“To Evaluate the Effectiveness of Vibratory Stimulation on Space Closure from a Customized Tooth Vibratory Device, as a Method of Accelerated Orthodontic Tooth Movement: A Split Mouth Study”

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ABSTRACT

Background: Orthodontic treatment involving extraction of premolars often requires substantial time for space closure. Various methods have been investigated to accelerate orthodontic tooth movement, including vibratory stimulation. A customized tooth vibratory device may provide a non-invasive approach to enhancing the rate of orthodontic space closure.

Aim: To evaluate the effect of a customized tooth vibratory device on orthodontic extraction space closure and compare its effectiveness with the conventional method.

Materials and Methods: This study included subjects aged 16–30 years who required bilateral maxillary premolar extractions. A randomized split-mouth study design was employed, with one side assigned to the experimental group receiving vibratory stimulation and the contralateral side serving as the control without vibration. A customized device delivered high-frequency vibrations ranging from 120 to 180 Hz. Space closure was assessed using study models at baseline (T0), 1 month (T1; 28 days), 2 months (T2; 56 days), and 3 months (T3; 84 days). The amount of tooth movement was compared between the two groups at the specified intervals, and the overall rate of movement and anchorage loss were evaluated over the study period.

Results: No statistically significant difference in space closure was observed between the experimental and control groups at baseline and the first follow-up. However, the experimental group demonstrated significantly greater space closure at 2 months ($p = 0.020$). This difference became more pronounced at 3 months, with significantly greater tooth movement in the vibration group ($p = 0.001$) compared with the control group.

Conclusion: Within the limitations of this study, customized high-frequency vibratory stimulation may enhance orthodontic extraction space closure over a 3-month period. The findings suggest that vibration-assisted therapy could serve as a potential adjunct to conventional orthodontic mechanics.

Keywords: Accelerated orthodontics; Customized tooth vibratory device; Orthodontic space closure; High-frequency vibration; Tooth movement

INTRODUCTION

The Orthodontics has experienced a significant rise in demand due to increased aesthetic awareness among both teens and adults. The desire for an ideal smile in today's image-conscious society has expanded the scope of orthodontic care, with more adults seeking treatment and pushing the upper age limit for intervention.

An article released by The New York Times in February 2012 reported a 58% rise in the number of American adults receiving orthodontic treatment from 1994 to 2010, while the number of patients below 18 years of age grew by just 15% over the same time frame[1].

According to the 2014 AAO Economics Orthodontic Survey[1], adult orthodontic patients increased by 16% from 2012 to 2014[1]. A study at Saveetha Dental College[2] also reported that adults now outnumber adolescents and children in seeking orthodontic treatment, with both genders equally likely to pursue it.

Fixed orthodontic treatment typically lasts 20–30 months[3,4], often leading to complications and patient dissatisfaction, prompting many adults to choose faster but less effective alternatives. Hence, modern orthodontics must balance function, aesthetics, and efficiency, making the identification of cellular regulators crucial to accelerating tooth movement and reducing treatment duration.

Kole[5] proposed a technique for rapid tooth repositioning by performing interdental and subapical osteotomy cuts through the cortical and medullary bone. He believed mobilizing bone segments rather than individual teeth would accelerate movement, minimize root resorption, and reduce retention time[5].

Wilcko et al[6] (2001) attributed rapid tooth movement to transient demineralization-remineralization in alveolar bone and introduced PAOO[6] by combining refined corticotomy with alveolar augmentation.

This accelerated tooth movement is attributed to the Regional Acceleratory Phenomenon (RAP), described by **Frost[7]**, which enhances bone and soft tissue healing by 2–10 times through rapid remodeling and increased turnover[6].

To overcome RAP's limitations, various minimally invasive surgical, pharmacological, and physical methods have been developed to enhance bone remodeling and accelerate tooth movement with fewer drawbacks[8].

SURGICAL METHODS

Due to the invasive nature of the corticotomy procedure, more recent minimally invasive techniques have been introduced, including the following examples:

a) Piezocision

To reduce corticotomy invasiveness, Dibart et al[10] introduced piezocision, a minimally invasive technique using buccal microincisions and a piezoelectric knife; however, it still carries root damage risks if not performed carefully[8–10].

b) Micro-osteoperforations

Micro-osteoperforation (MOP) involves creating 2–4 small perforations (3–7 mm deep) in the alveolar bone, typically on the buccal cortical plate near the mesial and distal sides of target tooth roots, to stimulate cytokine release and accelerate bone remodeling during orthodontic treatment[11].

