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The Effect of Mechanical Vibration on the velocity of Orthodontic tooth Movement

Effect of mechanical vibration on orthodontic tooth movement

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ABSTRACT

Aims: The present study designed to evaluate effect of mechanical vibration on the rate of orthodontic tooth movement.

Material and method: This study used 14 male albino rabbit. The animals were randomly divided into two groups containing of 7 rabbits each. Group I was the control group and group II served as mechanical vibration group. In both groups, an orthodontic open coil spring with two bands placed on the lower central incisors to deliver 60 g force for orthodontic tooth movement. In the II group, the distal mechanical vibration with Hummingbird (Oral B, USA) was applied to lower right mandibular incisor nine times(three times a week) for ten minute over 22 days and tooth movement were measured indirectly from digital radiograph using planmeca Dimaxis Pro X-ray machin with dimaxis classic imaging software at nine time points in addition to measuring at scarifying time .

Results: although the amount of tooth movement at incisal and cervical region was greater in the vibration group when compared with the control group on all days but the only significant differences were shown in the amount of tooth movement at incisal edge on 10^{th} ,19^{th} and 22^{nd} days.no significant differences between right and left side in the control group ,while in the vibration group the vibrated side had increased OTM when compared to its contra-lateral non-vibrated on all days except on 1^{st}, 12^{th} and 14^{th} days .

Conclusions: Vibration in orthodontics is a new field and shows mechanical vibration can accelerate orthodontic tooth movement.

Keywords: mechanical vibration, orthodontic tooth movement.

INTRODUCTION

Since fixed orthodontic treatment usually takes place over a long Period of time, the problems of caries [(1)], periodontal disease [(2)], external root resorption [(3)] and prolonged treatment period are weary for the patient. Thus, accelerating orthodontic tooth movement and the resulting shortening of the treatment duration would be quite beneficial.
To date, several novel modalities have been reported to accelerate orthodontic tooth movement ranging from reducing appliance friction[(4)] and using adjunctive pharmacological or hormonal therapies [(5)] to the more recent introduction of surgical corticotomy and distraction techniques [(6,7)], however these techniques are often invasive or further complicate treatment. Several studies more recently, have investigated the efficacy of mechanical vibration in relation to increasing the rate of OTM [(8,9)] and also has the advantage of minimal side effects in comparison to other treatments, on the other hand.
Marie [(10)]found vibration to be possible to reduce pain in orthodontic patients, but without looking at the vibratory stimulation effect on orthodontic tooth movement..
As one of the pioneers focusing on this issue, Liu [(11)]has reported that when mechanical vibration (4Hz, 20μm displacement, 5 min/day) is applied to orthodontically move teeth for 4 weeks in mice, compared with the non-vibrated tooth movement group, the tooth movement rate under vibration is increased by about 50%.[(12)]

With the advancement of research, A new oral vibrating device, the Acceledent device (OrthoAccel technologies Inc, USA), has recently become commercially available To explore the clinical effects of this device, Kau et al[(13)] conducted a clinical trial in which 14 orthodontic patients were recruited and instructed to use the device for 20 minutes daily for a period of 6 consecutive months. As a result, it was found that the total rate of movement for the mandibular crowding was 2.1 mm per month and for the maxillary arch was 3.0 mm per month, which apparently is faster than the traditional finding as of about 1.0 mm per month. [(14)], Mao and co-workers found cyclical forces between 1 Hz and 8 Hz, with forces ranging from 0.3N to 5N, increased bone remodelling[(15-

[17]commonly by an order of up to 2.5 times the non- vibration rate.

To date, however there are few studies on the effect of vibration using different methods on orthodontic tooth movement [8,9,11,16-19] but The vibratory protocols (i.e. frequency, duration, and amplitude) utilised in the literatur lack standardisation and vary considerably, making it difficult to formulate appropriate conclusions regarding the most effective protocol[16,17].

