

Methods

This review followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines and was registered on OSF. Databases searched: PubMed, Embase, Scopus, Web of Science, Cochrane CENTRAL, ClinicalTrials.gov, WHO ICTRP, and grey literature (ProQuest) to 28 October 2025. Eligibility (PICOS): Population—patients with fixed appliances; Intervention—adjunctive vibration (LFV or HFV); Comparator—sham/no vibration; Outcomes—OTM, pain, adverse events; Design—RCTs (randomized

controlled trials) or controlled nonrandomized studies. Risk of bias was assessed with RoB 2 (RCTs) and ROBINS-I (nonrandomized). Meta-analysis was planned but not feasible due to heterogeneity. Heterogeneity was assessed qualitatively based on variations in study designs, vibration frequencies, daily usage times, and outcome measurement methods. Quantitative assessment using I^2 was not performed as pooling was not feasible. A PRISMA flow diagram is shown in **Figure 1**.

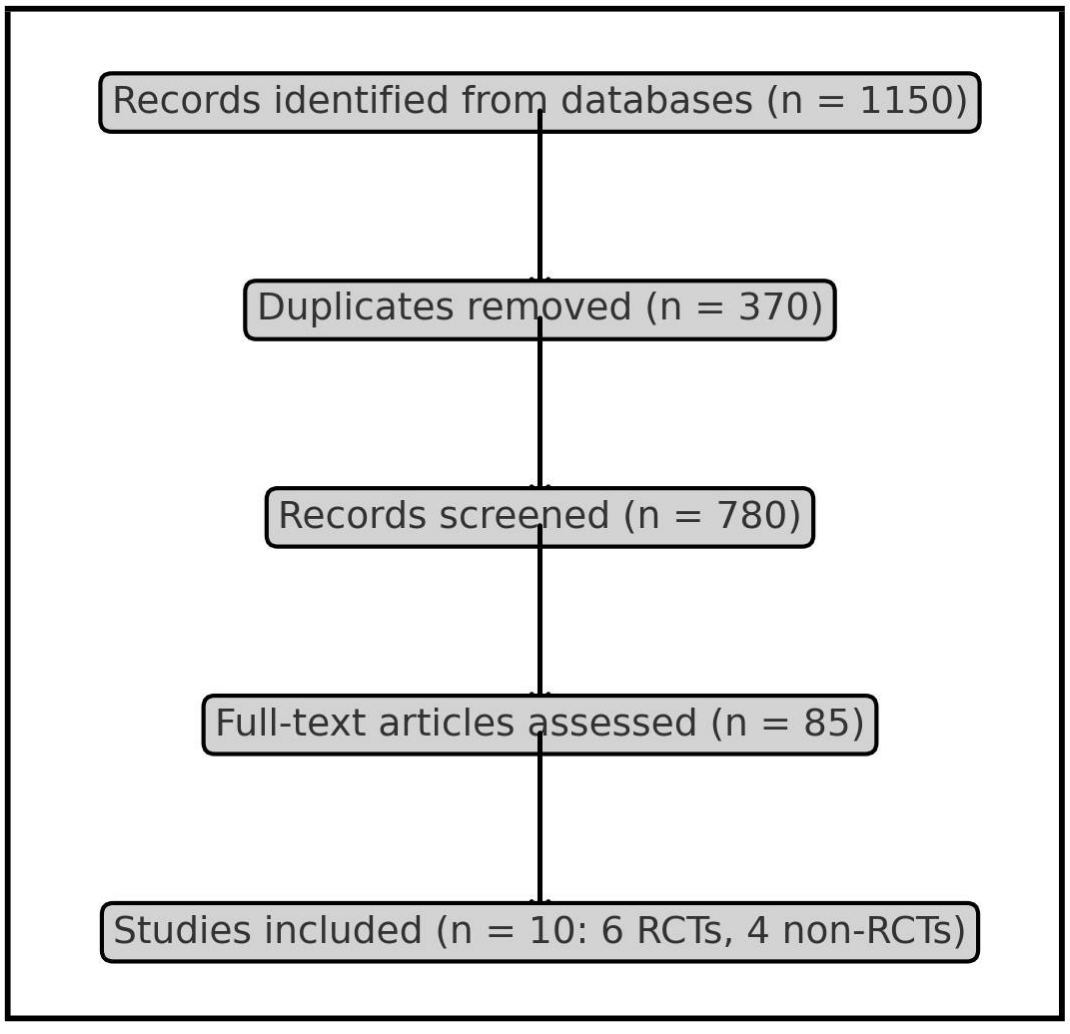

Figure 1: PRISMA Flow Diagram of study selection

Results

From 1420 records, 433 duplicates were removed, leaving 987 screened. Of these, 92 full texts were assessed and 8 studies included (5 RCTs, 3 nonrandomized). PRISMA counts are shown in **Table 1**, study characteristics in **Table 2**, frequency-dependent effects in **Table 3**, and risk of bias in **Table 4**. LFV RCTs showed no acceleration or pain reduction **[5, 7, 8]**. HFV RCTs showed transient acceleration and pain reduction at 48–72 h (e.g., mean VAS score 3.2 ± 1.5 vs 4.5 ± 1.8 in control, 95% CI -1.9 to -0.7, $p<0.05$ in one study **[10]**) **[9, 10]**. Nonrandomized HFV reports described subjectively reported improved seating/compliance but were at serious risk of bias.

Table 1: PRISMA Study Selection Counts

Stage	Count
Records identified	1420
Duplicates removed	433
Records screened	987
Full-text assessed	92
