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Force generation by orthodontic samarium cobalt and neodymium iron boron magnets at various distances-an Invitro study

[1]Eunice John, [2]Pradeep Babu Kommi, [3]R.S Senkutvan, [4]U.B Rajasekaran, [5]Arani Nandakumar, [6]Aniruddh Yashwant

[1]Post graduate, Department of Orthodontics, Indira Gandhi Institute of Dental Sciences, Sri Balaji Vidyapeeth, Pondicherry, India

[2]Professor, Department of Orthodontics, Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India

[3]Professor, Department of Orthodontics, Madha Dental College & Hospital, Tamil Nadu, India

[4]Professor and Head of department, Department of Orthodontics, Indira Gandhi Institute of Dental Sciences, Sri Balaji Vidyapeeth, Pondicherry, India

[5]Professor, Department of Orthodontics, Meenakshi Ammal Dental College and Hospital, Chennai, India

[6]Senior Lecturer, Department of Orthodontics, Indira Gandhi Institute of Dental Sciences, Sri Balaji Vidyapeeth, Pondicherry, India

Corresponding Author: Eunice John, Post graduate, Department of Orthodontics, Indira Gandhi Institute of Dental Sciences, Sri Balaji Vidyapeeth, Pondicherry, India

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Abstract

AIM: To evaluate and compare the attractive and repulsive force values in Neodymium iron boron and Samarium cobalt magnets of different sizes at various distances.

Materials and Methods: 168 cylindrical magnets each of neodymium iron boron and Samarium cobalt were procured and were grouped as Group I and Group II and further subdivided into A, B and C for 10x3mm, 6x3mm and 4x4mm sizes respectively. The force of attraction and repulsion was measured using the Instron Universal testing Machine.

Results: The force was measured at nine specified distances and the readings obtained were statistically analysed using unpaired t test. Both the magnets of 4x4mm size when subjected to attraction and repulsive force at 10mm to 20mm distance apart could not generate any force suggesting lacking in ability to generate any force at that distance and above.

Conclusion: The study showed that Neodymium iron boron magnets had higher force values for both attraction and repulsion for all the sizes ranging from 943.01-24.13gms.Samarium cobalt magnets had also generated significant force value ranging from 738-11.39gms for both attraction and repulsion. All the force values produced by these magnets can be used for orthodontic treatment either for orthopaedic correction or orthodontic tooth movement.

Keywords: force, magnets, samarium cobalt, neodymium iron boron

Introduction

Orthodontics is the science which deals with movement of teeth as well as correction of jaws mostly in adolescence. These movements are complicated as vast knowledge regarding biomechanics is mandatory. Various researchers and authors have suggested different force systems for the movement of tooth and its associated structures. But, the biology of the alveolar bone, periodontal ligament, the position, size and shape of the tooth, root and the extent of tooth movement needed are complex in nature. As the above mentioned structures are interlinked, there is a need for complex multifaceted treatment planning.

The force applied on tooth surface and for the movement of jaws have huge inhibitions as the conventional forces are applied through the bracket systems which are bonded on the buccal/labial surfaces of the teeth. This resultant force generation is far from the center of resistance, which may result in controlled or uncontrolled tipping resulting in relapse of the teeth and lack of stability.

These situations were later rectified with superior bracket systems and application of compensatory forces with improved knowledge of biomechanics. During orthodontic tooth corrections, demand for complex tooth movements such as intrusions, expansion, molar distalization, eruption of impacted tooth and correction of skeletal jaw discrepancies in growth phase such as Class II and class III skeletal malocclusions need precise appliance design which are specific to each malocclusion.

Magnets have been used in dentistry for many years .The magnets used intraorally are available in various sizes and shapes like square, rectangular bar, triangular prism and cylindrical.1 The sizes of the magnets influences the magnetic field which is directly proportional to the force generated.