PHARMACOLOGICAL METHODS

Orthodontic forces stimulate fluid flow in the periodontal ligament, leading to cellular changes that promote bone remodeling and tooth movement[12]. Pharmacological biomodulators like Prostaglandin E2 and E1 have been studied to enhance this process.

a) Prostaglandin E2 and Prostaglandin E1

Prostaglandin E2 (PGE2), a metabolite of arachidonic acid, enhances tooth movement and bone resorption as shown in animal studies[13,15], while Prostaglandin E1 (PGE1), under mechanical stress, promotes remodeling and significantly increases movement with small injections, as shown by Patil et al[16].

b) Misoprostol

Due to the hyperalgesia from PGE1 injections, misoprostol a similar compound was tested and found to effectively enhance orthodontic tooth movement[17].

c) Parathyroid hormones

Parathyroid hormone (PTH) promotes bone remodeling by enhancing osteoblast survival via IGF-I and stimulating RANKL-mediated osteoclast activation[8]; these effects are observed with intermittent administration[18].

d) 1,25-Dihydroxycholecalciferol

Calcitriol, also known as 1,25-Dihydroxycholecalciferol, the most active metabolite of vitamin D, operates similarly to PTH by promoting osteoblastic proliferation and function[19]. Calcitriol aids in alveolar bone remodeling, resulting in enhanced tooth movement during the application of force[15,20].

e) Intravenous immunoglobulins

Intravenous immunoglobulin (IVIg) preparations, used in immunodeficient patients, have been shown to stimulate COX-2-mediated PGE2 and cytokine production[21], suggesting potential future applications in enhancing orthodontic tooth movement.

The majority of these agents are still in experimental phases, and only a limited number of human trials have been conducted.

PHYSICAL METHODS

Despite many attempts to develop minimally invasive surgical techniques, they continue to be considered invasive procedures. This has led to the recognition of alternative methods that can accelerate tooth movement during orthodontic treatments. Some of the most commonly utilized physical approaches presently include:

a) Vibratory stimulus

Nishimura et al[22] demonstrated that resonance vibration enhances tooth movement via RANKL expression in the periodontal ligament, while the AcceleDent device[23] applies 0.2 N at 30 Hz for 20 minutes to stimulate bone remodeling and accelerate movement.

b) Low-level laser therapy

Low-level laser therapy (LLLT)[24] enhances orthodontic tooth movement through its biostimulatory effect, which slightly raises tissue temperature and promotes cellular activity without causing thermal damage.

c) Low-level LED phototherapy

The Biolux LED device[25] employs near-infrared light (850 nm) at low power (<50 mW/cm²) with a divergent beam to deliver low-level phototherapy aimed at accelerating orthodontic tooth movement.

d) Low-intensity pulsed ultrasound

Low-intensity pulsed ultrasound (LIPUS)[27] promotes soft and hard tissue healing through mechanical energy-induced biochemical changes, typically delivered at 1.5 MHz, 200 μs pulse width, 1 kHz repetition, and 30 mW/cm² for 20 minutes daily.

While invasive techniques can speed up orthodontic tooth movement, their associated pain and discomfort limit their use. Vibratory methods offer a safer, minimally invasive alternative with potential to shorten treatment time effectively.

Akbari et al[3] reported that vibrational force (VF) enhances osteoblast and osteoclast activity, promoting bone remodeling and accelerating tooth movement via NF-κB signaling. Compared to invasive methods that often cause pain and tissue trauma, vibratory techniques are safer, easily applicable, and effective in reducing orthodontic treatment time.

Vibration, used since the 1800s[28] and shown to benefit bone and muscle health[29], has anabolic effects in orthodontics as noted by **Akbari et al[3],** enhancing bone remodeling and offering a safe, repeatable alternative to reduce treatment duration.

Nishimura et al[22] found that vibration accelerates orthodontic tooth movement in rats by increasing RANKL expression in the periodontal ligament, with further studies[26] showing that cells respond more effectively to cyclic forces, enhancing bone remodeling and reducing overall treatment time.

Research has explored commercial vibration devices and powered toothbrushes for enhancing orthodontic tooth movement; however, their generic trays fail to deliver consistent vibrational force due to poor adaptation to individual occlusal planes[28],[29].

To overcome these limitations, we propose a split-mouth in-vivo study using a customized tooth vibratory device. This device ensures precise force delivery, incorporates a mobile application for regulating vibration duration and frequency, and includes an alarm for compliance. This study aims to evaluate the efficacy of vibratory stimulation over 3 months (84 days) with 1-month intervals and assess any anchor loss on the experimental and control sides.

