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Intermittent vibratory stimulation to accelerate tooth movement: A clinical study

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ABSTRACT

Introduction: Vibratory stimulus is non-invasive and non-pharmacologic method for acceleration of Orthodontic tooth movement in adult patients. As powered toothbrush can provide cheaper alternative to Acceledent (a patent and expensive device) it was decided to evaluate the effectiveness of vibratory stimulation from powered toothbrush as a method of accelerating individual canine retraction.

Materials and Methods: Sample consisted of 24 patients undergoing fixed Orthodontic treatment, in whom separate canine retraction was planned after extraction of all first premolars using NiTi closed coil spring. Force was standardized as 150 grams and checked at each appointment using Dontrix gauge. Following split mouth study design, right side was the experimental side where patients were asked to apply the vibratory stimulus through powered tooth brush (133Hz frequency) for 6 minutes (3 minutes labially and 3 minutes palatally) three times daily at regular intervals for a period of 3 months. Study models were taken at T0 (start of canine retraction), T1 (after 1st month), T2 (after 2nd month) and T3 (after 3rd month). Mean amount of canine movement and molar movement with respect to 3rd palatine rugae was measured on Digimizer software on both the sides for different time intervals.

Results: Statistically significant increase in canine movement was seen for total canine movement (T0-T3), movement from T0-T1 and from T2-T3. There was statistically insignificant difference in mesial movement of molars for different time intervals.

Conclusion: There was an increased rate of canine movement on the side of vibratory stimulation (right side) in comparison to the control side (left side) for all time intervals and can be used to decrease treatment time in adults.

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1. Introduction

The long duration of treatment with fixed mechanotherapy, especially in adult patients act as a major constraint for them in pursuing their treatment.

Acceleration of Orthodontic tooth movement in such cases would be beneficial in terms of reducing treatment time and decreasing potential side effects of Orthodontic treatment like white spot lesions, root resorption, periodontal diseases, etc. Many techniques have been introduced to accelerate the tooth movement like use of drugs, surgical methods and physical / mechanical stimulating methods, low level laser therapy (LLLT) by soft tissue LASERS.[1] Drugs given to hasten tooth movement, also had associated side effects. Surgical methods like corticotomy, osteotomy were extremely invasive and not well accepted by patients at all times. Other surgical methods like piezosurgery, fiberotomy, microosteoperforations, Wilkodontics[1] were comparatively less invasive but still considered as minor surgical

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procedures. LASERS were costly and required multiple visits of the patient to dental clinic. Vibratory stimulation provides non-invasive and non-pharmacological alternative.

Various methods have been used to induce vibratory stimulus like pulse vibration device (Acceledent),[2–6] ultrasonic or powered toothbrushes. Amongst these, Acceledent,[6–9] a hands free patent device with a occlusal template with a vibrator that works at frequency range of 30Hz to 120Hz,[7] is expensive. Ultrasonic brushes emit waves of higher frequency (20,000Hz), which is not desirable. Powered tooth brushes are comparatively cheaper, easily available in two frequencies (high and low) and had been used in previous studies to reduce pain due to Orthodontic treatment,[8–11] and to accelerate tooth movement both in animal and human studies.[12,13] As high frequency powered toothbrushes provides cheaper alternative to Acceledent device, hence were selected for the study.

Individual canine retraction is done in cases with high anchorage demand using frictionless (loops) or sliding mechanics (active tie backs or NiTi coil springs). Amongst the various methods used for canine retraction in sliding mechanics, NiTi coil springs were chosen based on their clinical effectiveness, constancy of force delivery[14] and less patient discomfort. Leethanakul[13] used powered toothbrushes to hasten individual canine retraction using E-chain, however, force calibration was difficult with E-chain, hence NiTi coil springs whose force can be calibrated using Dontrix gauge was used in the present study.