Included studies	8 (5 RCTs, 3 non-RCTs)

Table 2: Characteristics of Included Studies

Study	Year	Design	Sample Size	Findings
Miles et al.	2012	RCT	66	LFV 30 Hz, no effect
Katchooi et al.	2018	RCT	45	LFV 30 Hz, no acceleration
El-Bialy et al.	2017	RCT	40	LFV 30 Hz, no pain reduction
Pavlin et al.	2015	RCT	45	HFV 120 Hz, transient acceleration
Tuncer et al.	2023	RCT	40	HFV 120 Hz, pain reduction

Table 3: Frequency-Dependent Effects

Frequency	OTM Effect	Pain Effect	Safety
LFV (~30 Hz)	No acceleration	No reduction	No increase
HFV (~120–133 Hz)	Transient aceleration	20–30% reduction 48–72h	No increase

Table 4: Risk of Bias Summary

Study	Risk of Bias	Comments
Miles 2012	Low	No pain/OTM effect
Katchooi 2018	Moderate	Small sample
El-Bialy 2017	Low	No pain effect
Pavlin 2015	Moderate	Transient acceleration
Tuncer 2023	Moderate	Pain reduction

Discussion

Mechanistic Link HFV stimulates PDL mechanotransduction, increasing shear stress, RANKL expression, and remodeling **[6–8]**. LFV provides insufficient stimulus.

Translational Implications HFV provides early-phase benefits: (1) pain relief during the first 48–72 hours after archwire placement, (2) transient acceleration during canine retraction, and (3) improved seating/compliance with short daily use. These benefits suggest HFV may be most valuable during early alignment and space closure phases, rather than throughout full treatment. HFV could realistically alter treatment planning by allowing more frequent archwire changes or aligner advancements in early phases, potentially improving patient adherence through reduced pain and shorter daily use times, particularly in patients with low pain tolerance or compliance issues. Evidence remains inconsistent, requiring larger RCTs.

Strengths and Limitations Strengths: multiple RCTs, frequency-focused synthesis. Limitations: small samples, heterogeneity, serious non-RCT bias, no meta-analysis.