MATERIALS AND METHOD

Study/ trial design

An in-vivo, single-center, comparative observational study using a split-mouth design with 1:1 allocation was employed to minimize biological variability between the experimental and contra-lateral control sides.

Participants, eligibility criteria, and settings

Ethical approval was obtained from the university's ethical committee, and written informed consent was secured from all participants (or their guardians) in their native language. The study included patients aged 16 to 30 years, referred between October 2023 and April 2024, and participants were screened based on the following inclusion and exclusion criteria.

A) Inclusion Criteria:

Healthy patients having permanent dentition aged 16 years and above at the start of treatment.

Molar relationship either class I or unit class II with minor crowding (up to 3mm)

Cases requiring extraction of maxillary bilateral 1st or 2nd premolar.

Good oral hygiene and periodontal condition.

No radiographic evidence of bone loss.

No history of/current active periodontal disease.

No smoking.

No endodontic lesions.

B) Exclusion Criteria:Extreme skeletal class II relationship.

Significant vertical skeletal discrepancy.

Systemic disease or medication that affects bone biology.

Smoking.

Any radiographic evidence of bone loss.

Habits like thumb sucking, tongue thrusting.Congenital defects like cleft lip and palate.

Syndromic patients

A thorough medical history and clinical examination were conducted for each patient. Studies details, including objectives, procedures, risks, and benefits, were explained, ensuring confidentiality and emphasizing voluntary participation.

Sample size calculation

The sample size was calculated based on a type I error frequency of 5%. Power analysis with G* power software showed that 18mouth-side each would be needed as experimental and control side respectively, giving a total 18 mouth-side (n=18 patients).

Randomization

All participants will be selected for experimental purposes by an individual who is not involved in the clinical study to ensure unbiased selection. Each subject will be assigned a number, which will be placed in opaque, sealed envelopes. These envelopes will remain sealed until the time of space closure. On the day of the vibratory procedure, each participant will randomly select one envelope to determine whether the right or left quadrant will serve as the control or experimental side. The control side will receive only conventional orthodontic treatment, while the experimental side will receive vibration therapy three times a day in addition to orthodontic treatment.

T0 (baseline),

T1 (1 month/28 days),

T2 (2 months/56 days), and T3 (3 months/84 days).

Blinding

Blinding of either the patients or the orthodontist was not possible; therefore, blinding was applied at the measurement level. All study models were assigned codes, and measurements as well as data collection were conducted by a separate investigator who was unaware of which side received vibration.

MATERIALS USED – (Figure-1,2)

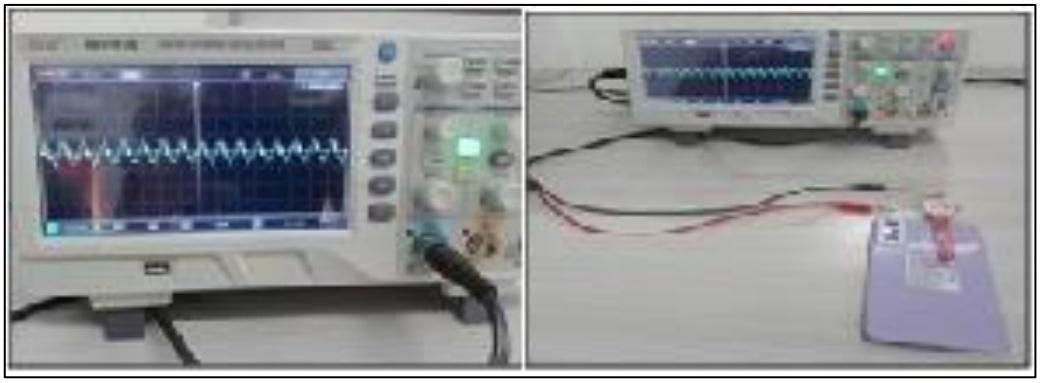
1. 022* 028 MBT appliance (AO)
2. Etchant (Frost)
3. Primer (Ormco)
4. Composite adhesive (Ormco)
5. Applicator tip
6. Ligature wire (Metro)
7. Elastic Modules (Garmy)
8. Chlorhexidine digluconate 0.2%
9. Surgical spirit (Cymer)
10. Plastic vacuum container
11. Customized resin stick (Ortho-Vibe)
12. Vibratory app (ORVIO) + Mobile phone with cover
13. Digital Storage Oscilloscope (SS-5100DS)
14. Dontrix gauge (Morelli)
15. Digital vernier caliper

