

Systematic Review Article

Mechanical vibration as an adjunct to clear aligner treatment for accelerating tooth movement: A review

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ABSTRACT

Many patients, particularly adults, may prefer clear aligner treatment due to its esthetics and ease of use. Some studies have shown that mechanical vibration can affect the rate of tooth movement and other aspects of orthodontic treatment. The purpose of this systematic review was to substantiate the effects of vibration as an adjunct to clear aligner treatment. A comprehensive search of the PubMed, Embase, Cochrane library, and Scopus and also hand searching of reference lists was conducted for finding published studies up to March 2021. Two authors reviewed the titles and abstracts independently to select relevant studies and the full texts where there was some skepticism. Seven papers were included in this study following removing duplicates and irrelevant studies, four of which were randomized controlled trial and three were retrospective studies. In the majority of studies, High-Frequency Vibration (HFV) has shown to be effective in accelerating tooth movement and reducing the exchange interval of aligners. Little data have advocated that HFV can increase bone density, reduce pain or root resorption. It seems that HFV is more effective than low frequency vibration in patients treated with clear aligners. Based on a low level of certainty, HFV can increase the rate of tooth movement and decrease the exchange interval of clear aligners. Further investigation is necessary to clarify the effects of vibration on pain and discomfort, bone density, and root resorption.

Key Words: Clear aligner appliances, orthodontic tooth movement, vibration

Received: 04-Jun-2021
Revised: 12-Nov-2021
Accepted: 19-Jan-2022
Published: 26-Sep-2022

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INTRODUCTION

Today, increasing number of orthodontic patients, especially adults demand for a more comfortable, less conspicuous orthodontic appliance.^[1] Clear aligners are removable transparent appliances which first introduced by Kesling in the early 1940s. They have been making progress ever since and become more popular as computer software design and material properties evolve dramatically.^[2,3]

Several advantages have been advocated for clear aligner treatment. The most prominent one is that they are invisible appliances which let us avoid placing conventional braces on teeth and has less negative impression on patients' social activity.^[3] Fixed orthodontic appliances can increase the accumulation of dental plaque and cause whiteness lesions, caries, and gingivitis during and after the orthodontic therapy;^[4,5]

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How to cite this article: Ghadirian H, Yazarloo S, Heidari S, Gholamrezayi E. Mechanical vibration as an adjunct to clear aligner treatment for accelerating tooth movement: A review. Dent Res J 2022;19:75.

however, removable appliances such as clear aligners can be removed for eating, drinking, brushing, and flossing and thus improve patient's oral hygiene.^[6,7]

On the other hand, there are some disadvantages including higher cost of treatment, challenges in treatment of some types of malocclusion, unpredictable appliance efficacy and effectiveness, and patients compliance.^[8,9]

The duration of the treatment is of paramount importance in adult orthodontic patients. Various surgical and nonsurgical methods have been suggested for reducing the treatment duration. Surgical methods have some limitation such as cost, patients' discomfort, and dissatisfaction. On the other hand, some have claimed that various nonsurgical methods (including direct electric current, vibrations, and low level laser therapy) can accelerate tooth movement.^[10,11] Among these conservative methods, vibration has gained a lot of attention since it can be administered by the patient at home.^[12] Furthermore, vibration devices claimed to have relieving effect on general and biting pain, therefore reducing discomfort in patients undergoing orthodontic treatment.^[13,14]

Vibration would seem to be an appealing adjunct to clear aligner therapy, because of its potential to accelerate tooth movement. However, evidence on vibration effectiveness was equivocal; some studies concluded that vibration can improve tooth movement rate while inducing higher level of inflammatory cytokines which are the indicators of orthodontic tooth movement.^[15,16] In contrast, some others revealed no significant alteration of tooth movement rate.^[17] The purpose of this literature review is to investigate the effect of varying vibration protocols on clinical outcomes in patients treated with clear aligner.

MATERIALS AND METHODS

Protocol and registration

The current systematic review followed the PRISMA guidelines^[18] and the Cochrane Handbook for the Systematic Review of Interventions (version 5.1.0)^[19] and was registered in the PROSPERO database (registration number: CRD42020223245).

