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Role of Magnets in Dentistry - A Review

Monika Dwivedi[1], Varsha Verma[2]
[1]*Private practitioner, Bhopal, Madhya Pradesh, India.*
[2]*Pg student, Department of Prosthodontics and Crown & Bridge, People's Dental Academy, Bhopal, Madhya Pradesh, India.*
Corresponding Author : Dr. Monika Dwivedi

Abstract: *Magnets are a topic of interest with their numerous applications in dentistry. They have been used most commonly in orthodontics and prosthodontics. Their main use in orthodontics has been for tooth movement, maxillary expansion, in functional appliances and in prosthodontics as a retentive aid in maxillofacial prosthesis and in overdentures. The reason for the popularity of magnets is related to their small size and strong attractive forces; these attributes allow them to be placed within prostheses without being obtrusive in the mouth. The force they deliver can be directed, and they can exert their force through mucosa and bone as well as within the mouth. This article reviews the types of magnets available, designs of magnetic attachments and their reaction with bone and mucosa, their applications, followed by their advantages and disadvantages.*

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I. Introduction

Magnets have been used in dentistry for many years, most commonly in prosthodontics to aid the retention of maxillofacial prosthesis, dentures and overdentures.[1-3] In orthodontics, they have been used in tooth movement, particularly in the treatment of unerupted teeth[4], for tooth movement along archwires[5],expansion, fixed retention[6], in the correction of anterior open bite and in functional appliances. Magnets are said to have significant advantages over other materials used to move teeth, such as elastic chain or push-coil, as they are able to produce a measured force continuously over long periods of time for various kinds of tooth movement. They can be made to attract or repel and the force they deliver can be directed, and can exert their force through mucosa and bone. Magnets which were initially used were bulky, and there were concerns raised about their possible toxic effects. However, the current available literature evaluating magnetic fields shows no evidence of any direct or acute toxic effects.[7] Hopp M, Rogaschewski S, Groth T through their study found that samarium–cobalt magnets had a strong tendency for corrosion and showed considerable cytotoxicity. Neodymium–iron–boron magnets had a lesser tendency for corrosion and were only moderately cytotoxic, but coating samarium–cobalt magnets with tin or titanium rendered the material non-toxic.[8] Improved safety with better coating and the introduction of rare earth magnets led to a dramatic reduction in magnet size and stimulated further interest in the field of dentistry.[9,10]

⌗ Classification

A. Based on alloys used ;
- Those containing cobalt. Examples are Alnico, Alnico V, Co-Pt, Co5Sm
- Those not containing cobalt. Examples are Nd-Fe-B, Samarium Iron Nitride.

B. Capability to retain magnetic properties (intrinsic coercivity or hardness) ;
- Soft - These are easy to magnetize or demagnetize but magnetism is temporary. Used in electromagnets and transfomers.Examples are: Pd-Co-Ni alloy, Pd-Co alloy,Pd-Co-Cr alloy, Pd, Co-Pt alloy, Magnetic stainless steels, Permendur (alloy of Fe-Co), Cr-Molybdenum alloy.
- Hard – These are difficult to magnetise but retain their magnetism permanently. Used for permanent magnets in devices such as motors, loudspeakers, and in various household and industrial devices. Examples are: Alnico alloys, Co-Pt, Co5Sm, Nd-Fe-B.

C. Type of surface coating (materials may be stainless steel, Titanium or palladium)
- Coated
- Uncoated

D. Based on the type of magnetism
- Repulsion
- Attraction

E. Based on type of magnetic field

- Open field ,
- Closed field
- Rectangular closed-field sandwich design,
- Circular closed-field sandwich design,

F. By the number of magnets in the system

- Single
- Paired.

G. Based on the arrangement of the poles

- Reversed poles
- Non reversed poles.

Designs Of Magnetic Attachment

Magnetic system may either be ;

- Open field
- Close field
- Cup type
- Sandwich type
- Modified pole type
- Split pole with slant magnetisation
- Cylinder type

Open field system

It consists of a cylindrical magnet with open ends and can be either single or paired. Only one pole is used for the attachment to the keeper.

