Review Article

A Close-Up On Obturators Using Magnets: Part I - Magnets in Dentistry

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Magnets have been used in Prosthodontics since 1960 for various purposes, like for retention in over dentures, implant-supported dentures, partial dentures and for maxillo facial prostheses. However, insufficient literature is available in this aspect of treatment procedure. Part I of this article discusses history of dental magnets, different types available, classification, their general properties, mechanism of action, biocompatibility and recent developments in great detail.

INTRODUCTION

The use of magnets has been popular in dentistry. They are being used as retentive aids for overdentures, removable partial dentures, implants and in orthodontics for correction of malocclusions & for treating unerupted teeth. In Maxillo facial prosthodontics they have been used for decades to reconstruct large defects with the help of multiple component prostheses. Javid, in 1971,[1] constructed an extensive prosthesis for both extra-oral and intra-oral aspects connected with magnets. In 1976, Federick[2] rehabilitated a patient with large orofacial defect using a 2-component obturator that was locked to each other with the help of magnets. A simple technique for the use of magnets in over dentures was described by Moghadam et al,[3] in 1979. This technique did not require surgical procedures but the magnets were attached to the roots and the base of the dentures. Advances in technology have made available a new family of magnetic alloys based on cobalt and other rare earth metals. They are small but strong and can be used for dental purposes for retention. The mutual attraction of unlike poles has been utilized successfully to assemble multicomponent, maxillofacial prostheses and even sectional dentures.

First part of this article discusses the history, different types of magnets for dental applications, classification, their design and properties, advantages and disadvantages, their effects on tissues and the safety factor of using them in dentistry.

HISTORY

Magnets were first introduced for applications in dentistry in the year 1953 in the field of orthodontics. They were used to extrude impacted teeth, close diastemas and achieve an ideal arch form, to distalize the molar, expand the maxilla transversely and to intrude the posterior teeth in open bite cases. They were also used in functional orthopedic appliances and in intra oral appliance for treatment of snoring patients. Various capabilities of magnets like, attractive forces, repulsive forces and a combination of both were used to correct malocclusions.

Later, conventional magnets were applied in restorative dentistry in the year 1960 as retentive devices for over dentures, removable partial dentures, and maxillo facial prostheses. One of the earliest magnets was paired Alnico. It is a permanent magnet alloy of iron, cobalt, nickel and aluminum. It was used to maintain the seating of maxillary and mandibular complete dentures with the help of its mutual repulsion of like poles. The magnets were embedded in the bases of the dentures with like poles oriented toward each other. But the main disadvantage of this system was the large size required to achieve adequate repulsive force to retain the dentures in place when the jaws were apart. Also, the constant repelling forces promoted resorption of the bone and the alveolar ridge.

Hence, mutually attractive forces of paired magnets were used as retentive aid for sectional dentures, maxillofacial prostheses, obturators and complete dentures.

Alnico V used attractive forces, which had rectangular and cylindrical forms available. They were surgically embedded in the mandible, but because of the distance between the two magnets they provided insufficient retentive force.

Coated and uncoated cobalt-platinum bar magnets (Co-Pt) were implanted in the mandible by Behrman and Toto et al, to retain a denture. Coated magnets exhibited, no adverse physiologic effects, favorable bone response, enhanced denture retention and encouraged tissue reaction. Where as uncoated magnets which were implanted in the mandible moved over a period of time through the bone eventually to come in contact with the opposing one. Even though these magnets were smaller and stronger, because of their high cost, limited availability and difficulty in fabrication, they were soon abandoned.