Eligibility criteria

According to the PICOS format, selection of papers was performed based on the following criteria:

1. Population: Patients which treated with clear aligner

2. Intervention: Vibration application
3. Comparison: Patients treated with clear aligner without any adjunctive therapy like vibration
4. Outcomes:
 - Primary outcomes: Rate of tooth movement, clear aligner exchange intervals, and treatment duration
5. Secondary outcomes: Other clinical effects such as pain experience, root length and...
6. Study design: Randomized or nonrandomized clinical trials and observational studies which include control groups.

Exclusion criteria

- a. Animal study
- b. Studies involving orthognathic surgery
- c. Review articles, case reports, case series, and experimental animal studies
- d. Studies in a non-English language.

Information sources and search strategy

A comprehensive electronic search with no limitation regarding the language or the publication year was carried out in PubMed, Scopus, Cochrane library, and Embase databases, until March 2021. Search strategy for PubMed was developed as follows: (Vibratory Orthodontic Device) OR (vibration)) OR (accelerated)) OR (acceleration)) OR (AcceleDent)) OR (low frequency vibration)) OR (high frequency vibration)) OR (VPro)) OR (Propel orthodontics)) AND (((((clear aligner)) OR (aligner appliance)) OR (invisalign)) OR (Clear Aligner Appliances) OR [Propel orthodontics])). The same strategy was applied for other databases (the search strategy for each database is mentioned in Table 1). We also performed manual searching of the references list of all identified trials for further studies.

Deduplication and management of all citations were done using Endnote X7.

Study selection and data extraction

Two investigators independently performed the screening process of titles and abstracts considering the inclusion and exclusion criteria. Disagreement between reviewers resolved by consensus or by the decision of a third independent reviewer. Full text of relevant papers was reviewed thoroughly. The details about the study design, publication year, type of appliance used, the items reviewed, the diagnostic method, the number of participants, the different groups, and outcomes are provided in Table 2.

Assessment of risk of bias

Two review authors independently assessed the risk of

bias of the included studies. Cochrane’s risk of bias tool was used for the assessment of randomized controlled trials (RCTs).^[19] The study was considered as low risk of bias if all the domains were low. If only one domain assessed as high risk, the study was considered as high risk. A moderate risk of bias was considered when at least one domain was judged as unclear.

The Newcastle-Ottawa Quality Assessment Scale was utilized for retrospective studies,^[20] considering the number of stars in each category.

RESULTS

Study selection and characteristics

An overall of 83 papers were found out through the electronic search. One article was found in manual search. After duplicate papers were removed, 53 papers

were left. Forty-one studies excluded based on title or abstract. Full-text was reviewed for studies that could not be excluded definitively based on the titles and abstracts. Figure 1 illustrates the flow diagram of electronic search procedure, inclusion, and exclusion of studies.

Seven studies were ultimately picked out for the systematic review. Four studies were randomized clinical studies,^[12,21-23] and three were retrospective studies.^[24-26]

Six studies evaluated the tooth movement rate in different manner (accuracy of tooth movement, exchange interval of aligner, rate of alignment.),^[12,21-24,26] three the pain and discomfort,^[21-23] one the cytokine level,^[21] one bone density,^[24] one oral health-related quality of life and compliance,^[22] and one tooth length.^[25]

Assessment of risk of bias

The quality of included studies in this systematic review was comprehensively appraised to determine the potential risk of bias. Among four RCT, one was