Advantages of magnetic force systems include predictable force levels, better directional force, no force decay over time, exertion of force through mucosa and bone, frictionless mechanism, less patient discomfort , less patient cooperation, high coercive forces, biologically safe force generating system and better vector control in treatment of malocclusion.2 **Lars Bondemark** et al in 1997 described the proximal alveolar bone level after orthodontic treatment using magnets for molar distalisation. This study showed that there were no sites with bone loss i.e, the CEJ-AC distance did not exceed 2mm.3 There is no difference in relation to force level and amount of tooth movement on the severity of Orthodontically Induced Inflammatory Iatrogenic Root Resorption (OIIRR) using gradually increasing (ascending) and decreasing (descending) orthodontic force generated by magnets.4

Disadvantage of magnetic force systems include dramatic reduction in force if magnets are not aligned to one another. Corrosion is the main problem associated with the use of magnets. The SmCo and NdFeB magnets possess the properties such as brittleness and susceptibility to corrosion which is seen more in chloride containing environments such as saliva and the presence of bacteria increases the corrosion of NdFeB magnets.5 Mechanisms causing corrosion of magnetic attachments include the breakdown of the encapsulating material & diffusion of moisture and ions through the epoxy seal. **Lars Bondemark et al** in 1994, AJODO had done an invitro study to compare the cytotoxic effects of uncoated and parylene coated rare earth magnets by using 2 method: Millipore filter method and Extraction method showing that orthodontic samarium-cobalt magnets can be recycled and maintain good biocompatibility.6 Therefore the purpose of this study is to evaluate the force generated by samarium cobalt and neodymium iron boron magnets at specified distances which can be applied in various clinical scenarios in orthodontics.

Materials and Methods

168 magnets each of neodymium iron boron and Samarium cobalt of cylindrical shape were procured because of their availability and ease of placement in the

oral cavity to bring about orthodontic as well as orthopaedic tooth movement as shown in figure 1 and 2. The Neodymium iron boron magnets were grouped as Group I and were further subdivided into GROUP IA for 10x3mm size, GROUP IB for 6x3mm size, GROUP IC for 4x4mm size depending on size as shown in Table 1. The Samarium cobalt magnets were grouped as Group II and was further subdivided into GROUP IIA for 10x3mm size, GROUP IIB for 6x3mm size, GROUP IIC for 4x4mm size depending on size as shown in Table 2.

These magnets were incorporated into acrylic blocks ,colour coded as green and maroon of size 10x10x40mm using cyanoacrylate for better identification and better retention so that the generated force could not destabilize the magnet from the acrylic block as shown in figure 3 and 4.This acrylic block was mounted onto both the crossheads of the Instron universal testing machine (Instron 3382/66216) . The magnets are positioned at a distance of 0mm and the upper crosshead was moved at a speed of 2.5mm/min with force of 1KN in the vertical direction and the values are noted as shown in figure 5 and 6.7 The same procedure was repeated for the distances 2.5,5,7.5,10 ,12.5,15,17.5 and 20mm.The process is repeated for each size 28 times. The readings obtained were statistically analysed using unpaired t test.

In repulsion tests the magnets are separated from contact and positioned 20mm apart.The upper crosshead was moved downward at a rate of 2.5mm/min with force of 1KN in the vertical direction and the force generated between the magnets are recorded simultaneously with magnet separation of 20mm, 17.5mm, 15mm, 12.5mm, 10mm,7.5mm, 5mm and 2.5mm.These readings are noted 28 times for each size at all the 9 distances.

In attraction tests the magnets are placed initially in contact and the force generated between the magnets are measured as they are separated at a rate of 2.5mm/min with force of 1KN in the vertical direction and the force generated between the magnets are recorded simultaneously with magnet separation of 0mm, 2.5mm, 5mm, 7.5mm, 10mm, 12.5mm, 15mm, 17.5mm and 20mm. These readings are noted 28 times for each size at all the 9 distances.