Split mouth study design was selected where one quadrant of the mouth served as experimental side and other side served as control. The attractiveness of the split mouth design is that it eliminated the inter-participant variation associated with differences in initial extraction space sizes, malocclusion types and variations in inter-appointment interval, as each participant acted as his/her own control.

Thus the aim of this study was to evaluate the effectiveness of vibratory stimulation from powered toothbrushes as a method of accelerating individual canine retraction using NiTi coil spring in subjects who have undergone extractions of all first premolars. Additionally, mesial movement of molars that were attached by TPA, was also recorded to see if there was any undue effect on molars because of vibratory stimulation by powered toothbrushes.

2. Materials and Methods

2.1. Sample

The study was conducted on 24 patients in the age range of 15-25 years comprising of both males and females and undergoing fixed Orthodontic treatment in our department and in whom separate canine retraction was planned after 1^{st} premolar extractions. The approval from the Institutional Ethical and Research Committee was taken. Written informed consent was obtained from all the selected subjects participating in this study before the start of study.

The selected subjects had no history of previous Orthodontic treatment; no clinical or radiographic evidence of loss of periodontal attachment, morphological anomalies or pathologies associated with maxillary canine; had minimal crowding of less than 2 mm with no systemic illness, or on any kind of drug therapy that can alter tooth movement.

2.2. Method

2.2.1. Use of powered tooth brush

Individual canine retraction was started on 0.019X0.025 SS archwire using NiTi closed coil spring of 12 mm of length with force standardized as 150 grams using Dontrix gauge (Figure 1). The force was maintained and periodically checked at each appointment.

Following Split mouth study design, the patients were instructed to apply the vibratory stimulus through powered tooth brush (133 Hz frequency), only on the experimental side (right side) for 6 minutes (3 minutes labially and 3 minutes palatally) three times daily at regular intervals for a period of 3 months (Figure 2). All the patients were asked to continue their regular tooth brushing for 2 to 3 minutes 3 times a day with the conventional toothbrush and instructed not to clean their teeth with vibratory toothbrush. To monitor patients compliance, a chart was given to each patient where they could tick mark the number of times, they used powered toothbrush. Non-compliant subjects were excluded from the study.

Fig. 1: Canine retraction using NiTi closed coil spring on right and left side

2.3. Study models

Besides pretreatment model taken for each patient, study models were repeated at four time intervals i.e. T0 – At beginning of canine retraction, T1 - After 1^{st} month, T2 - After 2^{nd} month and T3 - After 3^{rd} month.

2.4. Analysis of study models

A line was drawn along mid palatine raphe to serve as mid sagittal plane. Blue coloured pencil was taken to trace elevations of 1^{st}, 2^{nd} and 3^{rd} palatal rugae on study model.

Fig. 2: Canine retraction using NiTi closed coil spring on right and left side

A digital photograph of maxillary models with traced 3^{rd} palatal rugae and mid sagittal plane were taken with central projection perpendicular to the occlusal plane, along with millimeter scale mounted in this plane. Millimeter scale was used to calibrate and standardize the model being photographed. The digital photographs then transferred to the computer and analysed by Digimizer software (Figure 3).

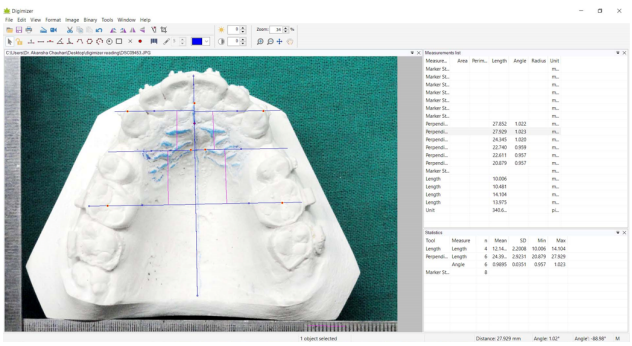

Fig. 3: Analysis of photograph of study made with mid sagittal plane and traced 3^{rd} palatal rugae using Digimizer software

Location of landmarks are shown in Figure 4.