Close field system

It consists of paired magnets and an attached keeper and a detachable keeper. The magnet pairs are arranged with opposite poles adjacent, and magnet faces abut magnetizable alloy 'keepers'. Keepers can be either oval or circular disks. The paired magnets may be 2.5 mm in diameter and 1.5 mm high or 3 mm in diameter and 2.5 mm high. The 'keepers' are magnetizable, low-coercivity,stainless steel end plates which join the unlike poles of a magnet. These 'keepers' provide a closed field pathway for the magnetic field and almost eliminate the external field. [3,11,12] The first closed-field design was the split pole design, which consisted of two magnets arranged with opposite poles adjacent to each other. A soft magnetic keeper was attached to the top of the magnets, and a similar keeper was built into the root. The split poles can be either reversed as designed by Gillings or nonreversed split poles.Various designs exist that are based on circular andrectangular assemblies. Circular closed-field sandwichtype design has the highest retentive capacity among all.[13]

Reaction Of Bone And Mucosa To Implanted Magnets And Tissue Safety

The implantation of a platinum-cobalt alloy magnet is well tolerated by cortical bone and the overlying mucoperiosteum. A dense fibrous capsule forms around the magnet, separating it from the bone.The addition of masticatory forces to the fixed splint caused additional tension on the wires, causing resorption of the bone. The resulting mobility of the splint no doubt was a source of chronic irritation to the mucosa.[14] The safety of the rare-earth magnets has been thoroughly investigated. The effects on biological tissues has shown that static magnetic fields do not appear to result in any changes to the human dental pulp or gingival tissues adjacent to the magnets [15]. An in vitro study on osteoblasts failed to show any differences in the cell cultures when exposed to the static fields associated with these magnets [16]. Furthermore the fields do not produce any effect on blood flow [17]. The magnets themselves have a cytotoxic effect in vitro which is related to the uncoated cobalt-samarium. The uncoated neodymium-iron-boron magnet has a small cytotoxic effect on cells.[18] A model system of mouse and human fibroblasts showed that both alloys are cytotoxic and this is possibly related to corrosion products although the effect of the magnetic fields may not be discounted [19]. The human oral mucosal fibroblasts were most sensitive to the effects of these rare earth magnets. In vivo work has shown conflicting results. Cobalt-samarium magnets were implanted into the mandibles of dogs for a six month time period [20]. No pathology was seen on microscopic examination. However, only five animals were used (three magnets and two controls). In a separate study, 30 rats had small orthodontic magnets (Co-Sm) applied to the tibia with the other leg serving as a control. [21]. Morphometric evaluation showed that areas of resorbtion increased progressively after stimulation with static magnetic fields. This may be a possible inhibitory effect on the osteoblasts.

⌘ Applications Of Magnets In Prosthodontics

Magnet retained overdentures

Magnets are used as retentive aids in tooth supported and implant supported overdentures. Samarium-cobalt is the most widely used magnet in dental applications. It has shown to deliver twice the magnetic field strength of previously used Alnico and platinum-cobalt magnets. More importantly, rare earth magnets deliver high attractive forces in very small sizes that is a prime consideration in dental appliances.

Magnetic systems do not direct undue stress to root-abutments, as mechanical “lock-on” attachments do. Also magnets do not resist lateral movement of overlay appliances; they merely slide across the faces of the keepers, the ferromagnetic inserts cemented into the abutment tooth.[22]