Thus the aim of this study was to investigate the effect of mechanical vibration using Hummingbird (Oral B, USA) , applied over 3 weeks to mandibular right central incisor on the velocity of orthodontic tooth movement and compare the amount of tooth movement among different days in the control and vibration groups.

MATERIAL & METHODS

▪ ***Animals*:**

This study included fourteen male rabbit. All animals were housed in a 12-h light/dark environment at the same conditions of good ventilation, adequate stable diet, temperature and humidity They had free access to water and food throughout the experiment. Their average weight 1400 grams ranged between1250 grams and 1500grams at the beginning of the experiment. The animals were randomly divided into two groups containing of 7 rabbit each . Groups I was the control group and group II served as mechanical vibration group.

▪ ***Orthodontic appliance:***

After anaesthetization with Intramuscular injection of a mixture of Xylazine (10.0mg/kg of body weight) and Ketamine (40 mg/kg of body weight**),**a fixed orthodontic appliance incisors in both the experiment and control groups was constructed from two adapted stainless steel orthodontic bands on the right and left incisors that cemented to the mandibular incisors with zinc oxyphosphate cement. Orthodontic nickel titanium open coil spring (.010"×0.030", FDA ,USA) were compressed between these bands along the rectangular stainless steel wire 0.016"×0.022" (Dentarum, Germany) to produce a 60g of reciprocal force measured with a dynamometer (Hahnkolf, Stuttgart, Germany) .this wire was inserted into band slot with ligature elastic (Dentarum, Germany) and was then crimped over on the ends to prevent its loss as shown in Figure(1) . The springs were not reactivated during the experiment.

Method of Vibration

Using a split-mouth study design, each animal was randomly assigned a “Vibration” and “Non-vibration” side. vibration was applied with a Hummingbird (Oral B, USA) as illustrated in Figure(2) to the mandibular right lower central incisor for 10 minutes per day on 1, 3, 5, 8, 10, 12, 15, 17, and 19 day(total of 9 sessions within the 22-day experimental period).
According to the operating specifications the Humming Bird operates at approximately 6800 RPM, which corresponds to 113 Hz. The batteries in the device were changed every 1 weeks to ensure maximal consistent output.

▪ ***Radiographic Examination:***

Standardized digital radiographs using a (planmeca Dimaxis Pro X-ray machin with dimaxis classic imaging software .Helsinki,Finland 2003); were taken at a constant distance (The distance between the end of the long cone and the sensor was fixed to 5 cm) and the cone was kept perpendicular to the sensor all the time. these radiographic images were taken at 60KVp,8mA and .048sec.The read out starts automatically, the image was displayed gradually on the computer screen, when the read out was completed; the newly read image was stored.

Measurement of tooth movement:

The distance of tooth movement between mandibular incisor***s*** was measured in millimeters in both the control and vibration group on the occlusal radiograph using digital radiograph at various region as observed in Figure (3);

1. Distance between the mesioincisal line angles of mandibular central incisors.
2. Distance between mesial surface of right and left mandibular central incisors at the level of infradental at lingual side.
3. Distance between the midpoint of the narrowest space between mandibular central incisors at the cervicolingual surface of lower central incisors(infradentale at lingual side) and mesial surface of root for right and left mandibular incisor.

reading were taken over the 22 day experiment: on days 1, 3, 5, 8, 10, 12, 15, 17, and 19 and 22 under the same anesthesia protocol to standaradize the amplification ,to increase the accuracy of the small morphological measurement changes.the images were magnified two times the original size with the known scale and were traced with selected distance.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics, Version 19 (IBM Corporation, USA) were performed . Descriptive statistics were given as mean, standard deviation, minimum,and maximum.To compare means of tooth movement between two groups(vibration versus non vibration group and right versus left side), independent samples T-test was used. One-way ANOVA was used to compare means of more than two groups, followed by Duncan's multiple range analysis test to examine difference in tooth movement among days within each group at $p \leq 0.05$.

