Magnets in dentistry

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Abstract

For the last two decades permanent magnets have been used for various medical and dental applications. One reason for increased use of magnets is the recent development of small magnets made of new, powerful, permanent magnet alloys. In dentistry, rare earth magnets have been used successfully for fixation of dentures and in force systems for tooth movements. However, magnets have not yet been routinely used, may be owing to high cost.

This article demonstrated the use of magnets and magnetic forces in dentistry in different removable and fix appliances.

Key words: *dentistry, magnets, magnetic force.*

Introduction

For the last two decades permanent magnets have been used for various medical and dental applications. One reason for increased use of magnets is the recent development of small magnets made of new, powerful, permanent magnet alloys. So called rare earth magnets like samarium-cobalt ($SmCo_5$ and Sm_2Co_{17}) and Neodymium-Iron-Boron (Nd2Fe14B) have been of special interest as these alloys have properties superior to previously used magnetic alloys like alnico, ferrite, and Platinum-Cobalt (Pt. Co) magnets. In dentistry, rare earth magnets have been used successfully for fixation of dentures and in force systems for tooth movements. However, magnets have not yet been routinely used, may be owing to high cost.

What is a magnet?

A loadstone: Native iron oxide attracts iron, also a bar of steel or iron that attracts iron and has magnetic polarity.

What is magnetism?

The study of properties of magnets, magnetic substances and of associated phenomena. A magnet (Natural or artificial, permanent or temporary) is one which exhibits two important properties, namely

1) Attractive property

2) Directive property

Magnets attract small pieces of substances like iron or steel. This property of attraction is found to be the greatest near the two ends of the magnets. The points near the ends lying inside the magnet where magnetism appears to be concentrated are called the poles of the magnet. When a magnet is freely suspended in a horizontal plane, it always comes to rest approximately in the N-S direction. Accordingly, a magnet has North Pole and South Pole. Poles can never be isolated.

Coulomb's inverse square law in magnetism

Magnetic poles always occur in pairs. However, the concept of an isolated magnetic pole is very useful in understanding magnetism. Between two isolated magnetic poles there exists a magnetic force.

Under the action of this force "like poles repel while unlike poles attract each other". The inverse square law states that "The force between two isolated magnetic poles is directly proportional to the product of their pole-strengths and inversely proportional to the square to the distance between them."

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$$F = K \frac{M1M2}{D2}$$

M1 and M2 > two poles of strength M1 and M2

K - Constant

d - M1 and M2 separated by a distance 'd'

Pole strength of a magnetic pole

Pole strength of a magnetic pole is numerically equal to 107 times the force in Newton that it exerts on a unit North pole (North pole of 1 Am) placed at a distance of 1 m. from it in air or vacuum.

Magnetic field is the space in which a magnetic pole experiences a force.

Uniform magnetic field is one in which the force on a unit North Pole is the same at all points in it.

Non – uniform field is Force on a unit north pole is different at different points.

Null point is a combined magnetic field is that point at which the resultant magnetic field is zero.

Magnetic lines of force

A line of force in a magnetic field is the path along which an isolated unit north pole moves or tends to move.

It may be straight or curved. In curved line of force, the tangent drawn to the curve at any point gives the direction of the resultant field at that point. Two lines of force never interest.

Magnetic flux density

The numbers of lines of force passing normally through unit area of cross section around a point is called the magnetic flux density at that point. It is a measure of the magnetic field. It is a very significant quantity. It is dented by B. It is expressed in Weber per meter square.

Wb (M-2) or Tesla (T)

1 wb m-2 = 1T

Magnetic flux density or magnetic field B at a point is defined as the force in Newton acting on a north pole of strength 1 Am kept at the point.

AM (Ampere Meter)

Magnetic moment

It is numerically equal to the moment of the couple experienced by the magnet when placed at right angles to a uniform magnetic field of one tesla.

Magnetic Dipole

A change in motion constitutes an electric current and a magnetic field is produced by a current. Each atom of the material can be considered as a tiny magnet.

Effects Of Samarium Cobalt Magnet And Pulsed Electromagnetic Fields On The Tooth Movement

It is suggested that PEMF causes a change in the membrane permeability allowing increased flow of calcium, sodium and potassium ions across the cell membrane, there by affecting the activity of intracellular cyclic adenosine monophosphate and cGMP. Also two fold increase in the alkaline phosphatase levels with low magnitude static magnetic fields and increased rate of phosphorylation of myosin in a cell free culture. It was found that PEMF of 15Hz or static magnetic rate of tooth movement of about 3mm per month. Also there is absence of classic lag phase initiation of tooth movement. This is explained by the fact that the presence of magnetic field had induced multipotential stem cells to differentiate more rapidly into active osteoclasts , thereby increase in the rate of bone resorption and hence tooth movement.