Table 1: Search strategy

Search engine	Details of the search method
Pubmed	(((((((((Vibratory Orthodontic Device[Title/Abstract]) OR (vibration[Title/Abstract]) OR (accelerated[Title/Abstract]) OR (acceleration[Title/Abstract]) OR (AcceleDent[Title/Abstract]) OR (low frequency vibration[Title/Abstract]) OR (high frequency vibration[Title/Abstract]) OR (VPro[Title/Abstract]) OR (Propel orthodontics[Title/Abstract]) AND (((((clear aligner[Title/Abstract]) OR (aligner appliance[Title/Abstract]) OR (invisalign[Title/Abstract]) OR (Clear Aligner Appliances[Title/Abstract]))
Scopus	((TITLE-ABS-KEY (Vibratory Orthodontic Device) OR TITLE-ABS-KEY (vibration) OR TITLE-ABS-KEY (accelerated) OR TITLE-ABS-KEY (acceleration) OR TITLE-ABS-KEY (AcceleDent) OR TITLE-ABS-KEY (low frequency vibration) OR TITLE-ABS-KEY (high frequency vibration) OR TITLE-ABS-KEY (VPro) OR TITLE-ABS-KEY (Propel orthodontics)) AND ((TITLE-ABS-KEY (clear aligner) OR TITLE-ABS-KEY (aligner appliance) OR TITLE-ABS-KEY (invisalign) OR TITLE-ABS-KEY (Clear Aligner Appliances))) AND (LIMIT-TO (SUBJAREA, "DENT"))
Embase	'Vibratory Orthodontic Device' OR 'vibration' OR 'caries' OR 'accelerated' OR 'acceleration' OR 'AcceleDent' OR 'low frequency vibration' OR 'high frequency vibration' OR 'VPro' OR 'Propel orthodontics' AND 'clear aligner' OR 'aligner appliance' OR 'invisalign' OR 'Clear Aligner Appliances'
Cochrane	((Vibratory orthodontic device) OR (vibration) OR (accelerated) OR (acceleration) OR (AcceleDent) OR (low frequency vibration) OR (high frequency vibration) OR (VPro) OR (Propel orthodontics)) AND ((clear aligner) OR (aligner appliance) OR (invisalign) OR (Clear Aligner Appliances)) in Title Abstract Keyword

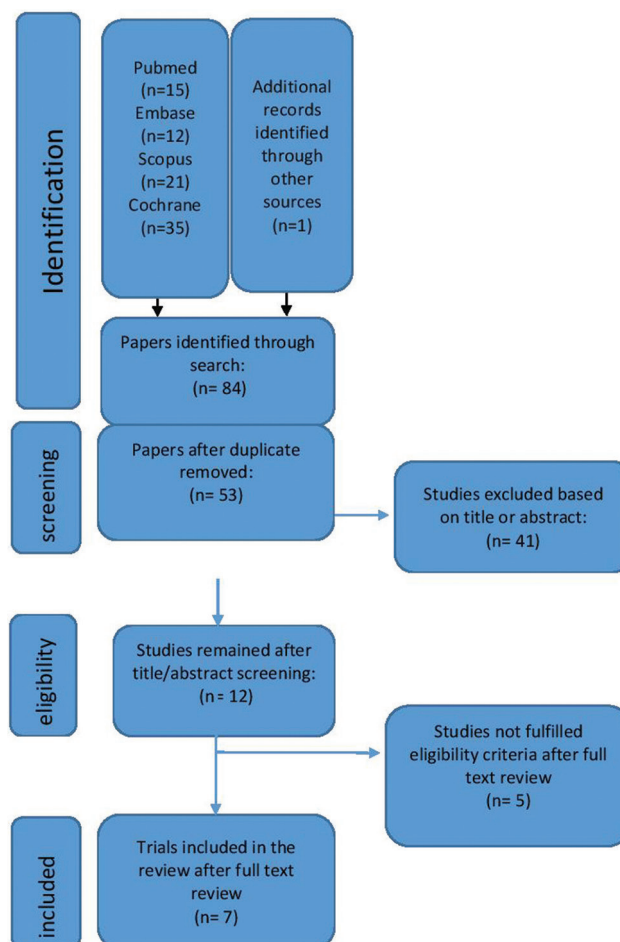


Figure 1: Flow diagram of the review.