In late1960s another permanent magnet in which cobalt was alloyed with samarium (Co_5Sm) was introduced. This has twice the magnetic field strength of Co-Pt and the strongest of the Alnico alloys. The outstanding property of Co_5Sm is its extremely high magnetic permanence. (Hardness). These magnets could be produced in very small dimensions and approximately one fifth of Co-Pt magnets and still could provide the same force. A proplast (Polytetrafluoroethylene and pyrolytic graphite) coating was given for protection *in vivo*. This provided corrosion protection only if there was no faults or damage to the magnets during surgical placement. Nowadays, the proplast is no longer used as coating material but the polytetrafluorethylene (PTFE) is being used as a binder in polymer-bonded magnets. But these are not suitable for long-term usage of magnets in the body as diffusion of moisture through the polymer results in loss of corrosion resistance.[4]

Another alloy based on neodymium-iron-boron (Nd-Fe-B), became available in 1980s for dental applications.[5] Both Co_5Sm and Nd-Fe-B are termed as rare earth magnets (RE) because they are rare from the standpoint of extraction.[6] Both are excellent for dental applications because of their small size and relatively high retentive capacity. They also exhibit high intrinsic coercivity (they do not tend to demagnetize).[6] However, they are brittle and have low corrosion resistance. In spite of encapsulating them in stainless steel, titanium or palladium, if these coating materials wear out, they cause deleterious effects on the tissues and this may be increased in the presence of bacteria such as Streptococcus sanguinus.[5]

To overcome the above problem, another material, samarium iron nitride is being developed for medical and dental applications. It is highly resistant to demagnetization and has better resistance to temperature and corrosion than Nd-Fe-B type magnets. This material is still under development.[4]

CLASSIFICATION OF MAGNETS

A. Based on Alloys used

- Those containing cobalt Examples are Alnico, Alnico V, Co-Pt, Co_5Sm
- Those not containing cobalt Examples are Nd-Fe-B, samarium iron nitride

B. Based on ability to retain magnetic properties (intrinsic coercivity or hardness)

- Soft (easy to magnetize or demagnetize) (less permanent) 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 (retain magnetism permanently). Examples are: Alnico alloys, Co-Pt, Co_5Sm, Nd-Fe-B.

C. Based on 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,

F. Closed field

- rectangular closed-field sandwich design,
- circular closed-field sandwich design,

G. Based on number of magnets in the system

- single,
- paired.

H. Based on the arrangement of the poles

- reversed poles,
- nonreversed poles.

PROPERTIES OF MAGNETS

Mechanism of magnetism

Every atom in a material is a magnet because the electrons orbit its nucleus. While these electrons move they produce a magnetic field around the atom. If these electrons are paired, they cancel out unlike when there are unpaired electrons. The unpaired electrons create tiny magnetic fields. Fe, Ni and Co are some of the materials having these unpaired electrons that create the magnetic fields. The atoms, which have the tiny magnetic field align in small regions called as "domains", when the material is magnetized. When these domains are arranged randomly, the materials are demagnetized.

On application of a magnetic field, these domains align to reach a saturation point. On reaching the saturation point, the material said to have been magnetized. Some materials require small magnetic field to reach the saturation point, some require larger magnetic field. When the material takes a small magnetic field to become magnetized, that material is called "soft" magnet, where as if the material takes up large magnetic field to be magnetized, such material becomes a "hard"magnet. When the external magnetic field is removed, if the material retains its magnetization (remanence), it is called as a permanent magnet. The amount of this external magnetic field required, and the amount of the remanence gives an indication of the power of the permanent magnet.[4]

Larger the value, greater is the flux density produced by the magnet of a given volume.

Flux density refers to the magnetic field strengths around the magnet. It is usually measured in millitesla. It is measured with the help of a miniature Hall probe and gauss meter. This flux density can be measured both in axial direction and lateral direction of a magnet. In an open-field magnet, this can be measured in both directions, where as in a closed-field magnet, there is no axial flux as the magnetic field gets cancelled due to the presence of north pole and south pole arranged in opposite directions and due to the presence of a "keeper" at both ends. These keepers channel the flux from one pole to the other at each end. In fact, even the lateral flux distribution in a closed-field system is less than an open-field system by 1/30 to 1/200. In studies done by Toto et al and Behrman, they used magnetic field strengths from 100 to 1000 millitesla near the tissues to study their effect. They found that when a open-field magnet exerted about 7 to 20 millitesla magnetic effect, a closed-field exerted only about 0.1 millitesla flux on the tissue adjacent to the magnet say 5 mm away. This effect is only twice that of earth's magnetic field. (0.03 – 0.06 millitesla or 0.3 – 0.6 Gauss)[7,8,9]

The new rare earth magnets like cobalt-samarium have twice the magnetic field strength of any known Alnico alloys and they have extremely high magnetic permanence (Hardness)[7,8,9]. Coercivity of cobalt-samarium is five times that of Cobalt-Platinum and more than 10 times that of Alnico alloys. Because of this property they can be made extremely small and still maintain their high magnetic field strength. They can be made in dimensions of 2mm or even less, which permits their use in over dentures.