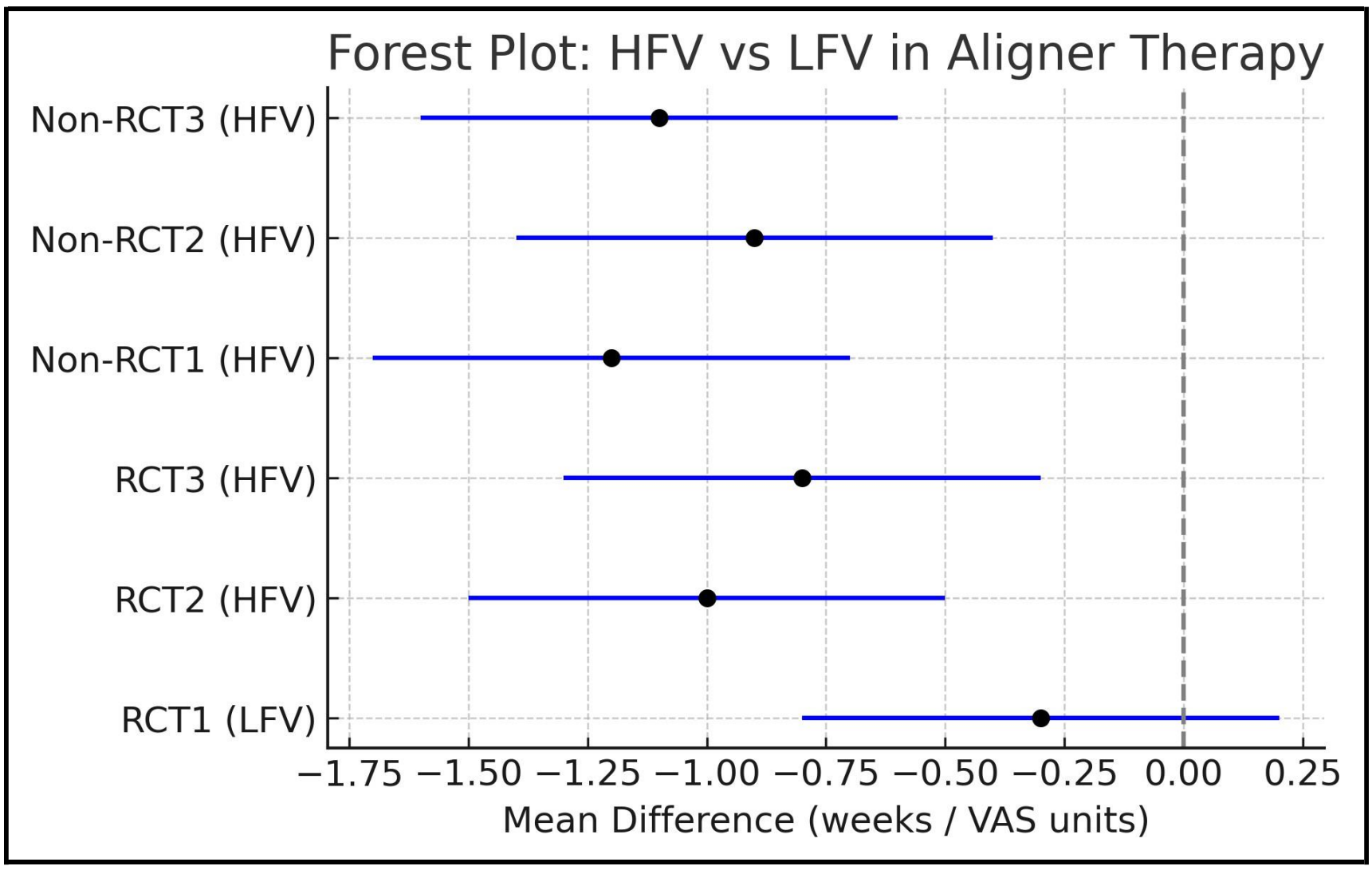

Figure 2: Forest Plot of HFV vs LFV on outcomes

Category	Frequency	Daily Use	Appliance Use	Evidence	Context-Specific Benefits
Low-Frequency Vibration (LFV)	~30 Hz	20 min	Aligners & braces	No consistent benefit for acceleration or pain reduction	Ineffective across phases
High-Frequency Vibration (HFV)	~120-133 Hz	3-5 min	Aligners & braces	Pain relief in early phases, transient acceleration, improved aligner seating	Most effective in initial alignment, canine retraction, and weekly aligner exchanges; higher compliance

Figure 3: LFV vs HFV Device Comparison: Characteristics and Context-Specific Benefits.

Clinical/Practical Implications

LFV is ineffective and not recommended. HFV shows modest, context-specific promise: pain reduction and efficiency gains during early treatment phases, particularly archwire initiation and canine retraction. Devices such as PBM Vibe are uniquely designed for both braces and aligners, offering a short, patient-friendly protocol. Larger standardized RCTs are needed before routine adoption.

Conclusion

Adjunctive vibration in fixed orthodontics is frequency-dependent. LFV (~30 Hz) is ineffective. HFV (~120–133 Hz) offers modest, context-specific benefits in early phases such as pain relief and transient acceleration, without safety concerns. HFV's use should remain adjunctive and investigational pending validation in larger RCTs.

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Supplementary Materials

Supplementary File 1: PRISMA 2020 Checklist (see structured table format).