Table 2: Summary of included studies

Author	Type of study	Number of participants	Type of intervention	Groups	Items reviewed	Diagnostic method	Conclusions
Sarah Alansari <i>et al.</i> (2018)	RCT	75	High frequency vibration application for 5 min per day	14 days control (15) 7 days sham (15) 7 days vibration (15) 5 days sham (15) 5 days vibration (15)	Anterior-posterior movement rate of one lower anterior tooth Cytokines level Pain	Superimposition of intraoral images and clincheck images After four aligners GCF at the completion of the second aligner Numeric rating scale at days 1 and 3 after each aligner change	Significantly reduced intervals between aligners Tooth movement tracked more closely to the clincheck prediction Higher levels of cytokines and bone remodeling markers Lower levels of pain and discomfort
Mina Katchooi <i>et al.</i> (2018)	RCT	27	Acceledent Aura device 20 min per day (30 Hz and 0.25 N)	Active (A) (n=14, 1 discontinued) Sham (B) (n=13)	Ability to complete the Initial set of aligners Incisor irregularity Aligner compliance, pain levels, and oral health-related quality of life	Digital scans (itero intraoral digital scanner) Questionnaires	No significant difference in completion rates, final irregularity index, change in irregularity index, compliance, pain, quality of life response between the 2 groups
Luca Lombardo <i>et al.</i> (2018)	RCT	45	Low-frequency vibration 20 min per day	Group A: Aligner replacement every 14 days (15) Group B: Vibration aligner replacement every 14 (15) Group C : Vibration aligner replacement every 7 days (15)	Accuracy/ imprecision of dental movements	Pre- and post-treatment digital models	The accuracy of dental movement was the same in Group A and Group C Group B demonstrated significantly greater accuracy with respect to Group A in upper incisor rotation and to Group C in vestibulolingual and mesiodistal tipping of the upper canines, and vestibulolingual tipping of the upper molars
T Shipley <i>et al.</i> (2020)	Retrospective study	30	HFV 120 Hz for 5 min per day	Control group (15) HFV group (15)	Tooth movement rate Posttreatment bone density	Average time for changing aligner CBCT	Treatment time was shorter as HFV allowed early aligner changes The HFV group demonstrated statistically significant increased bone density, whereas bone density did not show any significant change in control subjects relative to pre-treatment bone density
Khaled Farouk <i>et al.</i> (2018)	Retrospective	30	High-frequency mechanical vibration (HFV)	Group I: HFV (15) Group II: Control (15)	Maxillary Incisor's teeth lengths	CBCT	A statistically significant decrease in tooth lengths was noted in Control group compared to the HFV group, in which tooth lengths change were not statistically significant

Contd...

Table 2: Contd...

Author	Type of study	Number of participants	Type of intervention	Groups	Items reviewed	Diagnostic method	Conclusions
T Shipley <i>et al.</i> (2018)	Retrospective	16	HFAD	Experimental group: Exchanged aligners every 5 days + HFAD (8) Control group: Exchanged aligners every 14 days, no HFAD (8)	Clear aligner exchange intervals Treatment time for prescribed tooth movements	Total number of aligners used number of refinements required	Significant decrease in both treatment time, and number of aligners in experimental group with no refinements required, whereas 6 of 8 of the control subjects required 1 or more refinements
Bragassa <i>et al.</i> (2018)	RCT	33	Low-frequency vibration 20 min per day	Group 1: 2 weeks Aligner wear (10), Group 2: 4 days aligner wear without vibration (12) Group 3: 4 days aligner wear with vibration (11)	Efficiency and accuracy of incisor alignment, accuracy of overbite correction Discomfort Need for analgesic medication	Percent reduction and percent accuracy of reduction in PCPDI OB VAS survey	Vibration therapy had no effect on efficiency and accuracy of Incisor alignment, accuracy of OB correction nor the discomfort associated with accelerated (4 days) Invisalign®

HFV: High-frequency vibration; HFAD: High frequency acceleration device; GCF: Gingival crevicular fluid; PCPDI: Proximal contact point discrepancy index; OB: Overbite correction; VAS: Visual analog scale; CBCT: Cone beam computed tomography

assessed to be low risk, and three were considered to be high risk [Table 3]. All three retrospective studies have scored as low risk of bias [Table 4].

DISCUSSION

Vibration is low-level mechanical oscillatory signals which enhance bone metabolism, increase the remodeling rate, prevent osteoporosis, improve bone density, and diminish bone loss in postmenopausal women.^[27-29] Stimulation of cell differentiation and maturation, and therefore, bone remodeling required for tooth movement, is the basis of application of vibration in orthodontics.^[30]

Mechanical vibration implication in orthodontics is controversial. The recent systematic review concluded that evidences regarding the positive effects of mechanical vibration on different aspects of treatment (e.g., alignment of the anterior teeth, pain relief, space closure, etc.) are insufficient.^[31] However, many clinicians recommend the use of vibration as an adjunct to clear aligner treatment and claimed that the duration of treatment can be decrease 50% or more. Although the underlying mechanism is not clear, the tight contact of the aligner with the entire tooth surface and more efficient transmission of vibration to the root and surrounding bone is a rationale hypothesis.^[32]