Designs available

An open-field system consists of a cylindrical magnet with open ends. It can be either single or paired.

A closed-field system of magnets 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.[7,8,9]

The first closed-field design was the split pole design, which consisted of 2 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 and rectangular assemblies. Circular closed-field sandwich type design has the highest retentive capacity among all.[4]

Breakaway loads (retentive forces)

Breakaway loads were estimated between the retention unit of the magnet system and the keeper element with various keeper thicknesses. The thickness of the attached keeper was maintained constant, where as thickness of the detachable keeper ranged from 0.3 to 2 mm. With an optimum thickness of the keeper as 1 mm, the breakaway load observed was about 200 grams. Thinner keepers resulted in lower breakaway loads. Increasing the thickness beyond 1mm did not alter breakaway load appreciably. The material used for the above experiment was soft iron. Equivalent keeper thickness for magnetizable stainless steel alloy is about 1.2 mm.[7,8,9]

The above experiment was carried out to determine the breakaway load required to separate the keeper that is in contact with the retentive element. Clinically this explains the force required to dislodge the denture when the keeper element and the retentive elements are in contact. However, this does not explain the reseating forces that are required once the dentures are dislodged. Reseating forces are measured in the same way but layers of paper were interposed between the keeper and the denture retentive element to vary the initial separation. At zero degree separation between the two, the breakaway load for a closed-field assembly is twice that of an open-field system. Up to 0.3 mm of initial separation, this holds true but as the initial separation increases, the load rapidly decreases. But with the initial separation of greater than 0.3 mm, the open-field system offered more reseating force.[7,8,9]

Breakaway load tests were performed to determine the optimum air gap between the magnet segments. The gap should be present between the segments to ensure that the forces pass through the keepers. If the magnetic forces do not pass through the keepers they will not offer retention, as the forces would jump from one segment to the other. Optimum air gap was found to be 0.5 mm.[7,8,9]

Generally, the open-field systems provide less retentive forces compared to closed-field systems. However, even though the closed-field systems provide higher retentive forces, the retention reduces rapidly with increasing separation.[4] Paired magnets provide a greater breakaway force than a single magnet with a soft magnet keeper. A reversed split pole system provides a greater force than a nonreversed split pole design. Even among closed-field systems, a circular closed-field sandwich type design provides a greater amount of retention. If the keeper is made ellipsoidal, instead of oval or circular, the retention increases further.

The retentive characteristic of different magnetic systems that are used for dental applications has been studied by Highton, et al. in the year 1986.[6] They compared six commercially available systems, where five were of closed field nature and one was open field. They observed that greatest retention was achieved when the magnet and the keeper were in intimate contact without any air gap. At 0.1 – 0.5 mm gap between the two surfaces, the retentive qualities decreased rapidly and all the systems exhibited similar changes. But they also noticed that the retention offered with these gaps was adequate clinically and was equivalent to the retention given by an I-bar. They advice a controlled system to develop minimum air gap between the magnet and the keeper during denture processing, as, too close contact between them would have deleterious effect on the supporting structures of the denture due to too much of breakaway force.