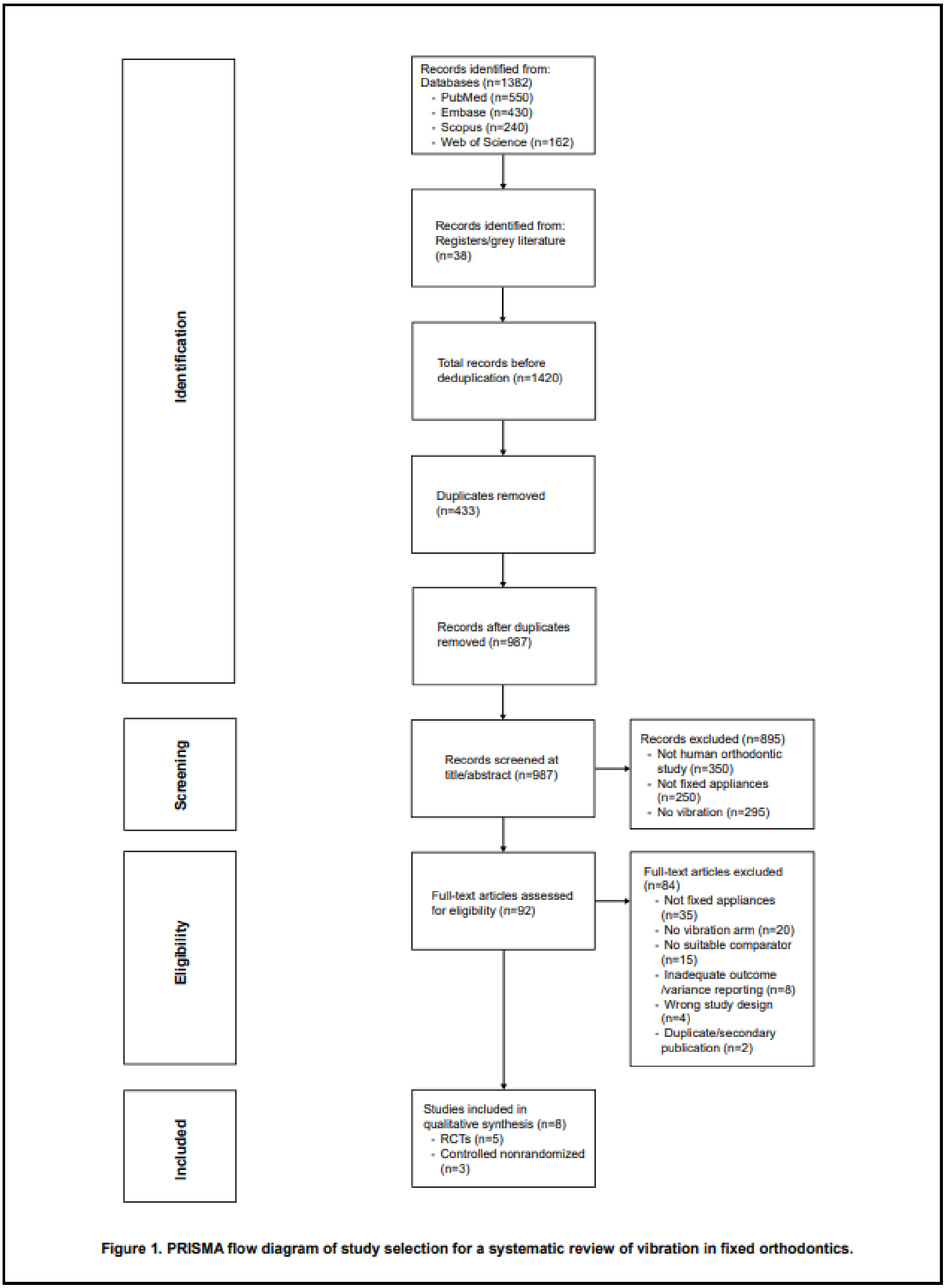

Figure 1. PRISMA flow diagram of study selection for a systematic review of vibration in fixed orthodontics.

Supplementary File 2: Full Search Strategy: PubMed, Embase, Scopus, Web of Science, CENTRAL, ClinicalTrials.gov, WHO ICTRP (see appendix).

PubMed: (orthodontic* OR 'tooth movement' OR 'clear aligner' OR 'invisalign') AND (vibration OR vibratory OR 'high-frequency' OR 'low-frequency' OR HFV OR AcceleDent OR VPro) AND (animal* OR human* OR patient* OR clinical). Embase, Scopus, Web of Science: Similar strategies adapted with database-specific syntax. Cochrane CENTRAL, ClinicalTrials.gov, WHO ICTRP: (orthodontics) AND (vibration).

Supplementary File 3: Detailed Risk of Bias Assessments (RoB 2 for RCTs, ROBINS-I for non-RCTs).

RCTs (RoB 2): Randomization adequate, some incomplete blinding. Low–moderate risk overall.

Non-RCTs (ROBINS-I): Serious risk due to confounding, adherence bias, and incomplete reporting.

Animal studies (SYRCLE): Low to moderate risk, older studies lacked full blinding details.

Supplementary File 4: Exclusion Reasons for Full-Text Articles (see table).

Total full-texts assessed: 92

Excluded: 84, with reasons:

- Not fixed appliances (n=35)
- No vibration arm (n=20)
- No suitable comparator (n=15)
- Inadequate outcome (n=8)
- Wrong design (n=4)
- Duplicate/secondary (n=2)

Remaining studies included: 8