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ORIGINAL ARTICLE

Effect of corrosive environments and thermocycling on the attractive force of four types of dental magnetic attachments

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Abstract *Background/purpose:* One of the problems that has limited magnets' wide acceptance by clinicians is their low corrosion resistance. The purpose of this study was to determine the effect of corrosive environments and thermocycling on the attractive force of different types of new generation magnetic attachments.
Materials and methods: We measured the attractive forces of 60 magnetic attachment systems (Hyper slim, Hicorex slim, Dyna, and Steco) with a universal test machine. We then immersed 40 of the magnetic attachment systems in two media, namely, 1% lactic acid solution (pH 2.3), and 0.9% NaCl solution (pH 7.3). The remaining magnetic attachments were put through 10,000 thermal cycles (5 °C/55 °C). We measured the attractive forces of the magnetic attachment systems again after immersion and thermocycling to compare data. The data were statistically evaluated with one-way analysis of variance, paired samples *t*-test, and *post hoc* Tukey–Kramer multiple comparison tests ($\alpha = 0.05$).
Results: We found significant differences between the mean values before and after immersion in corrosive environments ($P < 0.05$). In contrast to the Dyna and Steco systems ($P < 0.001$), the differences between the attractive forces before and after thermocycling were not statistically significant for the Hicorex slim and Hyper slim systems ($P > 0.05$).
Conclusion: Magnetic attachments showed lower attractive force after immersion in corrosive environments compared to their initial retentive force. In addition, closed-field systems were not affected by the thermocycling procedures and were more resistant than open-field systems to thermal variations characteristic of the oral cavity.

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Introduction

Over the past century, dental magnetic attachment systems have been used in prosthodontics[1–5] and orthodontics[6–8] to retain dentures, for overdenture retention,[2,8–11] and for multicomponent maxillofacial prostheses.[12] Magnetic attachments have several advantages, such as ease of cleaning, retention that is not reduced with use, ease of placement for both dentist and patient, automatic reseating,[5] and less horizontal stress transmission.[11]

The first recorded use of magnets in dentistry can be dated to 1941, when Freedman used curved magnets to improve the stability of dentures for grossly resorbed mandibular alveolar ridges.[13] Then in 1950, Behrman surgically implanted magnets in the mandible of an edentulous patient.[5,13] These first attempts used aluminum—nickel—cobalt (Al—Ni—Co) magnets. In 1952, the introduction of smaller and stronger cobalt—platinum (Co—Pt) magnets allowed continuation of clinical trials.[14] These early magnetic systems were unsuccessful mainly due to the large size of the magnets required to provide adequate retentive force and their lack of corrosion resistance in the oral environment. Significant advances have been made in the development of hard magnetic substances, and these advances have been quickly transferred into dental applications. The introduction of rare earth magnets such as neodymium—iron—boron (Nd—Fe—B) and samarium—cobalt (Sm—Co) has resulted in magnets with small enough dimensions to be used in dental applications that still provide sufficient force.[15] Since the advent of these small rare earth magnets, dental applications using magnets have increased.

Both neodymium—iron—boron and samarium—cobalt are extremely brittle and susceptible to corrosion, especially in chloride-containing environments such as saliva.[5,16] Preventing corrosion of magnets is the main problem that limits their long-term clinical use. One approach is encapsulation in stainless steel or titanium within the oral environment.[5,8] Corrosion occurs by breakdown of the encapsulating material or diffusion of moisture and ions through the epoxy seal.[16] Nowadays, a highly reliable technique, laser welding sealing, is in use on the new generation of magnetic attachment systems. In this technique, a shield ring made of stainless steel (SUS447J1 or SUS316L) or titanium is welded in the boundary between the cup and disk yokes using a laser beam.[17] On the other hand, a variety of magnetic systems including open- and closed-field are available. Attachment of closed-field magnets is more efficient because both the north and south poles are used to attract the keeper, and the keeper can contain magnetic flux, whereas only one pole is used in open-field systems.

In the oral cavity, materials are usually subject to thermal variation. Such thermal variation may cause fatigue fractures in the material during long-term clinical use.[18] Therefore, magnetic attachments must have high resistance to the thermal variation of the oral cavity. Thermocycling has been proposed as an efficient method to provide *in vitro* simulation of *in vivo* conditions. Thermocycling simulates the introduction of hot and cold extremes in the oral cavity that occur through eating, drinking, and breathing, thus simulating the natural aging process of dental restorations.[19] The ISO TR 11450 standard indicates that a thermocycling regimen of 500 cycles in water between 5 °C and 55 °C is an appropriate artificial aging test.[20] A recent literature review concluded that 10,000 cycles corresponds approximately to 1 year of *in vivo* exposure.[21]

The purpose of this study was to examine both the effect of two different pH corrosive environments and the effect of thermocycling on the attractive force of different types of new generation magnetic attachments. The null hypotheses were: (1) there is significant difference in attractive force of magnets after immersion in corrosive environments; and (2) attractive forces of magnets are not affected by thermocycling procedures.

Materials and methods

We selected four types of magnetic attachment systems for this study: Hyper slim 5513 (Hitachi Metals; Tokyo, Japan), Hicorex slim 3513 (Hitachi Metals), Dyna 500gr (Dyna Dental Engineering; Bergen, Holland), and Steco-Teleskop Titanmagnetics (Steco-system-technic; Hamburg, Germany) (Table 1). We prepared 120 acrylic resin blocks with dimensions of 20 × 20 × 20 mm using autopolymerizing acrylic resin (Vertex Orthoplast; Vertex-Dental B.V., Zeist, Holland). Magnetic attachments were embedded in the center of the acrylic resin blocks. Then, we fixed the specimens to the jigs of the testing machine with an adhesive resin (Super Bond; Sun Medical Co., Shiga, Japan). We measured the attractive forces of the attachment systems using a universal testing machine (Lloyd LF Plus; Ametek Inc. Lloyd Instruments, Leicester, United Kingdom) at a head speed of 50 mm/min. For each attachment system, we measured the attractive force by attaching the specimen to five different magnets measurements, repeating this procedure 10 times, and then averaging the data.

After the measurement of the attractive forces, the magnets were immersed in two corrosive media. We immersed five of each type of specimens individually in each plastic plate (Fıratmed; Fıratmed, Istanbul, Turkey)

Table 1 General properties of magnetic attachments.

	Magnetic field	Rare earth magnet	Use
Hyper slim	Closed-field	Nd—Fe—B	Sectional denture and obturator
Hicorex slim	Closed-field	Nd—Fe—B	Sectional denture and obturator
Dyna	Open-field	Nd—Fe—B	Root and implant
Steco	Open-field	Sm—Co	Root and implant