A customized tooth vibratory device was fabricated using resin material via 3D printing. It is detachable and clipped to the back of a mobile phone cover using a commercially available clip. After each use, patients store the device in an individual plastic vacuum container for hygiene and convenience. Vibration is applied adjacent to the extraction site and is generated and controlled by the Orvio **mobile application, developed by LNCT Electrical Engineering College,** Bhopal. The app transmits vibration to the device, which delivers it to the buccal and palatal sides for 40 seconds each. It also includes an alarm to remind patients of usage. The **vibration frequency (120–180 Hz) is measured using a Digital Storage Oscilloscope (SS-5100DS) from the Department of Electronics and Communication, Sagar Institute of Science & Technology, Bhopal.**



Figure 1- (a) Material used for vibration stimulation, with customized resin stick (Ortho-Vibe) and (b) vibratory app (ORVIO) + mobile phone with cover

Figure 2-Digital Storage Oscilloscope (SS-5100DS)



METHODOLOGY

A) Orthodontic space closure protocol

Atraumatic extractions of the first or second premolars were performed either four months prior to space closure or at the start of treatment to avoid confounding effects from the Regional Acceleratory Phenomenon (RAP), which can be triggered by surgical trauma. All extractions were carried out by the same surgeon to eliminate intra-operator variability. Participants were bonded with a pre-adjusted Edgewise 0.022″ × 0.028″ MBT appliance system in both arches. Initial leveling and alignment were done using nickel-titanium (NiTi) archwires, progressing to 0.019″ × 0.025″ stainless steel (SS) wires. After canine-to-canine consolidation, the final working wire (0.019″ × 0.025″ SS) was placed passively in the bracket slot for four weeks to minimize bias from wire binding. Second molars were included to reinforce anchorage. Space closure was initiated using the active tieback method, applying 150g of force (measured with a Dontrix gauge) from the first molar to the canine hooks. (Figure-3)

B) Vibration application

Vibration therapy will be administered three times daily using a customized vibratory device placed adjacent to the extraction site (maxillary first or second premolar) on the experimental side. The procedure will begin on the same day as space closure, following a standardized protocol to ensure consistency. Prior to each session, patients will rinse with 0.2% w/v chlorhexidine digluconate mouthwash for 60 seconds to maintain oral hygiene and reduce infection risk. The device will then be applied for 40 seconds each on the buccal and palatal sides of the extraction area. Sessions will be spaced at regular intervals to maximize therapeutic effect. The vibrations aim to stimulate surrounding tissues, promote bone remodeling, and accelerate tooth movement. After each use, the device must be cleaned with surgical spirit and stored in a plastic vacuum container. Patients will be monitored every 28 days through clinical evaluations to assess progress, check for discomfort, inflammation, or any changes in tooth movement. (Figure-3)



Figure 3- (a) right side, (b) left side, (c) right side with vibration application and (d) palatal side with vibration application-Orthodontic space closure protocol and Vibration application

Method of data collection

Data collection occurred over a span of 3 months (84 days) starting from the initiation of the space closure phase. At the beginning of the study, before space closure began (T0), an upper alginate impression was taken. Subsequently, impressions were taken at three 28-day intervals (T1, T2 and T3). The study models were fabricated using utilizing high-grade Orthokal dental material, labeled with the patient's name and the respective date, and stored. After the study, all models were retrieved and blindly examined by an individual who was not involved in the study to eliminate any potential bias. (Figure 4,5)



Figure 4- Data collection at T0, before initiation of space closure and data collection at T1, after 1 month/ 28 days of space closure



Figure 5- Data collection at T2, after 2 months/ 56 days of space closure and data collection at T3, after 3 months/ 84 days of space closure

Determination of rate of space closure

The space closure was measured directly on the study models using a vernier caliper. The distance between the most prominent portion of the distal surface of canine and the mesial surface of second premolar bilaterally at T0, T1, T2, and T3 was measured to determine the rate of space closure on the experiment and the control side respectively. "**The space closure measurement is calculated using the formula: (T0 - T3) / time.**" (Figure-6)

Determining Anchor loss

Anchor loss was assessed to ensure unaffected canine movement. Using Ziegler and Ingervall's method, study models were photographed and calibrated with a metallic scale. A central reference line along the midpalatal raphe and a perpendicular line to the mesial contact point of the first molar were drawn. The distance from the posterior rugae to the mesial molar contact point was measured on both sides pre- and post-treatment to detect any anchor loss. (Figure-6)



Figure 6- Measurement of space closure and measurement of anchor loss

STATISTICAL ANALYSIS

The data were analyzed using SPSS Version 25 (Chicago Inc., IL, USA). The Shapiro-Wilk test confirmed normal distribution. Mean and standard deviation were used for comparisons. An independent *t*-test was applied to assess differences in the rate of tooth movement and space closure between the experimental and control groups. A p-value < 0.05 was considered statistically significant.