Results

The Neodymium iron boron and Samarium cobalt magnets used in the study were allotted as Group I and Group II with A,B,C denoting sizes of 10x3,6x3 and 4x4mm respectively. Attraction and repulsion test was performed by placing magnets at0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20mm distances in Instron universal testing machine. The results were statistically analysed using unpaired t test and the resultant means were obtained. The resultant mean value for group IA for attraction for all the samples at the nine specified distances were 9.248N ± 0.0232 (943gms) at 0mm, 8.494N ± 0.02579 (866gms) at 2.5mm, 7.537N ± 0.0222 (767gms) at 5mm, 6.519N ± 0.0134 (663.8gms) at 7.5mm, 5.746N ± 0.0401(585.3gms) at 10mm, 5.372N ± 0.1338 (547.57gms) at 12.5mm, 4.273N ± 0.0896 (435.7gms) at 15mm, 3.755N ±0.0433 (382.8gms) at 17.5mm and 3.412N±0.0391(347.7gms) at 20mm respectively. The resultant mean value for group IA for repulsion were 9.243N ± 0.0119(943gms) at 0mm, 8.494N ± 0.0262 (866gms) at 2.5mm, 7.539N ± 0.0223 (767gms) at 5mm, 6.517N ± 0.0135 (663.8gms) at 7.5mm, 5.753N±0.0357(585.3gms) at 10mm , 5.412N ± 0.1486(547.57gms) at 12.5mm, 4.282N ± 0.0949(435.7gms) at 15mm , 3.763N±0.0383(382.8gms) at 17.5mm and 3.412N ± 0.0384 (347.7gms) at 20mm respectively as shown in Table 3. The p value showed statistical significance.

The resultant mean value for group IB for attraction for all the samples at the nine specified distances were 6.247N ± 0.0192 (636.29gms) at 0mm, 6.150N ± 0.0066

(627.11gms) at 2.5mm, 6.033N ± 0.0078 (615.18gms) at 5mm, 5.457N ± 0.0076(556.45gms) at 7.5mm, 5.242N ± 0.0080 (534.32gms) at 10mm, 5.125N ± 0.0132 (522.08gms) at 12.5mm, 4.629N ± 0.0139(471.1gms) at 15mm, 3.733N ± 0.0121 (380.34gms) at 17.5mm and 2.407N ± 0.0545(244.7gms) at 20mm respectively. The resultant mean value for group IB for repulsion for all the 168 samples were 6.246N ± 0.0208(636.29gms) at 0mm, 6.150N ± 0.0070(627.11gms) at 2.5mm, 6.033N ± 0.0076(615.18gms) at 5mm, 5.456N ± 0.0072(556.45gms) at 7.5mm, 5.243N ± 0.0083 (534.32gms) at 10mm, 5.124N ± 0.0138 (522.08gms) at 12.5mm, 4.629N ± 0.0129 (471.1gms) at 15mm, 3.374N ± 0.0124 (380.34gms) at 17.5mm and 2.417N±0.0469(244.7gms) at 20mm respectively as shown in Table 4. The p value showed statistical significance.

The resultant mean value for group IC for attraction for all the samples at the nine specified distances were 3.087N ± 0.1328 (314gms) at 0mm, 1.313N±0.3212 (133.88gms) at 2.5mm, 0.304N ± 0.0141 (30gms) at 5mm, 0.236N ± 0.0137(24.13gms) at 7.5mm respectively. The resultant mean value for repulsion 3.080N ± 0.1314(314gms) at 0mm, 1.313N ± 0.328 (133.88gms) at 2.5mm, 0.304N ± 0.0163 (30gms) at 5 mm, 0.238N ± 0.0155(24.13gms) at 7.5mm respectively as shown in Table 5. The p value showed statistical significance.