RESULTS

The descriptive statistics and comparison between control and vibration groups for the amount of tooth movement at incisal edge and cervical region as illustrated in Table(1) and(2) respectively showed that amount of tooth movement was greater in the vibration group when compared with the control group on all days but the only significant differences were shown in the amount of tooth movement at incisal edge on 10^{th} ,19^{th} and 22^{nd} days.
The descriptive statistics and comparison the amount of tooth movement at cervical region between right and left side in the control and vibration groups showed there is no significant differences between right and left side in the control group as shown in Table(3)
While in the vibration group the right side had greater amount of tooth movement than left side on all days except on 1^{st}, 12^{th} and 14^{th} days as illustrated in Table(4).

The comparison of amount of tooth movement at cervical region between control and vibration group at right side showed that vibration group had greater amount of tooth movement than control group on 5^{th}, 8^{th} and 19^{th} day as shown in Table (5) and Figure (4),while at left side there was no significant difference on all days as observed in Table (6) and Figure(5).

One way ANOVA showed there is a significant differencs in the amount of tooth movement among different days for the control and vibration groups as illustrated in Table(7) . The amount of orthodontic tooth movement increased over days in all groups as observed in Table (8) by Duncan's multiple range analysis test .

DISCUSSION

Animal Species

However, all previous experimental studies were carried out on rats, mices and very few in rabbits. In this study albino rabbits were used because of ease of handling and fabrication of intraoral appliance is comfortable compared to rats [20]. Since the short cycle in female rabbit causes hormonal variation [22] ,this study was carried out with male rabbits.

Study design

Mandibular central incisors were selected to fix the orthodontic appliance .They were selected because of their greater cervico-incisal length and better accessibility for preparation and placement of the appliance [22] . The present study used indirect measurement because direct measurements can arguably be more prone to error [23] . The vibration was applied three times a week every 48h for three weeks.

Differences of OTM between groups and between sides

The complex of tooth and PDL is considered to be viscoelastic. [24] It was reported that an intermittent vibrating force is mechanically more effective than a static force in changing the PDL's viscoelasticity, and that this effect persists over a certain period of time. [25]

In our study, a significant greater amount of tooth movement was noticed when the vibration was applied to the right incisor as compared to left non vibration side, while in the control group there was no significant difference between right and left side this indicate that mechanical vibration accelerate orthodontic tooth movement.
This support the findings of other studies. Shimizu [26] studied the movement of the lateral incisor in *Macaca fusca* loaded with a vibrating force. The vibration was done for 1.5 hours per day over 3 weeks. The results showed 1.3-1.4 times greater tooth movement than loading a static force. In 2008, Nishimura along with Shimizu again investigated the

effects of stimulation by resonance vibration on the speed of tooth movement in rats. The experimental group consisted of adding a vibrational stimulant (60 Hz, 1.0 m/s^2) to the maxillary first molars for 8 minutes on days 0, 7, and 14. Their results showed a 15% significant increase in the rate of tooth movement .[8]

Direct comparisons between the present and previous studies is complicated by a number of factors. Different vibration protocol (frequency,duration and amplitude) and various animal models have been used; some papers omit important aspects related to study design

The lack of significant difference in the amount of tooth movement between control and vibration groups may be attributed to individual variation that could have masked subtle differences that may have existed between groups**.** It is also possible that differences could have emerged if the study had been conducted over a longer period of time.

Differences of OTM among different days in the control and vibration groups

It is generally considered that orthodontic tooth movement consists of clearly separatable three phases occurring in the periodontal ligament:an initial compressive phase consisting of changes in the viscoelasticity of periodontal ligament for 1-4 days;afollow-up lag phase in which the tooth movement slows down for 4-7days with the appearance of tissue with no cells and fibers in the periodontal ligament;and finally a phase in which the tooth moves progressively in association with bone resorption for 7-14day.[27]

Tooth movements occurred on both control and vibration group in the present study.The greatest rates of tooth movement was observed on 3rd day in both groups at incisal and cervical region , with the slowest rate of movement occurring between day 3 and 8 for control group and between day 3and 5 for vibration group at cervical region.