Parameters used to determine amount of maxillary canine retraction (right & left side) and the amount of anchorage loss at different time intervals are shown in Figure 5.

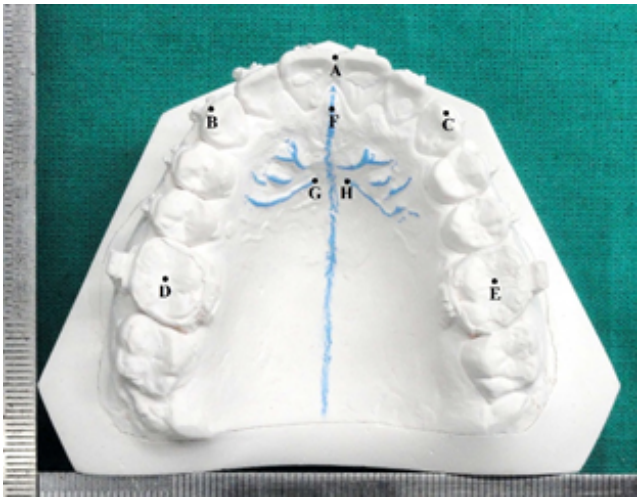

Fig. 4: Points and landmarks on maxillary cast
Point A- Mesio-incisal angle of maxillary central incisors (contact point) Point B&C-Cusp tip of maxillary canine (right and left)
Point D&E- Central fossa of first permanent molar (right and left)
Point F- Mid-point of incisive papilla
Point G&H- Mesial end of 3^{rd} palatal rugae

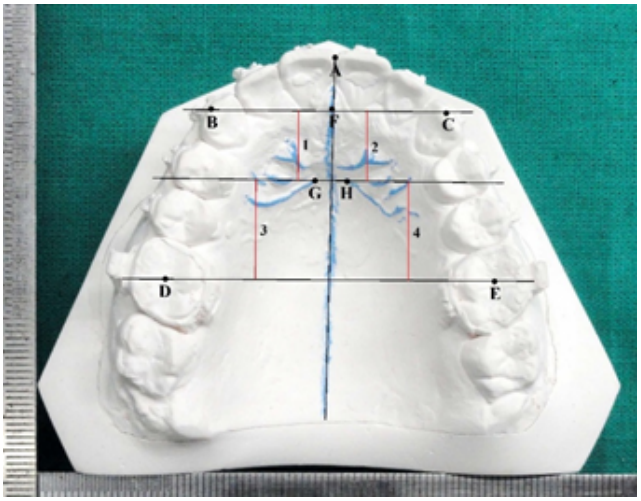

Fig. 5: Parameters used on maxillary cast for the study 1- CT_R-$3R_R$ (Right)
2- CT_L-$3R_L$ (Left)
3- MCF_R-$3R_R$ (Right)
4- MCF_L-$3R_L$ (Left)

2.5. *Statistical analysis*

Data were summarised as Mean ± SD (standard deviation). The data were subjected to statistical analysis and analysis were performed on SPSS (Statistical Package for Social Sciences) 20.0 version. The paired t test and one way ANOVA test was applied to find the significant difference in rate of tooth movement between control & experimental group at different time points at 0.05 level of significance.

2.6. Reliability analysis

The reading of 5 randomly selected samples for the amount of canine retraction at T0, T1, T2 and T3 was repeated at an interval of 15 days by the single investigator. All the measurements were recorded on Microsoft excel (2013) spreadsheet. It was observed that there was no statistical significant difference amongst the two readings using paired t- test.

3. Observation and Results

Table 1 shows the distance of canine from 3^{rd} palatal rugae during canine retraction and distance of 1^{st} molar from 3^{rd} palatal rugae to access anchorage loss (Mean ± SD) on Right and Left side at T0, T1, T2 and T3.