Participant flow

Eighteen participants aged 16 to 30 years were enrolled between October 2023 to April 2024, with data collection completed by October 2024. No bracket failures or adverse events were reported during the study.

RESULT

A total of 18 subjects per group was analyzed. The results of the study showed that there was no significant difference in space closure between the experimental and control groups at T0 and T1. At **T0 (Baseline)**, the mean space was 6.0944 ± 0.7825 mm (experimental) and 6.1000 ± 0.7577 mm (control), with a non-significant mean difference of -0.00556 mm (p = 0.983). After the **1st month (T1)**, space reduced to 5.6778 ± 0.7750 mm (experimental) and 5.9944 ± 0.7612 mm (control), with a mean difference of -0.3167 mm (p = 0.225), still not significant. However, by the **2nd month (T2)**, the experimental group showed significantly faster closure: 5.2167 ± 0.8638 mm vs. 5.8778 ± 0.7589 mm, with a mean difference of - 0.6611 mm (p = 0.020). This difference became highly significant at **T3 (3rd month)**, with 4.7222 ± 0.9039 mm (experimental) and 5.7611 ± 0.7717 mm (control), yielding a mean difference of -1.0389 mm (p = 0.001). These results indicate that customized vibratory stimulation significantly enhances space closure from the second month onward. [Table-1-2, Graph-1]

Additionally, **Comparison of Overall Tooth Movement** The experimental group showed a mean overall tooth movement of 1.3722 ± 0.2718 mm, significantly greater than the control group's 0.3389 ± 0.0778 mm. The mean difference of 1.0333 mm was highly significant (p = 0.000, t = 15.506, df = 34), indicating enhanced tooth movement with vibratory stimulation. [Table-3, Graph-2], also comparing **Overall Rate of Tooth Movement** The experimental group showed significantly greater tooth movement than the control group. Baseline measurements (T0) were comparable (p = 0.983), but by T2 and T3, space closure was significantly faster in the experimental group (p = 0.020 and p = 0.001). Total movement was higher (1.3722 ± 0.2718 mm vs. 0.3389 ± 0.0778 mm; p = 0.000), as was the monthly rate (0.4578 ± 0.0903 mm/month vs. 0.1128 ± 0.0259 mm/month; p = 0.000), confirming the efficacy of vibratory stimulation in accelerating tooth movement. [Table-4]. And also **Comparison of Total Anchor Loss between**

Groups shows that the total anchorage loss was significantly higher in the control group (1.55 mm) compared to the experimental group (1.03 mm), with a highly significant difference (p = 0.000). This indicates that vibratory stimulation not only accelerated space closure but also helped minimize unintended anchorage loss, with the p-value confirming the reliability of this finding. [Table-5, Graph-3]