Magnets in maxillofacial prosthesis

The use of magnets as a retentive aid is the most efficient means of providing retention and stability in patients with deformities requiring complex rehabilitations. In large intraoral defects, the prosthesis can be divided into oral and obturator sections. And obturator section can be further divided into two or more parts, if needed. The majority of such prostheses are designed with using magnetic pairs to connect the sections. The magnets are embedded in the respective contacting surfaces at a depth of 0.5 mm. Magnets are used in orbital prosthesis, auricular prosthesis, large and small maxillary defects and intra oral-extra oral combination prosthesis.[23] Due to their strong attractive forces Fe-Pt dental magnetic attachments are commonly used for retention of prostheses. And since the Fe-Pt magnetic attachment system (magnet and keeper) can be cast in a dental casting machine, any size or shape of castable magnetic attachment can be fabricated for prostheses. It has been estimated that dental magnets can provide about 300 g of standard magnetic retentive forces. Also, these forces are constant and they do not decrease with time and use.[24]

Magnetic retention for sectional dentures

Applications of cast iron-platinum keeper to collapsed denture[25] and NdFeB magnetic attachments[26] incorporated in sectional denture for patients with microstomia.

⌘ Applications Of Magnets In Orthodontics

Magnets used to close diastemas, for relocation of unerupted teeth, as retainer, for correction of hemifacial microsomia and for molar intrusion.

In 1984, Muller[27] used small rectangular magnets (approximately 531 mm) directly bonded to the labial aspect of the teeth to deliver light continuous forces to close diastemas without archwires. He suggested that tooth rotations and angulation problems can also be corrected with this technique.

In 1987, Kawata et al[28] soldered Sm-Co magnets plated with chromium and nickel to Edgewise brackets for administration of mesio-distal magnetic forces for closure of interdental space.

Vardimon et al[29] introduced a magnetic attraction system, with a magnetic bracket bonded to an impacted tooth and an intraoral magnet linked to a Hawley type retainer. Vertical and horizontal magnetic brackets were designed, with the magnetic axis magnetized parallel and perpendicular to the base of the bracket, respectively. The vertical type is used for impacted incisors and canines,and the horizontal magnetic bracket is applied for impacted premolars and molars.

Springate and Sandler[30] in 1991 reported the use of two Nd-Fe-Bo micro-magnets as fixed retainers bonded to mesio-lingual surface of central incisors to retain closure of mid-line diastema, as they does not hinder oral hygiene. In 1995, Chate[31] reported the development of the PUMA or Propellant unilateral magnetic appliance, which uses magnets incorporated in unilateral bite blocks for correction of hemifacial microsomia.

Hwang and Lee[32] (2001) reported the use of magnetic force in conjunction with a corticotomy procedure, to intrude over erupted molars following loss of their antagonist.

Maxillary expansion and molar distalization

Repulsive magnetic forces for maxillary expansion were first described by Vardimon et al[33] using samarium-cobalt magnets on monkeys. Repulsive magnetic force was applied using direct as well as indirect placement of magnets. This showed that the expansion is slow compared with rapid maxillary expansion and, consequently, there are fewer tendencies for the mid-palatal suture to fracture. In addition, as the forces can be made to be more physiological it avoids the complications of the rotations of the maxilla seen in the high force appliances, such as rapid maxillary expansion (RME).

Gianelly et al[34] reported the intra-arch placement of repelling magnets against the maxillary molars in conjunction with a modified Nance appliance that was cemented on the first premolars, to distalize the Class II molars. Itoh et al[35] described an appliance called the Molar Distalization System, which also made use of repelling magnets. The mesial magnet of each pair is mounted so that it can move along a sectional wire.

Bondemark and Kurol[36] treated a group of ten patients by distalization of 1st and 2nd molars simultaneously, using a similar appliance, but they included the second premolars as anchorage.

Functional appliances for class II and class III malocclusions

Vardimon et al introduced new functional appliances to correct Class ll dento-skeletal malocclusions and Class lll malocclusions that exhibit midface sagittal deficiency with or without mandibular excess,called the functional orthopedic magnetic appliance (FOMA) II and III respectively. The (FOMA) II uses upper and lower attracting magnetic means ($Nd_2Fe_{14}B$) to constrain the lower jaw in an advanced sagittal posture.[37] The FOMA III consists of upper and lower acrylic plates with a permanent magnet incorporated into each plate. The upper magnet is linked to a retraction screw and is retracted periodically (e.g., monthly) to stimulate maxillary advancement and mandibular retardation.[38] Darendeliler et al treated a case of Class III dental malocclusion and bilateral cross bite with a combined magnetic activator device (MAD) III and MED appliance.Upper and lower buccally placed Samarium cobalt (Sm_2Co_{17}) magnets were used for correction of antero-posterior discrepancy.[39]