For the ease of understanding, difference in amount of canine retraction between different time intervals was allocated in groups as shown in Figure 6.

Similar allocation was used for mesial movement of molars as RM1 (T0-T1), RM2 (T1-T2), RM3 (T2-T3) and RMT (T0-T3).

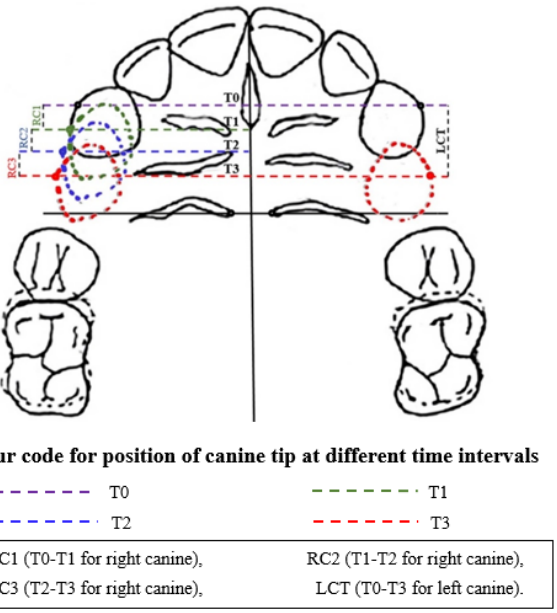

Fig. 6: Allocation of groups for mean movement of canine at different time intervals

Table 3 summarises the one-way ANOVA to compare the significant difference at different time intervals for right and left canine as well as molar.

4. Discussion

Orthodontic tooth movement is mediated by application of mechanical forces on the teeth through the brackets that move the teeth within the bone by initiating remodeling process in the periodontal ligament (PDL).[1] Acceleration of remodeling process by different means holds a definite potential in reduction of treatment time in Orthodontics.

The results of the present study showed that there was significantly increased rate of canine movement on experimental side (right side) in comparison to control side (left side) for all the time intervals except from T1-T2 which showed non-significant difference between the sides (Experimental > Control) (Figure 7). There was no considerable mesial movement of molars noted from 3^{rd} palatal rugae from T0 to T3 as depicted by statistically insignificant difference between right and left side for different time intervals and also the total time period.

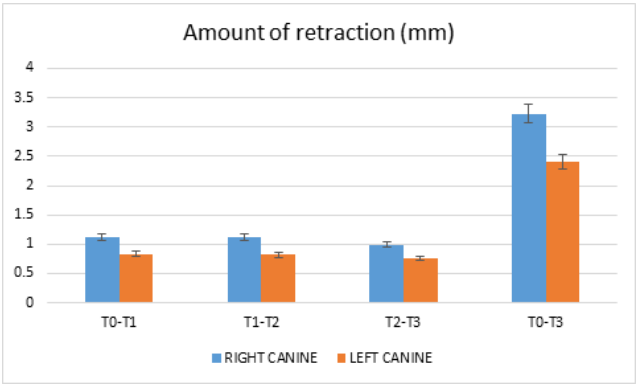

Fig. 7: Bar diagram showing comparison of amount of canine retraction between the groups $p > 0.05$ NS (Not significant); *$p < 0.05$ (Just significant); **$p < 0.01$ (Moderate significant); ***$p < 0.001$ (Highly significant)

In conventional Orthodontics, tooth movement occurs at the rate of 1 mm per month. Therefore, in cases where premolar extractions are necessary as a part Orthodontic treatment plan, canine distalization occurs in a period of 6-8 months followed by incisor retraction. If tooth movement can be accelerated to more than 1 mm/month, treatment duration will decrease. Many studies[12,13,15–34] have shown Acceleration of tooth movement using different methods. Acceleration of tooth movement by vibratory stimuli included studies done using Acceledent devices or powered toothbrushes. Amongst the studies using Acceledent, (frequency 30 Hz), randomized clinical trial by Pavlin[15] demonstrated accelerated tooth movement in terms of canine distalization (1.16 mm/month for AcceleDent® in comparison to 0.79 mm/month in the control group). He calculated total movement and divided by number of months but did not calculate tooth movement for individual months as done in our study (RC1> RC2> RC3). The contradictory results were given in studies by DiBiase[16] for en masse space closure in mandibular arch and Miles[18] et al for en masse space closure in maxillary arch. DiBiase[16] et al divided the subjects in 3 groups i.e. Acceledent group, Acceledent sham device group and no