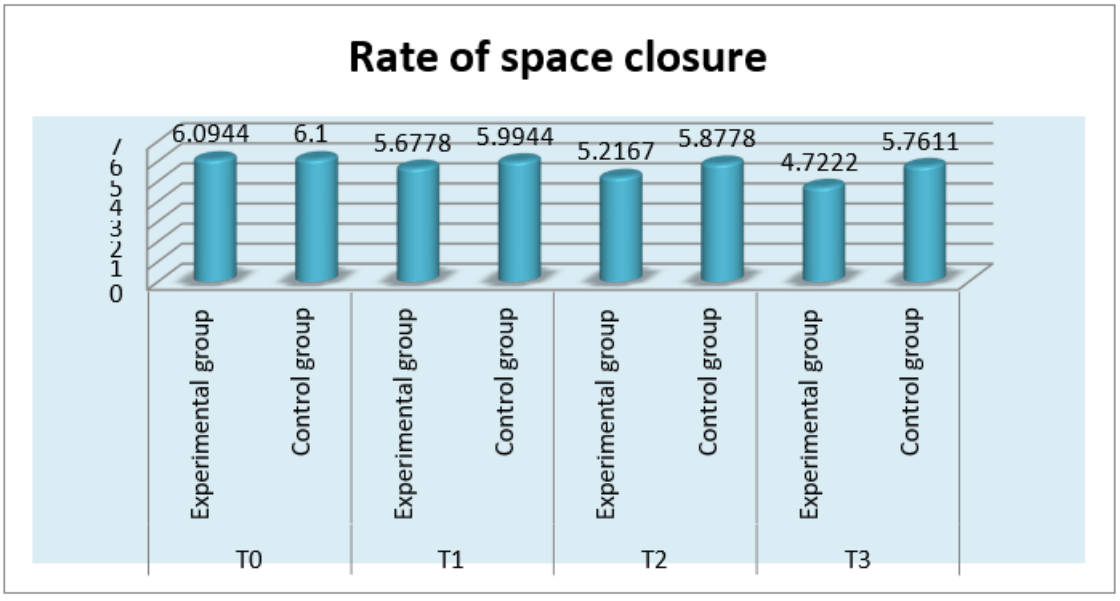
N	T0 (Exp)	T3 (Exp)	Total Movement (Exp) (mm)	Rate of Movement (Exp) (mm/month) **RTM = (T0 - T3)/3**	T0 (Con)	T3 (Con)	Total Movement (Con) (mm)	Rate of Movement (Con) (mm/month) **RTM = (T0 - T3)/3**
	6.0	5.0	1.0	0.33	6.0	5.7	0.3	0.10
	6.8	6.0	0.8	0.27	6.8	6.5	0.3	0.10
	6.8	5.3	1.5	0.50	6.8	6.4	0.4	0.13
	7.0	5.6	1.4	0.47	7.0	6.7	0.3	0.10
	6.0	4.6	1.4	0.47	6.0	5.7	0.3	0.10
	7.0	5.4	1.6	0.53	7.0	6.7	0.3	0.10
	5.9	4.5	1.4	0.47	5.8	5.4	0.4	0.13
	6.0	4.3	1.7	0.57	6.0	5.7	0.3	0.10
	7.0	5.7	1.3	0.43	7.0	6.6	0.4	0.13
0	5.5	4.1	1.4	0.47	5.5	5.0	0.5	0.17
1	7.0	5.5	1.5	0.50	7.0	6.7	0.3	0.10
2	6.0	4.6	1.4	0.47	6.0	5.7	0.3	0.10
3	6.8	6.0	0.8	0.27	6.8	6.5	0.3	0.10
4	5.9	4.6	1.3	0.43	5.8	5.5	0.3	0.10
5	5.5	3.9	1.6	0.53	5.5	5.0	0.5	0.17

6	5.0	3.2	1.8	0.60	5.0	4.7	0.3	0.10
7	4.8	3.3	1.5	0.50	4.8	4.4	0.4	0.13
8	4.7	3.4	1.3	0.43	5.0	4.8	0.2	0.07

Table 1: Overall rate of tooth movement for both the experimental and control groups:

Time Interval	Groups	N	Mean	Std. Deviation	Mean Difference	't' statistic	df	P value
T0	Experimental group	18	6.0944	.78251	-.00556	-.022	4	.983 (NS)
	Control group	18	6.1000	.75771				
T1	Experimental group	18	5.6778	.77502	-.31667	-1.237	4	.225 (NS)
	Control group	18	5.9944	.76117				
T2	Experimental group	18	5.2167	.86382	-.66111	-2.439	4	.020*
	Control group	18	5.8778	.75891				
T3	Experimental group	18	4.7222	.90395	-1.03889	-3.709	4	.001*

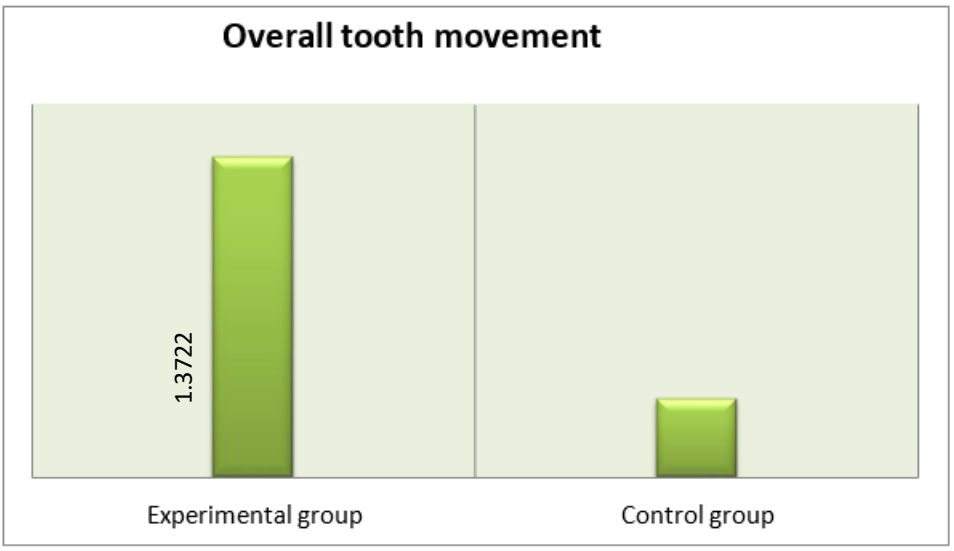
Table 2: Comparative evaluation of rate of space closure (mm) over the time intervals