The increase in the rate of tooth movement in the vibration group was suggested to be the result of a reduction of the initial lag phase when force is applied[9] indicating that vibration can accelerate orthodontic tooth movement

CONCLUSIONS

Vibration in orthodontics is a new field and shows mechanical vibration can accelerate orthodontic tooth movement .However the clinical significance of such application and potential optimal protocol should be evaluated on a sample undergoing a complete course of orthodontic treatment to ensure efficacy and safety.

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Figure (1): Orthodontic appliance in situ.

Figure (2): Oral B humanbirg Unit.

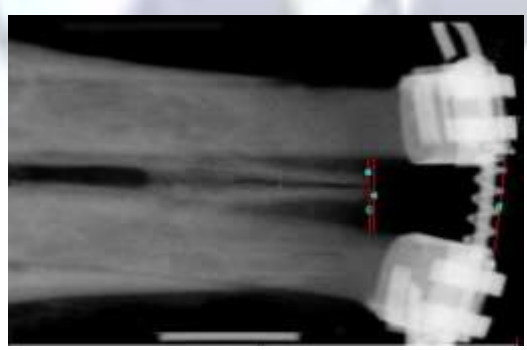
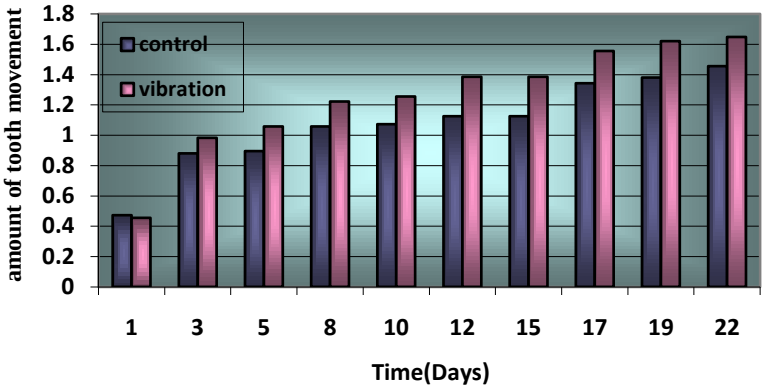


Figure (3): Radiographic measurements



Figure(4): comparison of orthodontic tooth movement at cervical region between control and vibration group in right side

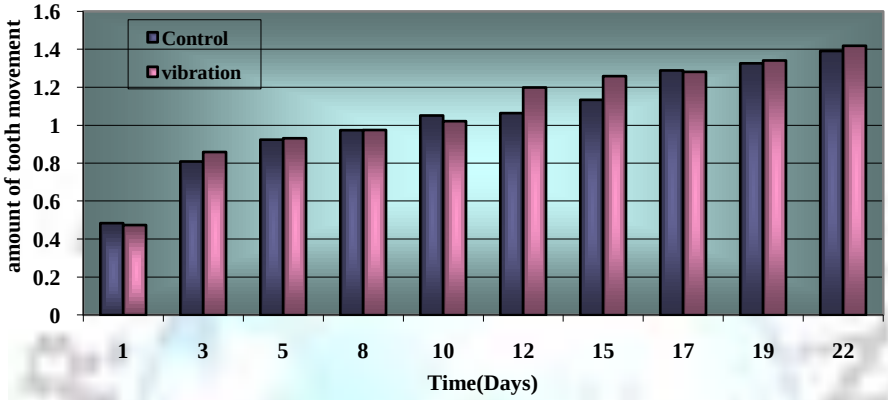


Figure (5): comparison of orthodontic tooth movement at cervical region between control and vibration group in left side

Table (1): Comparison the amount of tooth movement at incisal edge between control and vibration group on different days.