Table 1: Mean distance of canine and 1^{st} molar from 3^{rd} palatal rugae at T0, T1, T2, T3

Time interval	Mean distance of canine from 3^{rd} palatal rugae (n=24)		Mean distance of 1^{st} molar from 3^{rd} palatal rugae (n= 24)	
	Right side (in mm)	Left side (in mm)	Right side (in mm)	Left side (in mm)
T0	9.965 ± 2.192	9.774 ± 2.137	14.601 ± 2.062	14.428 ± 2.000
T1	8.840 ± 2.154	8.943 ± 2.195	13.999 ± 2.048	13.880 ± 2.081
T2	7.726 ± 2.168	8.123 ± 2.260	13.611 ± 1.975	13.481 ± 2.128
T3	6.736 ± 2.124	7.368 ± 2.364	13.123 ± 1.996	13.106 ± 2.167

Table 2: Mean movement of canine and molar between different time intervals

Time interval	Canine movement		Molar movement	
	Right side (in mm)	Left side (in mm)	Right side (in mm)	Left side (in mm)
T0-T1	RC1= 1.124 ± 0.806	LC1= 0.831 ± 0.589	RM1= 0.602 ± 0.538	LM1= 0.547 ± 0.510
T1-T2	RC2= 1.114 ± 0.725	LC2= 0.819 ± 0.798	RM2= 0.388 ± 0.441	LM2= 0.399 ± 0.377
T2-T3	RC3= 0.990 ± 0.523	LC3= 0.755 ± 0.537	RM3= 0.488 ± 0.352	LM3= 0.374 ± 0.333
T0-T3	RCT= 3.229 ± 1.375	LCT= 2.406 ± 1.303	RMT= 1.478 ± 0.785	LMT= 1.322 ± 0.750

Table 3: Analysis of variance (ANOVA) for comparison between and within groups

		Sum of Squares	df	Mean Square	F	Sig.
Right canine	Between Groups	.270	2	.135	.280	NS
	Within Groups	33.366	69	.484		
	Total	33.637	71			
Left canine	Between Groups	.080	2	.040	.094	NS
	Within Groups	29.319	69	.425		
	Total	29.399	71			
Right molar	Between Groups	.551	2	.276	1.356	NS
	Within Groups	14.022	69	.203		
	Total	14.573	71			
Left molar	Between Groups	.422	2	.211	1.230	NS
	Within Groups	11.828	69	.171		
	Total	12.249	71			

$p > 0.05$ NS (Not significant); *$p < 0.05$ (Just significant); **$p < 0.01$ (Moderate significant); ***$p < 0.001$ (Highly significant)

device group and found no significant differences among the groups for overall space closure rate in mandible. The mean rate of space closure was only 0.89 mm per month in Acceledent group and according to the authors, space closure mechanics was not consistent, forces were not quantified and Acceledent device operated at lower frequency of 30 Hz.

Similarly, Miles P[18] in his randomized clinical trial found statistically insignificant difference in the rate of space closure in maxillary arch. (Control side < AcceleDent side only by 0.13 mm per month).

There are only few studies evaluating acceleration of tooth movement using powered toothbrush. The similar results as seen in the present study had been seen only in a previous study by Leethanakul[13] and contradictory results were seen in a study by Jain et al,[12] Kannan et al,[35] Azeem et al.[36] Other randomized controlled trials by Woodhouse,[17] Miles and Fisher,[20] Katchooi,[21] Aljabaa[21] evaluated the rate of tooth movement by Little's irregularity index (for relieve of crowding) and did not find statistical significant difference between the control and Acceledent group.