There is also increase in newly formed woven bone and uncalcified matrix because there is localized increase in calcium deposition, which neutralizes the tissue net negative charge, allows for subsequent vascularisation and initiation of osteogenesis.

Types of magnetic materials used

In the various dental applications of magnets, the following materials have been used:-

1. Platinum Cobalt (PtCo)
2. Aluminium – nickel – cobalt (ALNICO)
3. Ferrite
4. Chromium – Cobalt – iron
5. Samarium – Cobalt (SmCo)
6. Neodymium – Iron – Borin (Ne_2, Fe_{14} B)

Pioneer Work Using Magnets To Move Teeth

1978 first used resin coated Alnico magnets to move teeth in cats. They used 2 cats of similar age, weight and sex. One cat had magnets in attraction fixed to the molar and canine of one side via whole dent pins. The other side had similar pins but elastics to move teeth. The other cat had similar set up of pins but with magnet on one side and sham on the other.

Each animal served as its own control. After nine months the canines in the magnet and elastic quadrate showed approx. equal distal movement. No movement on sham side. Radiographs and histopathologic sectioning showed no pathology thus corroborating the efficiency and safety of magnets for tooth movement.

Application Of Magnets In Orthodontics

1) Tooth movement in orthodontic treatment is achieved by mechanical and / or physiologic forces acting on the teeth and their supporting structures which cause the teeth to move through bone. Traditional mechanical appliance make use of arch wires in conjunction with elastics and springs till the pioneering work and **Blechmen and Smiley** (1978) indicated that magnets have enough force to move teeth.(1)

2) **Woods M.G.** has said that repelling force of the opposing magnets is reported to cause intrusion of the posterior teeth. He tried to intrude the posterior teeth with magnets in non growing baboons. He concluded in this study that it is possible to use occlusal bite blocks containing repelling magnets to push molar teeth back into their sockets.(2)

3) **Springate S.D.** and sandier (1991) used micro magnetic retainers, as an attractive solution to fixed retention. In pettiest with persistent discussing (NE-Fe-Fe-B) (3)

4) We can use magnetic appliances for correction of Class II and Class III malocclusion. The appliances are called as **functional orthopedic Magnetic Appliances II and III** i.e. FOMA II and FOMA III.[4]

5) Magnets are used to distalize the molars. The system is called as **magnetic distalization system** (MDS).[5]

6) **John Daskologiannakis** used rare earth magnets for **canine retraction**. A magnet exerts constant force for a longer time. This property was made use for canine retraction by John. But he concluded that duration of force application seems to be a critical factor in regulating rate of tooth movement.[6]

7) Magnets are used in the treatment of **anterior open bites**. The appliances is called as **Active Vertical Corrector** (AVC).[7]

8) **Noar** concluded that Nd-FB magnets could be used to give predictable repulsive forces in the mouth.[8]

9) **Dellinger** reported that the rate of tooth movement with a removable bite block system containing repelling $SmCo^5$ magnets was considerably greater than conventional approaches.[9]

10) A new technique for hemi facial microsomia was reported by **chate.** He named the system as the Propellant **Unilateral Magnetic Appliance** (PUMA). PUMA is an appliance with SmCo5 magnets embedded in unilateral blocks of acrylic. This stimulates an autogeneous costochondral graft, in a case with hemifacial microsomia.[10]

11) **Darendeliler** used light maxillary expansion forces with the magnetic expansion device. An **active maxillary magnetic expansion device (**MAD) was developed to be used clinically. It seems that 250 – 500 g. of continuous magnetic forces can produce dental and skeletal movement in a light force expansion concept.[11]

12) **Muller** in 1984 used SmCo magnets bonded on the labial aspect of incisors reported success in closing diastemas.[12]

13) **Sandler** in 1991 viewed the problems associated traditional methods of treating an erupted teeth when there was sufficient space.[13]

Advantage of using magnets

Blechman[14] noted that present methods of treatment sepecially with elastics maybe satisfactory but problems do exist which can be over come using magnets.