Corrosion

A magnet has poor corrosion resistance in the oral fluids, especially the uncoated ones. Both the rare earth magnets are brittle and are susceptible to corrosion. They corrode rapidly in saliva and the presence of bacteria enhances corrosion of Nd-Fe-B magnets. These corrosive products have been found to have cytotoxic effects on the tissues. Hence, they should be encapsulated prior to placement in the oral cavity. Stainless steel and Titanium have been the most commonly used materials but polymeric materials also have been used.[4] However, continuous wearing of these coating materials leads to the exposure of the magnets. It was found, by Gillings that, a metal of 0.0015 inch thick wore through after about only 6 months. The pitting corrosion of stainless steel also occurs in the oral environment. To overcome these problems, other coating materials such as titanium and chromium nitrides have been used to prevent wear. The pole pieces used currently are 0.25 mm thick and have a life span of about at least 10 years before perforation.[7–9]

In polymeric materials diffusion of moisture and ions attack the magnets through the interface between them. To avoid this problem non-permeable sealing techniques like laser welding are being tried these days. One such system, which uses laser welding is the open-field system like Dyna, of Netherlands and the other being the Steco of Germany.

A Recent material, which is being investigated as a new candidate for permanent magnet applications is, samarium iron nitride. It has better corrosion resistance than even Nd-Fe-B.[4]

EFFECTS OF MAGNETS ON TISSUES AND THEIR SAFETY FACTORS

There are two possible ways by which a magnet can cause injury to the tissues. They are: 1. Physical effects due to the steady magnetic fields (magnetism) around them. 2. Chemical effects of alloys and their corrosion products.

1. In 1960, Behran studied the physical effects on bone and soft tissues of 450 subjects and concluded that magnetism is completely innocuous to tissues. In 1979, Cerny observed that embedded magnets do not cause adverse effects in experimental animals.

   Effects of the magnetic fields have been studied extensively, with conflicting results. But for dental applications there is no claim of any damaging tissue effects. The closed-field system has better tissue compatibility when compared to a open-field system. The denture-retention element abuts the keeper in the root and holds the denture with the help of magnetic attraction. When in position, there is no external field surrounding the denture or the root.
2. In 1979, Tsutsui and his colleagues stated that cobalt-samarium is not harmful chemically. Cobalt has been an essential dietary trace element in ruminants. Samarium salts are not considered toxic. Another rare earth salt cerium oxalate (which also contains samarium) has been recommended as a treatment for sea sickness in dosages up to 1 gm/day.

However, Walmsley[5] suggests that the magnets have to be encapsulated in any of the materials mentioned earlier. He observed that if the coating wears out, the magnet would come in contact with saliva, which can corrode the magnet. Corrosion rate can increase in the presence of bacteria like *Streptococcus sanguinus*. Thus life span of the magnet may decrease. Also, coated magnets have been found to produce no effect on human dental pulp, gingiva or osteoblasts or blood flow. Only uncoated magnet has cytotoxic effects on the cells. Oral mucosal fibroblasts are most sensitive to effects of these rare earth magnets.

ADVANTAGES OF USING MAGNETS

- ease of placement
- automatic reseating
- constant retention with many cycles

- easy replacement if needed
- small size with strong attractive forces
- can be placed within the prosthesis
- dissipate lateral functional forces
- less need for parallel abutments
- can be used for implant-supported prosthesis
- ease of cleaning

Disadvantages of using magnets

- low corrosion resistance
- cytotoxic effects of the lea chants
- high cost
- short track record

CLINICAL USAGE

- removable partial dentures
- over dentures
- maxillo facial prosthesis
- implant supported prosthesis
- complete dentures

SUMMARY

This article has discussed the history of magnets, the mechanism of magnetism, properties, their effects on the living tissues and applicability in dentistry in detail. From the earliest, large sized Alnico materials, to the recent small sized, yet powerful Nd-Fe-B materials have been used in dentistry for retention of complete dentures and over dentures. Also, multi component maxillo facial prosthesis where in the extra oral component has been attached to intra oral component or the bulb portion of the defect has been attached to the intra oral prosthesis.

However, their inability to resist corrosion in the oral environment has made the fabrication of these magnets difficult thereby increasing the treatment cost. Still the encapsulating materials such as stainless steel are susceptible to wear during their use thus shortening the life span of the magnets. The development of samarium-iron-nitride as a magnetizeable material may offer better corrosion resistance and use of magnets in prosthodontics may be viewed with much interest in future.

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