Leethanakul[13] (2016) investigated the effects of application of vibratory stimulus in patients who had undergone first premolar extraction for fixed mechanotherapy on GCF volume (no significant difference was seen), interleukin (IL)–1b secretion (Control side: Pressure > Tension at T1 only; Experimental side: Pressure > Tension at T1 > T2 >T3) and amount of canine movement in patients (Experimental > Control at all time intervals). Similarly increase in rate of canine movement was seen in our study.

In a study by Jain et al,[12] mechanical vibration using powered toothbrushes (60 Hz frequency) did not accelerate the rate of canine distalization significantly. They applied vibration for three months but made measurements for four months. The contradictory results could be due to use of brush of lower frequency (60 Hz), compared to high frequency (133 Hz) powered toothbrush of our study, use of active tie backs instead of NiTi coil springs used in our study and measurements were made using palatal plug and reference wire wherein chances of fitting of same palatal plug in all sets of study models might have resulted in lesser

Table 4: Comparison in the rate of canine and 1^{st} molar movement at different time intervals

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
RC1 - LC1	.2938333	.6365335	.1299318	.0250488	.5626178	2.261	23	.033*
RC2 - LC2	.2947083	.7145339	.1458536	-.0070129	.5964295	2.021	23	NS
RC3 - LC3	.2344167	.4993819	.1019359	.0235462	.4452871	2.300	23	.031*
RCT - LCT	.8229583	1.0016064	.2044521	.4000170	1.2458996	4.025	23	.001***
RM1 - LM1	.0544583	.3055699	.0623742	-.0745725	.1834892	.873	23	NS
RM2 - LM2	-.0111667	.4379197	.0893900	-.1960839	.1737506	-.125	23	NS
RM3 - LM3	.1133750	.3448263	.0703874	-.0322324	.2589824	1.611	23	NS
RMT - LMT	.1566667	.4635322	.0946181	-.0390658	.3523992	1.656	23	NS
LC1 - LC2	.0112500	.9987646	.2038720	-.4104913	.4329913	.055	23	NS
LC1 - LC3	.0754583	.5340668	.1090159	-.1500583	.3009749	.692	23	NS
LC2 - LC3	.0642083	.9183668	.1874608	-.3235840	.4520006	.343	23	NS
RC1 - RC2	.0103750	.9953779	.2031807	-.4099362	.4306862	.051	23	NS
RC1 - RC3	.1348750	.8673765	.1770525	-.2313860	.5011360	.762	23	NS
RC2 - RC3	.1245000	.8472710	.1729485	-.2332712	.4822712	.720	23	NS

p > 0.05 NS (Not significant); *p < 0.05 (Just significant); **p < 0.01 (Moderate significant); ***p < 0.001 (Highly significant)

accurate measurements. Also reference wires were made distal to lateral incisor, that may move itself, if lateral incisor experienced some distal tipping because of active tie backs.

Contrary to our study, Kannan S,[35] Azeem et al[36] found statistically non-significant difference between experimental group and control group. The difference again was attributed to low frequency powered toothbrush and measurement using palatal plug and not the 3^{rd} palatal rugae as used in the present study.

Amongst the other non-surgical methods, many studies were conducted using low level laser therapy (soft tissue lasers). Limpanichkul W et al[31] did not find significant increase in the rate of tooth movement. The significant increase in mean rate of canine distalization was found to be ranging from 1.04 mm to 1.16 mm in different time intervals in a study by Silva Sousa et al[33] and was 2.30±0.45 mm and 3.9 ± 1.41 mm respectively in studies by Doshi Mehta et al[30] and Üretürk et al[34] at the end of 3 months. These results are comparable to our study. LLLT is costly and requires multiple visits of patient to dental clinic as per the schedule which is tedious and uncomfortable for the patient. Hence powered toothbrushes are cheaper alternative to LLLT and can be used by patient at home as per his/her comfort.