Coperation in wearing elastics – failure or infrequent wear can compromise treatment. This is overcome vastly with magnets as they are totally operator controlled. Thus the demand for patient co-operation is less.

Continuous application of magnetic force results in decreasing treatment time and so eliminate deleterious effects of long treatment like periodontal problems, caries and root resorption. Shorter treatment time may make orthodontic therapy therapy available to a wider spectrum of population. Permanent magnets provide better directional force control Example—when used for inter max. force if patient opens the jaws, the air gap between the magnets increase and so the vertical component of force vector decreases. This is an advantage over elastics where there is an increase in vertical force vector which can increase the cant of occlusal plane.

Magnets are biomechanically better and can deliver continuous, high deflection, low rate force with precise control; achievement of proper moment to force ratio and tipping, root translation and torquing are possible. They produce predictable force levels without decay over time. No potential health hazards- Talc and starch used as dusting powder on elastics have been reported in the literature to be probably related to granulomatosis, plmonary talcosis, immunogenic reactions and possible carcinoma and sometimes manifesting after many years.

Magnets For Inter And Intra Maxillary Mechanics In Clinical Orthodontics

The success of animal experiments prompted to do the first in vivo magnet study using various inter and intra maxillary forces. **Blechman**[14] used a full banded technique combined with a sectional arch wire to held the magnets.

He preferred Sm Co magnets over Alnico. He listed the following technical reasons which had a direct bearing on the generated force.

1. Energy product (BXH) which is an indication of stored energy and Potential forces generated of SmCo is best suited as it has value of 14 to 31 Orstead.
2. In a general sense, the inverse square law is applicable so that small Air gap between the magnets generate proportional larger forces and Large air gaps generate relatively smaller forces.
3. The force is approx. proportional to magnet size and shape. A cube Of SmCo produced optimum test values but the natural intra oral buccolingual constraint necessitates a relatively flat square or rectangular shape.
4. Mass of magnet determines available potential force and for the Shape needed intra orally to deliver forces of 50 to 300 grams, the SmCo is ideally suited.
5. As air gap decreases between attracting magnets, a situation uique In ortho force systems develop where the force increased gradually with time and with the distance the teeth moved. Repulsion magnets have a wider range of motion because tooth movement could be started from 0 mm air gap as there is no natural stop as with attraction (i.e.when poles contact)
6. Another unique characteristic of magnetic force application is Generation of magnetic moments. By laterally off setting the poles in attraction or repulsion, in addition to vertical and horizontal vectors, a third lateral can be generated in the third plane and can be adjusted in the mouth for desirable application. Eg.can be harnessed with CI II mechanics to establish posterior, intrusion or extrusion with simultaneous cross bite correction and is operator controlled.
7. When only 2 dimensional controls are erequired, magnets can be used. For inter arch mechanics in deep bite or open bite cases. Attracting magents can extrude posterior segments in deep bite cases resulting in bite opening as well as move the teeth mesiodistally. In open bite cases, repelling magnets can intrude posterior teeth resulting in closing the bite as well as move teeth mesiodistally.

In addition to all this

a) The traditional arch wire manipulation will generate forces to about desired movement.

b) Posterior intrusion or extrusion independent of arch wire.

c) Use magnetic force only on anterior segment.

Treatment Mechanisms

1. Treatment of first premolar extraction case with class II inter arch mechanics-Force system is as illustrated.

The upper sectional arch to which the magnetic assembly is attached is free for sliding through the occlusal upper molar tube and is ligated to the mesial aspect of upper canine bracket. The lower magnet is attached to a similar sectional arch passing through the occlusal tubes of the lower molar band. Upper and lower magnets must faces each other in order to generate the force necessaery to move the upper canine distally along the base arch wire, and the lower buccal segment mesially along the base wire, if this is desired. If lower anchor loss is not required, this can be controlled in traditional way be means of tip back bends in base arch wire.

Orthodontics locks (Russell, Gurin or Miller) are attached to upper sectional arch mesial and distal to magnetic assembly and mesial to lower magnet which allows for adjustment of the air gap. The force developed in this solely determined by the distance that is said between the magnetic poles i.e. air gap becomes smaller, greater the force and conversely, greater the air gap lesser the force. Rate of decrease of force is inversely proportional to the square of distance of air gap. Clinically this results in a force which is essentially horizontal and most effective between centric and rest positions. This is significant as this range of mandibular motion occurs most ofter with reflex swallowing of saliva as well as speech and degutition.