Day	Group	Min.	Max.	Mean	SD	T value	Sig.
1	Control	.00	.00	.00	.00	-	-
	Vibration	.00	.00	.00	.00		
3	Control	1.44	2.00	1.7467	.28378	1.755	.140
	Vibration	1.86	2.45	2.160	.3238		
5	Control	1.44	2.20	1.9300	.42509	1.599	.161
	Vibration	1.90	2.52	2.294	.235		
8	Control	1.43	2.3	1.91	.44193	1.520	.189
	Vibration	1.90	2.68	2.348	.327		
10	Control	1.80	2.30	2.0500	.35355	2.737	.052 *
	Vibration	2.37	2.97	2.725	.258		
12	Control	2.32	2.43	2.3750	.07778	1.648	.175
	Vibration	2.33	3.29	2.883	.408		
15	Control	2.50	2.57	2.5350	.04950	.646	.564
	Vibration	2.14	3.72	3.115	.758		
17	Control	2.58	2.86	2.7033	.14295	1.485	.198
	Vibration	2.37	3.72	3.250	.611		
19	Control	2.86	2.90	2.8800	.02828	2.747	.052 *
	Vibration	3.25	3.94	3.558	.329		
	Vibration	2.88	2.94	2.910	.0424		
22	Control	3.06	3.17	3.1150	.07778	3.294	.030*
	Vibration	3.51	4.00	3.735	.2469		

* indicates significant values, ($p < 0.05$)
- t can not be computed because the standard deviations of both groups are 0.

Table (2): Comparison the amount of tooth movement at cervical region between control and vibration group on different days.

Day	Group	Min.	Max.	Mean	SD	T value	Sig.
1	Control	.93	1.08	1.0050	.06758	1.360	.223
	Vibration	.86	1.04	.9300	.08718		
3	Control	1.68	1.90	1.7900	.11605	-.075	.943
	Vibration	1.68	2.03	1.7975	.16276		
5	Control	1.70	1.94	1.8200	.12754	-1.915	.104
	Vibration	1.86	2.11	1.9900	.12356		
8	Control	1.80	2.45	2.0325	.28791	-1.121	.299
	Vibration	2.01	2.40	2.1980	.15057		
10	Control	1.94	2.47	2.1375	.24144	-1.038	.339
	Vibration	2.16	2.40	2.2775	.12010		
12	Control	1.87	2.52	2.1775	.34043	-2.263	.064
	Vibration	2.42	2.94	2.6450	.23402		
15	Control	1.97	2.55	2.3075	.25277	-1.490	.187
	Vibration	2.24	3.04	2.6175	.33069		
17	Control	2.50	2.84	2.6325	.15218	-1.392	.213
	Vibration	2.60	3.15	2.8375	.25211		
19	Control	2.55	2.95	2.7075	.17289	-1.617	.157
	Vibration	2.69	3.32	2.9625	.26387		
22	Control	2.69	3.14	2.8750	.19296	-1.316	.236
	Vibration	2.86	3.23	3.0400	.16021		

Table (3): Comparison of amount of tooth movement at cervical region between right and left side of control group on different days

Day	Group	Min.	Max.	Mean	SD	T value	Sig.
1	Right	.50	.54	.5200	.02309	1.347	.227
	Left	.43	.54	.4850	.04655		
3	Right	.82	.94	.8800	.06377	-.728	.494
	Left	.86	.96	.9100	.05228		
5	Right	.82	.97	.8950	.08103	-.642	.545
	Left	.88	.97	.9250	.04655		
8	Right	.94	1.25	1.0575	.13475	.808	.450
	Left	.86	1.20	.9750	.15351		
10	Right	.98	1.27	1.0725	.13401	.085	.935
	Left	.96	1.20	1.065	.11475		
12	Right	1.00	1.30	1.1250	.15000	.592	.576
	Left	.87	1.22	1.0650	.19380		
15	Right	1.02	1.30	1.1725	.11587	.411	.695
	Left	.95	1.25	1.1350	.14107		
17	Right	1.23	1.54	1.3425	.14175	.737	.489
	Left	1.27	1.30	1.2900	.01414		
19	Right	1.26	1.55	1.3800	.12356	.788	.461
	Left	1.29	1.40	1.3275	.04992		
22	Right	1.37	1.62	1.4550	.11269	.495	.638
	Left	1.32	1.52	1.3925	.08524		

Table (4): Comparison the amount of tooth movement at cervical region between right and left side in vibration group on different days.