Amongst the surgical methods of accelerating tooth movement, increased rate of tooth movement had been reported in corticotomy assisted group[19,22–29] and in subjects who had undergone periodontal distraction and dentoalveolar distraction.[23,27–29] Surgical approach involved either use of intraoral distractors (Sayın et al,[27] Rizwan Ahmed,[28] Prabhat KC et al[29]) or conventional orthodontic mechanics (Aboul Ela et al,[22] Alikhani et al,[24] Abed and Al-Bustani,[25] Leethanakul,[19] Al-Naoum F et al,[26] Khanna et al[23]) to retract canine after corticotomy, osteotomy or perforations in bone.

The results of studies using surgical approach, demonstrated that rate of tooth movement ranged from 5.8 mm to 6.5 mm over a period of 15-18 days when intraoral distractors were used and ranged from 1.1 mm to 3.5 mm without use of distractors. The rate of canine movement as observed in the present study is lesser than that achieved with combination of surgical approach and distractors but rate of canine movement is almost similar to that achieved by surgical approach where intraoral distractors were not used.

As results of various studies are controversial, concept of use of vibratory stimulus in acceleration of tooth movement must be understood at cellular level and how it is different

from mechanism underlying surgical approach to accelerate tooth movement.

The rate of Orthodontic tooth movement depends on modeling and remodeling of the alveolar process while adapting to new biomechanical environment. Low level mechanical oscillatory signals (vibration) have a positive effect on bone metabolism, increasing the rate of remodeling in long bones during adaptation to mechanical loading and had been used for preventing osteoporosis. Application of Orthodontic force is considered as mechanical loading which stimulates the early mechanoresponsive cells in alveolar bone i.e. osteocytes and this mechanical loading is augmented by vibrations. This results in increase in number of osteoclasts, more number of RANKL positive osteoblast and PDL fibroblast on tension side and more number of RANKL positive PDL fibroblasts and multinucleated osteoclasts were seen on compressive side in an animal study by Nishimura et al.[2]

Mechanical vibration directly increase RANKL level resulting in production of cytokines like VEGF (vascular endothelial growth factor), TNF-α, interleukins, interleukin-B, matrix metalloproteinases and others. Surgical approaches to accelerate tooth movement do so by initiating regional acceleratory phenomenon[37] (RAP). In response to noxious stimuli bone remodeling is increased by inducing apoptosis in response to micro damage and by indirectly increasing RANKL/ OPG ratio (by inducing hypoxia and changes in blood flow).

The clinical application of results of the present study suggests powered tooth brushes can be used with conventional orthodontic treatment as well as clear aligners and it presents a good alternative to decrease treatment time in adults as patient is not subjected to trauma of surgical approach and to the risk of increased chances of loss of vitality of teeth adjacent to intraoral distractors. Powered toothbrushes can be used as per patient's comfort, at whatever time of the day that suits best for them and do not disturb their diet and oral hygiene routine. However, if patient has very specific treatment time goals like weddings, jobs in army, air hostess, etc. then surgical approach with intraoral distractor will be more beneficial.

Future research on the effects of vibration should focus on effect of vibratory stimulation on different biomechanics (loop mechanics, en masse retraction and molar protraction) along with testing of alternative force levels, frequencies, and durations of vibration. Also, understanding of signaling pathways associated with vibration and in-vitro gene expression of the vibrated osteoblasts, osteoclasts, and cementoblasts must be studied.

5. Conclusion

Following conclusions can be drawn from the present study.

1. Vibratory stimulation significantly increased the rate of canine movement (total, at T0-T1, T2-T3).
2. No considerable mesial movement of molars was noted.

6. Source of Funding

None.

7. Conflict of Interest

The authors declare no conflict of interest.

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