Upper canine retraction can be enhanced if necessary be addition of a 3rd magnet to the lower sectional arch positioned menially to repel the upper magnet. Anchorage for the lower arch is provided by a full heavy arch wire.

Simultaneous closure of all four premolar extraction forces.

A three magnet assembly is used. The upper magnet assembly is as previously described. In the lower, there are two sectional arches-one connected to the molar and the other to the canine, each carrying one magnet assembly. The lower magnets are no arranged that one is mesial and the other distal to the upper magnet. I.e. the upper magnetlies between the lower two magnets in an attraction mode with a 2 millimeter air gap (56 gms). Base arches guide tooth movement and provide the anchorage. Inter maxillary magnetic forces to close extraction spaces is done with the magnets positioned on separate arch wire to effect tooth movement. To the occlusall arch wire one magnet and to the gingival sectional wire another magnet. The sectional wire is ligated mesial to the canine. Multiple magnetic force design may also be used to develop intra maxillary forces. In non extraction case - CI II mechanics can be derived from magnets is attraction or repulsion to drive the upper buccal segments distally.

(a) Attraction

The magnet arrangement is similar to the first case but the sectional arch is jfree sliding in the anterior section as it hook distal to canine bracket. Three lock stops are utilized- one each mesially and distal to magnet as well as one mesial to molar tube. Lower magnetic assembly is attached to a single sectional arch with a lock stop distal to the magnet to adjust air gap. Anchorage-in base arch.

(b) Repulsion

Repulsion mode magnet placement scan be used for CI I and CI II mechanics but also to generate buccolingual and vertical forces simultaneously if desired. But ink repulsion mode the sectional wire has to be criss-crossed.

Magnets are placed in a repulsion mode and air gap eliminated. The upper magnet is immediately mesial to the molar tube and is distal to lower magnet. Zero air gaps are to facilitate maximum forces. Both magnets are positioned so that the line of their pole faces is approximately 70^0 from horizontal to reduce interference from mandibular movement.

Magnets can be used in the repulsion mode to-

a) For canine retraction intra arch mechanics the magnets are connected to teeth wires which are criss-crosses so that smaller magnet is connected to molar and larger to canine.

b) They can be used to generate buccolingual and vertical forces simultaneously if desired by a diagonal arrangement of two magnets, and the slight buccal offset of the upper magnet. Diagonalarrangement will move upper molars distally, prevent upper segments from extruding and the off setting initiates cross bite correction.

Vector diagram of two magnets slightly offset in repulsion- a value of the differentj vector components can be determined by simple trigometry. Straight line vector force whether horizontal, vertical or diagonal can be quantified on a straight gauge. E.g. If two magnets fasces diagonally in repulsion and only the straight line vector is known, the component vectors can be determined similarly as done for horizontal and vertical components of CI II elastic. A right angle triangle projection with horizontal and vertical vector components is drawn form diagonal of the inclined planej of the magnet. Since magnitude of hypotenuse vector is know, then Cos(-)is calculated which is then multiplied by hypotenuse to give gauge vector component.

Sin(-) x hypotenuse = V vector component.

In addition to above arrangement, if the canine distally move, a third magnet can be added to the upper canine and offset verically so as to function in attraction with the mesial pole faces of the lower magnet.

Magnetic Brackets

Kawata et al[15] demonstrated that tooth movement may cause a stress that reduces various biochemical changes. In studying methods of reducing stress induced by traditions orthodontic appliances, it was found that magnetic forces inflicted a minimum of such stress to a patient.

The traditional appliance make use of metal arch wired, springs and elastics and have the property of mechanical residency and this forces weakness as the object of movement recovered from initial distortion. In an orthodontic sense, it exerts great force in the initial stage and becomes progressively weaker as the movement of teeth progresses. They suggest; when patient’s stress is considered, a desired level of tooth moving force in the initial stage should be minimal. During later stages it should increase in small increments to reach an orthodontic optimal force. As mentioned earlier, magnetic forces is inversely proportional to square of the distance and with attracting magnet applied to teeth the forces is very light at first and as the teeth begins to move forces increases as distances between magnets decreases.

The advent of SmCo magnet which could be fabricated to minimal size yet delivers sufficient force for tooth movement was then responsible for design of a magnetic bracket because of high energy product, resistance to outer demagnetizing fields and suited to a flat circuit. Improve SMCo magnet can deliver a force of 250gm compare to 50gm of older magnets at the same time the volume of material decreased. This forces magnitude is sufficient to move canines and other teeth.