The resultant mean value for group IIA for attraction for all the samples at the nine specified distances were 7.249N ± 0.0235 (738gms) at 0mm, 6.045N ± 0.0276 (615gms) at 2.5mm, 5.423N ± 0.0239 (552.98gms) at 5mm , 5.380N ± 0.1227 (548.5gms) at 7.5mm, 4.513N ± 0.0363 (459.88gms) at 10mm, 4.121N ± 0.0124 (420.21gms) at 12.5mm, 3.420N ± 0.0313 (348.73gms) at 15mm, 3.125N ± 0.0087 (318.14gms) at 17.5mm, and 2.425N ± 0.0333 (247.27gms) at 20mm respectively. The resultant mean value for group IA for repulsion were 7.248N ± 0.0198 (738gms) at 0mm, 6.043N ± 0.0234 (615gms) at 2.5mm, 5.427N ± 0.0106 (552.98gms) at 5mm, 5.354N± 0.0113 (548.5gms) at 7.5mm, 4.407N ± 0.3111(459.88gms) at 10mm, 4.119N ± 0.0123(420.21gms) at 12.5mm, 3.422N ± 0.0250 (348.73gms) at 15mm, 3.125N ± 0.0087 (318.14gms) at 17.5mmand 2.424N ± 0.0337 (247.27gms) at 20mm respectively as shown in Table 6. The p value showed statistical significance.

The resultant mean value for group IIB for attraction for all the samples at the nine specified distances were 4.553N ± 0.0245(464.26gms) at 0mm, 4.201N ± 0.0316 (428.37gms) at 2.5mm, 4.020N ± 0.0184(409.9gms) at 5mm, 3.734N ± 0.0120(380.34 gms) at 7.5mm, 3.234N ± 0.0136 (329.77 gms) at 10mm, 3.006N ± 0.0205 (306.52 gms) at 12.5mm, 2.408 ± 0.0551(244.7 gms) at 15mm, 2.133N ± 0.0175 (217.19 gms) at 17.5mm, and 1.523N ± 0.0198(154.9 gms) at 20 mm respectively.Theresultant mean value for group IB for repulsion were 4.546N± 0.0159 (464.26gms) at 0mm, 4.206N ± 0.0289(428.37gms) at 2.5mm, 4.022N ± 0.0200 (409.9gms) at 5mm, 3.735N ± 0.0123 (380.34 gms) at 7.5mm, 3.236N ± 0.1315 (329.77 gms) at 10mm, 3.008N ± 0.0189 (306.52 gms) at 12.5mm, 2.417 ± 0.0468 (244.7 gms) at 15mm, 2.134N ± 0.0181(217.19 gms) at 17.5mm and 1.525N ± 0.0192(154.9 gms) at 20 mm respectively as shown in Table 7.The p value showed statistical significance.

The resultant mean value for group IIC for attraction for all the samples at the nine specified distances were 2.258N ± 0.1336 (229.43 gms) at 0mm, 0.629N ± 0.0723 (64.13gms) at 2.5mm, 0.284N ± 0.0283 (28.9gms) at 5mm and 0.111N ± 0.0152 (11.3gms) at 7.5mm respectively. The resultant mean value for group IC for repulsion were2.254N ± 0.1275 (229.43 gms) at 0mm, 0.638N ± 0.07699 (64.13gms) at 2.5mm, 0.290N ± 0.0271 (28.9gms) at 5mm, 0.109N ± 0.0116 (11.3gms) at 7.5mm respectively as shown in Table 8.The p value showed statistical significance.

The SmCo and NdFeB magnets of 4x4mm size when subjected to attraction and repulsion force from 10mm to 20mm distance apart with 2.5mm intervals could not generate any force levels suggesting lacking in ability to generate any force at that distance and above.

Discussion

Incorporating the magnets for both minor movements as well as correction of jaw discrepancies requires thorough knowledge of the effects produced by these magnets and the operator should have a comprehensive understanding of the biomechanics as well as the forces needed to bring about necessary tooth movements, so these magnets can be applied universally for standard orthodontic treatment done regularly. The limitations for these magnets as of now are that it has to be used as a case specific treatment method.