Graph 1: Comparative evaluation of rate of space closure (mm) over the time intervals

Groups	N	Mean	Std. Deviation	Mean Difference	't' statistic	df	P value
Experimental group	18	1.3722	.27183	1.033336	15.506	34	.000*
Control group	18	.3389	.07775				

Table 3: Comparison of Overall Tooth Movement



Graph 2: Comparison of Overall Tooth Movement

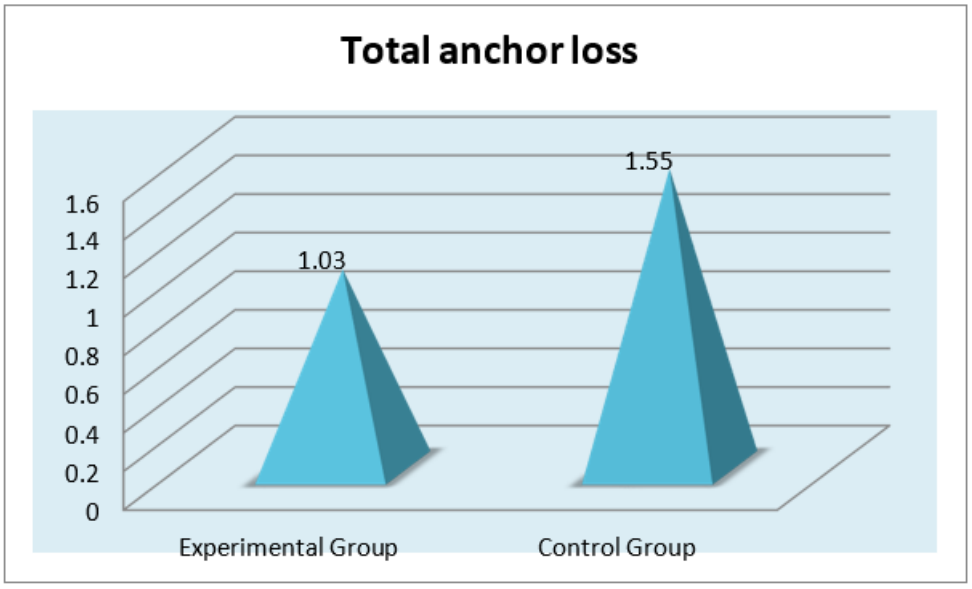
Groups	N	Mean	Std. Deviation	Mean Difference	't' statistic	df	P value
Experimental group	18	.4578	.09026	.34500	15.589	340*	.000
Control group	18	.1128	.02585				

Table 4: Comparison of Overall Rate of Tooth Movement

Groups	N	Mean Total Anchor Loss (mm)	Std. Deviation	Mean Difference	't' Statistic	df	P-value
Experimental Group	18	1.03	0.21	0.52	6.324	34	0.000*