Day	Group	Min.	Max.	Mean	SD	T value	Sig.
1	Right	.43	.50	.4550	.03317	-.627	.554
	Left	.43	.54	.4750	.05447		
3	Right	.93	1.14	.9825	.10500	2.649	.038 *
	Left	.75	.89	.8150	.07047		
5	Right	.97	1.14	1.0575	.08057	2.730	.034 *
	Left	.89	.97	.9325	.04349		
8	Right	1.18	1.29	1.2220	.04604	4.734	.001 *
	Left	.83	1.11	.9760	.10668		
10	Right	1.21	1.29	1.2550	.04123	5.180	.002*
	Left	.95	1.11	1.0225	.07974		
12	Right	1.21	1.57	1.3850	.16442	1.381	.216
	Left	1.21	1.37	1.2000	.07572		
15	Right	1.27	1.72	1.4175	.20500	1.677	.145
	Left	.97	1.32	1.2600	.15895		
17	Right	1.40	1.79	1.5550	.17407	2.818	.030 *
	Left	1.20	1.36	1.2825	.08421		
19	Right	1.44	1.86	1.6200	.17493	2.802	.031 *
	Left	1.25	1.46	1.3425	.09287		
22	Right	1.50	1.80	1.6475	.12580	3.883	.008*
	Left	1.36	1.43	1.4200	.03775		

* indicates significant values, ($p < 0.05$)

Table (5): Comparison the tooth movement at cervical region between control and vibration group at right side on different days using independent T-test.

Day	1	3	5	8	10	12	15	17	19	22
T value	.645	-1.66	-2.84	-2.60	-2.336	-2.08	-1.89	-2.24	-2.77	.279
Sig.	.540	1.57	.029*	.040*	.058	.083	.107	.066	.032*	.790

* indicates significant values, ($p < 0.05$)

Table (6): Comparison the tooth movement at cervical region between control and vibration group at left side on different days using independent T-test

Day	1	3	5	8	10	12	15	17	19	22
T value	.279	2.16	-.235	-.012	.608	-1.99	-.612	.176	-.285	.590
Sig.	.790	.074	.822	.991	.565	.093	.563	.866	.786	.577

Table (7): Comparison the tooth movement at incisal edge and cervical region among different days in the control and vibration groups with one way ANOVA test .

	Amount of tooth ovement at incisal edge		Amount of tooth movement at cervical region	
Group	Control	Vibration	Control	Vibration
F value	19.258	22.595	28.340	41.648
Sig.	.000*	.000*	.000*	.000*

* indicates significant values, ($p < 0.05$)

Table(8): Comparison the amount of tooth movement at incisal edge and cervical region among different days for control and vibration groups using Duncan's multiple range analysis test .

	Amount of tooth movement at incisal edge				Amount of tooth movement at cervical region			
Day	Control		Vibration		Control		Vibration	
	Mean	Duncan	Mean	Duncan	Mean	Duncan	Mean	Duncan
1	.0000	A	.0000	A	1.0050	A	.9300	A
3	1.7467	B	2.1600	B	1.7900	B	1.7975	B
5	1.9100	BC	2.2940	BC	1.8200	B	1.9900	BC
8	1.9300	BC	2.3475	BC	2.0325	BC	2.1980	C
10	2.0500	BCD	2.7250	BCD	2.1375	C	2.2775	C
12	2.3750	CDE	2.8825	CD	2.1775	C	2.6450	D
15	2.5350	DE	3.1150	CD	2.3075	C	2.6175	D
17	2.7033	EF	3.2500	DE	2.6325	D	2.8375	DE
19	2.8800	EF	3.5575	E	2.7075	D	2.9625	E
22	3.1150	F	3.7700	E	2.8750	D	3.0400	E

*Different letters vertically mean significant difference.