Bracket design

Bracket consists of SmCo magnet coated with chromium to prevent corrosion and with nickel to allow soldering for attathing the edgewise bracket. The nickel layer allowed for soldering below 500^0C. a mesh base was soldered to rear of the bracket to facilitate retention with bonding procedures. The brackets were designed to form an ideal arch in both maxilla and mandible on completion of treatment. The edgewise bracket selected was traditional one with an 0.018 inch slot.

Advantages

1) Works effectively
2) Less discomfort
3) Less stress for patient
4) Shorter treatment time when compared to traditional appliances.
5) Decreases incidence of periodontal problems, root resorption and carries.
6) The magnetic force products a piezo electric current which will remodel a alveolar bone

Disadvantages

1) Increased cost over traditional brackets

2) Magnetic force is not sufficient to move teeth which are more than 3mm apart. Hence in such cases, an elastic chain must be added to assist the magnetic force initially. Then when the teeth come, closer i.e. within 3mm, the power chain is removed and additional retraction can be done using magnets alone.

Appliance Design For Functional Appliance

FOMA II [16]

Magnetic housing into respective plate on the dental model which was then bonded to the teeth. Buccal and lingual 0.9-mm stainless steel wire formed the metal substrate. Premolar-canine area was excluded to permit tooth erruption. The two arch wires were luted together by acrylic overlying the incisors and molar crowns. The Neodynium magnets in attraction mode were protected from the corrosion by parallel and encapsulated in acrylic housing with an intermediate layer of composite material covering the colossal area to prevent abrasion. The magnets were inclined at 25^0 to form a magneto incline plane.

Foma III [17]

Consists of upper and lower acrylic plates with a neodymieum magnets in the attraction mode in each plate upper plate has a 0.031 inch stainless steel wire reinforcement which by passes the premolar canine segment to permit eruption. Uppper magnetic housing is lined to a retraction klscrew and the magnet is positioned along with mid palatal. Screw housing is linked to plate at the M1M2 level. Two guiding powers attached to the plate lingually to central incisors and laterally to screw housing restrain the magnetic unit from vertical deflection via guiding tubes. Lower magnetic housing permanently attached to the plate in maximal proximity to lingual surface of lower central incisor. The plates were bonded to the teeth. The upper magnet linked to the retraction screw is retracted periodically to stimulate the maxillary advancement and inhibit mandible.

Magnetic Twin Block Appliance

The use of magnets in occlusal inclined planes with functional appliance mechanisms is a new development. Magnetic force is under investigation as an activating mechanism in orthodontic and orthopedic treatment. Animal experiments mandibular advancement (vardimon et al 1990) indicate an enhanced mandibular growth response to magnetic functional appliances compared with nonmagnetic appliance of similar design. Similar experiments using magnetic appliance with an adjustable screw for maxillary advancement showed mid-facial protraction with horizontal maxillary displacement and anterosuperior premaxillary rotation (Vardimon et al, 1990).

Clinical investigations are now proceeding to develop new appliance systems to harness magnetic forces. The twin block technique lends itself to the addition of magnets to occlusal inclined planes. Reports by Darendeliler and Joho [18] (1991, 1993,1995) describing the magnetic activator device (MAD)II appliance for treatment of Class II, division IL malocclusion illustrate the possibilities for the addition of magnetsto win blocks, as reported by Clark to the E.O.C in 1990. The mechanism of correction in magnetic twin blocks is the application of occlusal forces to the occlusal inclined planes. The clinician should consider the normal frequency of tooth contacts when planning treatment.

This article demonstrated the use of magnetic forces in both an autonomous fixed appliance and a magnetic activator device(MAD II)

The authors reported a case of skeletal class II and a dental class II div 1 with multiple diastemas , increased overjet,overbite and mandibular deviation to the right. A two stage treatment was instituted, the first stage to close the diastemas using a full bonded upper and lower magnetic AFA using samarium cobalt magnets to obtain continuous force. The second stage to use a removable MAD II appliance to correct class II malocclusion and mandibular deviation. The magnetic arch tends to maintain an ideal arch form and to produce a dental movements similar to those of preadjusted appliance, thus eliminating the need for wires and brackets in certain cases.

Depending on the magnets dimension and the space between magnets, this initial force varies (20-30g here)

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