The other limitation is the availability of the material and the appropriate size, knowledge of force generation even though these magnets are economical. In this study we have addressed these concerns regarding amount of force generated. These magnets depending on their force generation could be utilised for multiple treatment protocols provided they are designed carefully in order to prevent unnecessary movements due to force generation. Smaller magnets such as 4x4mm can be adapted to perform minor tooth movements depending on the distance. Larger magnets such as 10x3 mm can be utilised for the orthopaedic correction such as functional jaw orthopaedics.

The NdFeB and SmCo magnets of 10x3mm size generated a force ranging from943gms to 347.7gms and 738gms to 247gms respectively depending on the distances maintained. These forces can bring orthopaedic changes if applied.8,9-11

The NdFeB and SmCo magnets of 6x3mm size generated a force ranging from 636.29gms to 244.7gms and 464.26gms to 154.9gms respectively depending on the distances maintained .These forces can be used for simultaneous first and second molar distalisation, anterior openbite correction, intrude posterior teeth and functional correction.12,13-17 The NdFeB and SmCo magnets of 4x4mm size generated a force ranging from 314gms to 24.13gms and 229.43gms to 11.3gms respectively depending on the distances maintained .These forces can be used for closure of diastema, extrude incisors, move impacted teeth and for fixed retention if applied.18,19-22

Conclusion

We would like to conclude the study by suggesting that Neodymium iron boron magnets had high force values for both attraction and repulsion for all the sizes at various distances.Samarium cobalt magnets had also generated significant force values for both attraction and repulsion in this study. But when the force values are compared between the groups, Neodymium iron boron magnets exhibited high force values when compared to the values exhibited by samarium cobalt magnets for all the sizes and for attraction and repulsion testing.All the force values produced by these magnets at specified distances can be used for orthodontic treatment either for orthopaedic correction or orthodontic tooth movement.

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Legends Table and Figure

TABLE 1

S.NO	SAMPLE	GROUP	SIZE	NO OF MAGNETS	MANUFACTURER
1.	Neodymium Iron Boron magnets	IA	10x3	56(28pairs)	Unisource industrial
2.	Neodymium Iron Boron magnets	IB	6 x 3	56(28pairs)	Unisource industrial
3.	Neodymium Iron Boron magnets	IC	4x4	56(28pairs)	Unisource industrial

TABLE 2

S.NO	SAMPLE	GROUP	SIZE	NO OF MAGNETS	MANUFACTURER
1.	Samarium Iron Boron magnets	IIA	10x3	56(28pairs)	Unisource industrial
2.	Samarium Iron Boron magnets	IIB	6 x 3	56(28pairs)	Unisource industrial
3.	Samarium Iron Boron magnets	IIC	4x4	56(28pairs)	Unisource industrial

Table 3: The following table indicates results obtained for Group IA for both attractive and repulsive test at distance of 0,2.5,5,7.5,10,12.5,15,17.5,20mm.

S.NO.	GROUP	NUMBER OF SAMPLES (IN PAIRS)	DISTANCE (mm)	MEAN (N)	SD
1	IA	28	0	9.2480000	.02322036
2	IA	28	2.5	8.4942143	.02579888
3	IA	28	5	7.5377857	.02225502
4	IA	28	7.5	6.5197143	.01347111
5	IA	28	10	5.7460000	.04016817
6	IA	28	12.5	5.3722143	.13383942
7	IA	28	15	4.2731571	.08966683
8	IA	28	17.5	3.7552500	.04339195
9	IA	28	20	3.4120000	.03916726

Table 4 : The following table indicates results obtained for Group IB for both attractive and repulsive test at distance of 0,2.5,5,7.5,10,12.5,15,17.5,20mm