Magnetic appliance for treatment of obstructive sleep apnea, snoring

Bernhold and Bondemark used a magnetic appliance to treat 25 male patients with handicapping snoring or obstructive sleep apnea. It consisted of a maxillary and a mandibular occlusal acrylic splint. In each splint, four cylindrical neodymium-iron-boron magnets were embedded and oriented to produce inter-maxillary forces that pulled the mandible forward. The appliance made the mandible rotate downward and backward, mean 7.8°, and this rotation mostly camouflaged the forward movement of the mandible.[40]

Gavish A, Vardimon AD (2001) conducted analyses and concluded that the functional magnetic system is a reliable mandibular repositioning appliance that has no apparent adverse effects.[41]

Advantages Of Magnets

- Magnets allows for upto 24 degrees of abutment divergence,which provides for an easy non-critical path of prosthesis insertion and removal.
- Parallelism of the roots or implants is not must .
- Soft tissue undercuts may be engaged.
- Automatic reseating if dislodged during chewing.
- Easy replacement if needed
- Small size with strong attractive force.
- Dissipates lateral or rotational functional forces.
- Roots with as little as 3mm of bone support are adequate for use as abutments with magnetic appliances.
- They do not directly induce stress to root abutments.
- Ease of cleaning

Disadvantages Of Magnets

- The main problem associated with the retention of magnets is corrosion .The SmCo and Nd-Fe-B magnets posseses the properties of brittleness and susceptibility to corrosion, more seen in chloride-containing environments such as saliva and the presence of bacteria increases the corrosion of Nd -Fe-B magnets.
- Mechanisms responsible or corrosion of magnetic attachments are,
  - The breakdown of the encapsulating material.
  - Diffusion of moisture and ions through the epoxy seal.
- It is therefore necessary to encapsulate or coat the magnets for use in dental applications. However, continual fading of the encapsulating material leads to more exposure of the magnet.
- Formation of deep scratches and gouges due to wear on the surface and also by debris and other particles that become trapped between the magnet and the root.
- Loss of retention that is provided by the attachment.
- The abrasive nature of the titanium nitride-coated soft magnetic tooth keeper which is also used with some implant system may lead to excessive wear of the magnet.
- High cost
- Short track record
- Cannot be repaired only replaced

II. Conclusion

The intraoral usage of magnets in early times were unsuccessful, mainly because of the large size of magnets at that time and the inadequate forces that they provided. However, since the introduction of rare earth magnets, such as samarium-cobalt and neodymium-iron-boron, it has become possible to produce magnets with small enough dimensions to be used in dental applications and still provide the necessary force. Within 10 years, magnetic forces have gained good acceptance in correction of skeletal and dental defects. In prosthodontic cases, the magnetic denture retention system is not advocated as a replacement for conventional precision retainers but as a useful alternative where, for reasons of convenience, cost, patient motivation or poor prognosis, conventional retainers are unsuitable. In orthodontic cases, magnets exert continuous forces with less friction, compared to other conventional orthodontic appliances. Teeth movement are bodily in nature and treatment time is shorter. They can be associated along with fixed, removable and functional appliances. The incidence of periodontal disturbances, root resorption and caries are considerably low and foremost no discomfort. However, the long term durability of the magnets remains a problem as they undergo tarnish and corrosion. Tarnish and corrosion products are cytotoxic. Tarnish and corrosive nature is prevented by casing them in stainless steel jackets (or) giving parylene coat.

Further research is required in the following areas: the biological compatibility of the new rare earth magnets, the corrosion resistance and the wear of the steel casing. Such research will hopefully provide a permanent magnet which will be resistant to the adverse environment of the oral cavity.

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