Different type of vibrations used in orthodontics such as LFV and HFV.^[33,34] Alikhani demonstrated in an

animal study that 30 Hz frequency application causes 1.45-fold increase in the rate of tooth movement. Increasing the frequency to 60 Hz and 120 Hz caused a 2.1-and 2.4-fold increase in the rate of tooth movement, respectively.^[35]

Among included studies in this systematic review, three used LFV^[12,22,23] and four used HFV.^[21,24-26]

A major determinative factor for clear aligner treatment duration is the frequency of aligner exchange. This interval is usually 2 weeks. Decreased interval is prone to failure because planned tooth movement will not succeed, which is known as “nontracking.”^[36]

Six studies included in this review, evaluate the effects of vibration on orthodontics tooth movement in different terms such as: exchange interval, accuracy of movement, rate of tooth movement, and incisor irregularity index. Three of them, used LFV,^[12,22,23] and three HFV.^[21,24,26] Shipley *et al.*^[24,26] and Alansari *et al.*^[21] showed that HFV reduce intervals between aligners, and the planned movement was more closely tracked by teeth. Therefore, they have claimed HFV as an adjunctive to clear aligner treatment can reduced length of treatment. Furthermore, Shipley *et al.*^[26] showed that in HFV group, number of aligners reduced, because no refinements were required, though in control group, six patients (75%) required 1 or more refinements. In contrast, Bragassa^[23] concluded LFV has no effect on tooth

Table 3: Summary of the risk of bias for randomized controlled trial studies according to the Cochrane Collaboration tool for assessing risk of bias

Authors	Design	Random sequence generation	Allocation concealment	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Others	Risk of bias
Katchooi <i>et al.</i>	RCT	Low	Low	Low	Low	Low	Low	Low
Alansari <i>et al.</i>	RCT	Low	High	Low	High	Unclear	Low	High
Luca Lombardo <i>et al.</i>	RCT	Low	High	Low	Low	Unclear	Low	High
Bragassa <i>et al.</i>	RCT	Low	High	Low	Low	Low	Unclear	High

RCT: Randomized controlled trial

movement efficiency and accuracy and also shorter aligner exchange interval (4 days vs. 14 days) did not reduce total treatment time due to the increased requirement for midcourse correction and refinement. Lombardo *et al.*^[12] conducted a RCT and found no difference between the accuracy of tooth movement at the 14-day replacement interval and the 7-day interval using LFV. Although this accuracy was not seen in group with 7 days' interval and no application of LFV, they concluded that LFV seems to improve the accuracy of conventional protocol. Another study done by Katchooi *et al.*^[22] placed all the participants on the 7 days' exchange interval and finally found no differences in completion rate of the initial set of aligner and irregularity index of incisors between the LFV group and control group.

In one of the studies, the level of inflammatory and bone remodeling markers in the gingival crevicular fluid were evaluated before the start of the aligner treatment and at the end of the second aligner. Statistically, significant higher levels of markers (interleukin [IL]-10, IL-8, IL-13, IL-1ra, and IL-4, granulocyte colony-stimulating factor, granulocyte-macrophage colony-stimulating factor, SCD40 L and receptor activator of nuclear factor Kappa-B ligand, epidermal growth factor, platelet-derived growth factor AA/BB, and platelet-derived growth factor AA) measured in HFV groups.^[21]

As Alikhani showed,^[35] the effect on tooth movement rate is more pronounced with higher frequency vibration. Judex and Pongkitwitoon^[37] compared the effect of different vibratory devices (HFV and LFV). They showed that both devices increase cell proliferation and gene expression in osteoblasts and fibroblasts, but greater response was seen with HFV compared to LFV. Type I collagen (COLA1), alkaline phosphatase (ALPL), Runt-related transcription factor 2 (RUNX2), fibroblast growth factor 2 (FGF2), and connective tissue growth factor (CTGF) were measured as the indicators of osteoblast activity,

osteoblast differentiation, osteoblast differentiation level, human periodontal ligament fibroblasts activity, respectively. There was an upregulation of COLA1, ALPL, FGF2, and CTGF levels by both devices, but their levels were greater in HFV. RUNX2 upregulated with HFV but not with LFV.