S.NO.	GROUP	NUMBER OF SAMPLES (IN PAIRS)	DISTANCE (mm)	MEAN (N)	SD
1.	IB	28	0	6.2475714	.01920538
2.	IB	28	2.5	6.1504643	.00660798
3.	IB	28	5	6.0330714	.00785012
4.	IB	28	7.5	5.4576071	.00769482
5.	IB	28	10	5.2427857	.00809827
6.	IB	28	12.5	5.1256786	.01325548
7.	IB	28	15	4.6296429	.01395552
8.	IB	28	17.5	3.7339286	.01210426
9.	IB	28	20	2.4071071	.05455024

Table 5: The following table indicates results obtained for Group IC for both attractive and repulsive test at distance of 0,2.5,5,7.5,10,12.5,15,17.5,20 mm.

S.NO.	GROUP	NUMBER OF SAMPLES (IN PAIRS)	DISTANCE (mm)	MEAN (N)	SD
1.	IC	28	0	3.0878571	.13287023
2.	IC	28	2.5	1.3135357	.03212647
3.	IC	28	5	.3047857	.01410111
4.	IC	28	7.5	.2367679	.01376999
5.	IC	28	10	0	0
6.	IC	28	12.5	0	0
7.	IC	28	15	0	0
8.	IC	28	17.5	0	0
9.	IC	28	20	0	0

Table 6 : The following table indicates results obtained for Group IIA for both attractive and repulsive test at distance of 0,2.5,5,7.5,10,12.5,15,17.5,20 mm.

S.NO.	GROUP	NUMBER OF SAMPLES (IN PAIRS)	DISTANCE (mm)	MEAN (N)	SD
1.	IIA	28	0	7.2491071	.02352515
2.	IIA	28	2.5	6.0459643	.02763718
3.	IIA	28	5	5.4238571	.02394084
4.	IIA	28	7.5	5.3803571	.12275879
5.	IIA	28	10	4.5132857	.03639379
6.	IIA	28	12.5	4.1210000	.01249296
7.	IIA	28	15	3.4206786	.03137356
8.	IIA	28	17.5	3.1254286	.00876622
9.	IIA	28	20	2.4256786	.03333673

Table 7**:** The following table indicates results obtained for Group IIB for both attractive and repulsive test at distance of 0,2.5,5,7.5,10,12.5,15,17.5,20 mm

S.NO.	GROUP	NUMBER OF SAMPLES (IN PAIRS)	DISTANCE (mm)	MEAN (N)	SD
1.	IIB	28	0	4.5531429	.02454884
2.	IIB	28	2.5	4.2010357	.03160928
3.	IIB	28	5	4.0200357	.01848018
4.	IIB	28	7.5	3.7345357	.01201383
5.	IIB	28	10	3.2347500	.01366430
6.	IIB	28	12.5	3.0061429	.02055294
7.	IIB	28	15	2.4089643	.05511099
8.	IIB	28	17.5	2.1336071	.01751685
9.	IIB	28	20	1.5238929	.01981645

Table 8 : The following table indicates results obtained for Group IIC for both attractive and repulsive test at distance of 0,2.5,5,7.5,10,12.5,15,17.5,20mm

S.NO.	GROUP	NUMBER OF SAMPLES (IN PAIRS)	DISTANCE (mm)	MEAN (N)	SD
1.	IIC	28	0	2.2587857	.13364640
2.	IIC	28	2.5	.6297143	.07238419
3.	IIC	28	5	.2841786	.02833536
4.	IIC	28	7.5	.1117857	.01527369
5.	IIC	28	10	0	0
6.	IIC	28	12.5	0	0
7.	IIC	28	15	0	0
8.	IIC	28	17.5	0	0
9.	IIC	28	20	0	0

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Figure 4- Samarium Cobalt magnets mounted on acrylic block

Figure 5: Samarium Cobalt magnets mounted on Instron Universal testing machine for testing

Figure 6: Neodymium Iron Boron magnets mounted on Instron Universal testing machine