Control Group	18	1.55	0.24	-	-	-	-

Table 5: Comparison of Total Anchor Loss between Groups



Graph 3: Comparison of Total Anchor Loss between Groups

DISCUSSION

The present split-mouth in-vivo study evaluated the effects of customized vibratory stimulation on the rate of orthodontic tooth movement and anchorage loss over a 3-month (84-day) period, compared to conventional treatment. To minimize age-related variability in bone remodeling—especially the RANKL: OPG ratio described by ***Nimeri G, Kau CH, Abou-Kheir NS, and Corona R***[31]—only participants above 16 years were included. Strict oral hygiene instructions were provided and monitored to eliminate confounding factors. Following ***Usumi-Fujita R, Hosomichi J, Ono N, et al***[32], who emphasized occlusal force influence, patients with similar malocclusion requiring bilateral upper first premolar extractions and <3 mm crowding were selected to ensure uniform treatment. To avoid transient effects of the Regional Acceleratory Phenomenon (RAP) post-extraction, teeth were extracted at least 3 months before space closure to allow bone remodeling to stabilize[47]. During this interval, standard leveling and alignment were done with a progressive archwire sequence ending in a 0.019×0.025-inch stainless steel wire. As the type of tooth movement influences retraction rate[48], bodily movement was ensured using a 0.022×0.028 MBT appliance system, with passive engagement of the working wire for 4 weeks before retraction to reduce friction. Vibration was randomly assigned to the left or right maxillary side to minimize masticatory force bias, as suggested by ***Yang C, Wang C, Deng F, and Fan Y***[36], who reported stress concentration near the distolabial cervical region of the canine during retraction.

Vibratory stimulus was applied distal to the canine and adjacent to the extraction site, as supported by ***Dobie, Thomas G***[4], who found vibration to enhance movement during alignment and retraction due to bone metabolism effects. ***Sasaki K, Takeshita N, Fukunaga T, Seiryu M, and Sakamoto M***[37] demonstrated that 70 Hz vibration increases TGF-β1 expression and osteoclastogenesis, accelerating movement. In this study, tooth movement was measured using interproximal distance between the canine and premolar as per ***Mayama A, Seiryu M, and Takano-Yamamoto T***[39], while anchorage loss followed the Ziegler and Ingervall[40] method. Studies by ***Garg AK, Tikku T, Srivastava K, Khanna R, Maurya RP, and Verma SL***[41] showed vibration increases canine movement and reduces treatment time. Similarly, ***Pavlin D, Anthony R, Raj V, and Gakunga PT***[42], using AcceleDent (25 g, 30 Hz, 20 min/day), reported faster retraction (1.16 mm/month vs. 0.79 mm/month). ***Gujar AN and Govinakovi Shivamurthy P***[30] found elevated PGE2 and faster movement after 90 days of vibration. Davidovitch et al[55] noted that vibration enhances phosphorylation in periodontal tissues, promoting alveolar bone turnover. ***Liao Z, Elekdag-Turk S, Turk T, Grove J, Dalci O, Chen J, Zheng K, et al***[46] found that 50 Hz, 20 g vibration significantly accelerated canine retraction and increased PDL

hydrostatic stress. ***Keerthana P, Diddige R, and Chitra P***[47] reported a 0.34 mm increase in movement in a meta-analysis, attributing it to enhanced PDL and bone remodeling. Conversely, ***Khera AK, Raghav P, Mehra V, Wadhawan A, Gupta N, and Phull TS***[28] observed no significant increase with custom 30 Hz devices, though ***Garg AK et al***[41] still noted improved movement on the vibrated side. ***Pascoal S, Oliveira S, Ascione M, Pereira J, Carvalho Ó, and Pinho T***[48] found high-frequency (60–120 Hz) vibration more effective than low-frequency, especially in fixed appliances. Mechanistically, high-frequency vibration stimulates bone biomarkers near moving teeth while preserving inflammation-free anchor regions, promoting efficient movement with minimal anchorage loss. Our study confirmed significantly lower anchorage loss on the vibrated side. ***Pavlin D et al***[42] also reported more anchor loss on the control side, though not statistically significant due to the use of TADs, which we avoided. Instead, anchorage was reinforced via second molars, and en masse retraction ensured consistent biomechanics.

Abd El Motaleb MA, El-Beialy AR, El-Sharaby FA, et al[49], using a non-split-mouth design, found no significant differences in individual tooth movement—possibly due to biological variability. In contrast, our split-mouth design provided intra-patient control, clearly demonstrating greater anchorage loss on the control side and the effectiveness of vibratory stimulation.

CONCLUSION

Within the limitations of this study, high-frequency vibratory stimulation (120–180 Hz) using a customized device effectively accelerated orthodontic tooth movement over a 3-month (84-day) period. When applied three times daily for 40 seconds on both buccal and palatal sides near the extraction site, it significantly increased the rate of space closure compared to conventional methods. Additionally, it reduced anchorage strain, enhancing overall treatment efficiency.

LIMITATION

The primary limitations of this study include the absence of inflammatory biomarker assessment and the short follow-up period, which did not extend to complete canine space closure.

The impact of varying numbers and locations on the speed and nature of tooth movement were not assessed

Space closure was measured directly on models, which is less precise than digital methods.

Additionally, potential side effects such as root and crestal bone resorption were not evaluated.

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