Two studies did not show the positive effect of vibration in composition with clear aligner treatment,^[22,23] used LFV (30 Hz). All studies using HFV (120 Hz) found out significant effect of vibration in the rate of tooth movement and more accurate tracking of planned movement.^[21,24,26] It seems that employing HFV combined with clear aligner treatment is more effective than LFV.

Three included studies, evaluated the patients' pain and discomfort. Two of them used LFV and one used HFV. Alansari *et al.*^[21] used the (Numeric Rating Scale-10) for patient's pain assessment. They concluded that HFA significantly reduces orthodontic force-related pain. On the other hand, two studies used LFV in conjunction with clear aligner showed no pain relief in patients.^[22,23] Previously, two RCTs have shown that LFV was not effective in reducing pain in fixed orthodontic treatment.^[38,39] It seems that HFV can be effective in reducing the pain of patients treated with clear aligner and is a practical option for patients due to its short duration of use (5 min/day).

Farouk *et al.*^[25] measured the maxillary incisor's teeth lengths, before and after clear aligner treatment, on the cone-beam computed tomography, and compared the results, in two groups, control and HFV. They investigated no significant change of tooth lengths in HFV group, while this was not the case in the control group. Previous studies about the role of vibration on root resorption are controversial. A study demonstrated that HFV in the presence of orthodontic force was catabolic and decreased the bone density. Therefore, roots moved through a nondense bone and this may prevent root resorption.^[35] On the other hand, Shipley *et al.* compared the bone density of

Table 4: Summary of the risk of bias for retrospective studies according to Newcastle–Ottawa Quality Assessment Scale criteria

Study	Representativeness of the exposed cohort	Selection of the nonexposed cohort from same source as exposed cohort	Ascertainment of exposure	Outcome of interest was not present at start of study	Comparability of Cohorts	Assessment of outcome	Follow-up long enough for outcome to occur	Adequacy of follow-up	Quality score
Farouk <i>et al.</i> , 2020	Somewhat representative of the average malocclusion in the community*	Yes*	Secure report*	No	Comparison of tooth length measurements to detect root resorption*	Independent blind assessment*	Yes*	Complete follow-up*	Low risk of bias
Shipley <i>et al.</i> , 2018	Somewhat representative of the average malocclusion in the community*	Yes*	Secure record*	No	Intergroup comparison of treatment duration and incidence of refinements*	Record linkage*	Yes*	Subjects lost to follow-up unlikely to introduce bias*	Low risk of bias
Shipley <i>et al.</i> , 2020	Somewhat representative of the average malocclusion in the community*	Yes*	Secure record*	No	Intergroup comparison of aligner exchange interval, intergroup and intragroup comparison of bone density change*	Record linkage*	Yes*	Complete follow-up*	Low risk of bias

*Good Quality: 3 or 4 stars in Selection domain AND 1 or 2 stars in Comparability domain AND 2 or 3 stars in Outcome domain

patients who treated with clear aligner and HFV with control group. They found that bone density in the HFV group was higher than control at the end of treatment and initiation of retention phase.^[24] This higher density is important for stability and avoiding relapse.^[40] Another study found that 113 Hz vibration for four weeks seems to prevent or reduce orthodontic root resorption.^[41] Further studies are needed to determine with certainty the effect of vibration with clear aligner on root resorption and bone density.

CONCLUSION

According to the studies discussed in this review (RCTs with high risk of bias and retrospective studies), applying vibration could produce the same tooth movement in a shorter period of time and more accurate tracking of the planned movements in clear aligner treatment. It also could reduce the interval of clear aligner exchange. However, further properly-designed RCTs are necessary to prove this claim.

The effect of vibration on patients' pain, root resorption, and bone density is ambiguous. Some data have proposed that HFV can reduce discomfort, root resorption, and increase the bone density, but more studies required to prove it.

In addition, it seems that combining clear aligner with HFV is more effective than LFV. HFV has shown pleasant results, whereas this is not the case for LFV.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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