# Effect of surface treatment with commercial primers on tensile bond strength of auto-polymerizing resin to magnetic stainless steel

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**Purpose**: It often happens that magnets clinically detach from denture bases. To establish the appropriate laboratory procedure to fix the magnet in the denture base, the tensile bond strength of magnetic steel in auto-polymerizing resin was measured under several conditions.
**Materials and Methods**: Magnetic stainless steel cylinders (AUM 20) of 4 mm diameter were prepared as specimens. The cross section of the specimens was ground with silicon-carbide abrasive paper (#800) to create a bondable surface. After grinding, half of the specimens were treated by air abrasion with 50 μm alumina. Both surfaces were treated with one of the three commercial primers: Metal Primer II (MPII), Metal Link Primer (MLP), and Meta Fast Bonding Liner (MFL). Auto-polymerizing resin was poured on the bonded surfaces of the metal. The tensile bond strength between the metal and resin was measured after the specimens were stored in water at 37˚C for 24 hours. Thermal cycle examinations, with immersion alternately in water baths at 4˚C and 60˚C for 1 minute up to 2,000 times were conducted.
**Results**: The bond strength of sanded surfaces with primer treatment varied from 21.6 to 32.2 MPa and the value increased significantly when primer treatments other than MPII were used. The bond strength of air-abraded surfaces with primer treatment varied from 31.1 to 38.3 MPa and the value increased significantly with all primer treatments. Bond strengths of all groups were significantly reduced by the application of thermal cycling ($p<0.05$). The bond strength of air-abraded surfaces with primer treatment varied from 3.6 to 4.2 MPa and the bond strength was significantly ($p<0.05$) larger than those in other groups.
**Conclusion**: The combination of air abrasion and primer application is the most effective procedure to fix the magnet. **(Int Chin J Dent 2005; 5: 7-11.)**

**Clinical Significance**: To solve the clinical problem of magnetic detachment, enhancement of bond strength is necessary.
**Key Words**: air abrasion, magnetic attachment, magnetic stainless steel, primer, tensile bond strength.

## Introduction

In the prosthodontic field, magnetic attachments that help to retain overlay dentures are being widely used and are becoming popular in the Asian and European regions.[1] This device was originally used as a stud attachment on the root cap and is becoming more widely applicable to dental implants and extracoronal attachments.[2] Asian people in particular have poor bone morphology and magnetic attachments are very useful for implant-supported/retained overlay dentures.

Magnetic attachments have several advantages: ease of dental laboratory and clinical work, and stability of retention force. Magnetic attachments consist of two parts: a rare earth magnet covered by stainless steel and a magnetic steel keeper. The keeper is fixed to an abutment coping using either cast-to technique, cementing or welding.[3] The magnet is embedded in the denture base using auto-polymerizing resin in the mouth. However the magnet often detaches from the denture base because of low bond strength between the resin and the magnetic stainless steel. Although various improvements have been reported: application of an undercut on the magnet, surface treatment of the magnet, and primer application on the magnet surface,[4] limited information is available concerning bonding procedure between the magnet and denture base, especially as related to chemical bonding primers. In addition, the magnetic stainless steel around rare earth magnet, has also been improved from SUS 316L (16%Cr-12%Ni-2%Mo-remaining Fe) to AUM 20 (19%Cr-2%Mo-0.2%Ti-remaining Fe).[5] The purpose of the present study was to evaluate bonding strength using commercial bonding primers on surface treatments and to clarify the appropriate clinical procedure for fixing magnet to the denture base.

## Materials and Methods

Magnetic stainless steel cylinders (AUM 20, 19%Cr-2%Mo-0.2%Ti-remaining Fe, Aichi Steel, Tokai, Japan) of 4 mm diameter were prepared as specimens. This material is the same material as the surface material of the magnet in the commercial magnetic attachment.

**Table 1.** Primers used in this study.

| Trade name | Manufacturer | Lot number | Adhesive monomer | Abbreviation |
|---|---|---|---|---|
| Metal Primer II | GC Corp., Tokyo, Japan | 0211131 | MEPS | MPII |
| Metal Link | Shofu Inc., Kyoto, Japan | 080304 | 10-MDDT, 6-MHPA | MLP |
| Meta Fast Primer | Sun-Medical Co., Ltd., Moriyama, Japan | 30301 | 4-META | MFL |

MEPS, methacryloyloxyalkyl thiophosphate derivative; 10-MDDT, 10-methacryloxydecyl 6,8-dithiooctanate; 6-MHPA, 6-methacryloxyhexyl phosphonoacetate; 4-META, 4-methacryloyoxyethyl trimellitate anhydride.

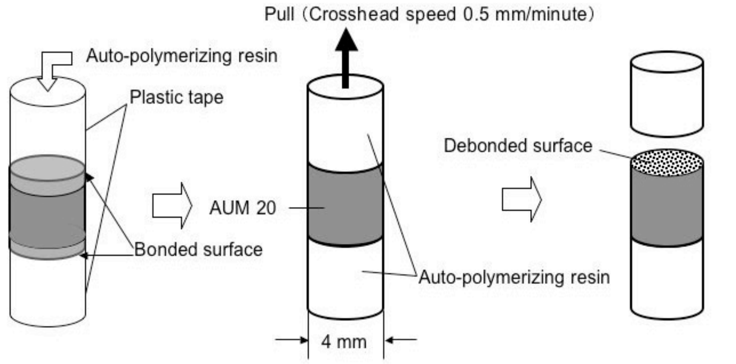



**Fig. 1.**
Diagram of tensile bond testing.

As a bonded surface the cross section of the specimen was ground with 800 grit silicon-carbide abrasive paper. After grinding, half of the specimens were treated by air abrasion with 50 µm alumina. The air pressure was 0.4 MPa and the distance of the nozzle from the bonded surface was 20 mm. Both surfaces were treated by one of the three commercial primers: Metal Primer II (MPII, GC, Tokyo, Japan), Metal Link Primer (MLP, Shofu, Kyoto, Japan), and Meta Fast Bonding Liner (MFL, Sun-Medical, Moriyama, Japan). Information on the primers is summarized in Table 1. Auto-polymerizing resin (Provinice, Shofu) was poured on the bonded surfaces of the specimens surrounded by plastic tape as shown in Fig. 1. The specimens were stored in water at 37˚C for 24 hours. The tensile bond strength was measured using a universal testing machine (AG-100A, Shimadzu, Kyoto, Japan) at cross head speed of 0.5 mm/minute before and after thermocycling (cycled between 4˚C and 60˚C water with a 1-minute dwell time per bath for 2,000 cycles). Five test pieces were prepared in each condition.

Bonded and debonded surfaces of specimens were also examined using a scanning electron and stereoscopic microscopes. The values of each group were compared by analysis of variance (ANOVA) and Duncan multiple range interval at 0.05 level.

## Results

Fig. 2 shows the bonded surface of the magnetic stainless steel by scanning electron microscope. Simple continuous scratch lines were observed on the specimen surface before air abrasion, whereas more complicated roughness was in the specimens after air abrasion.

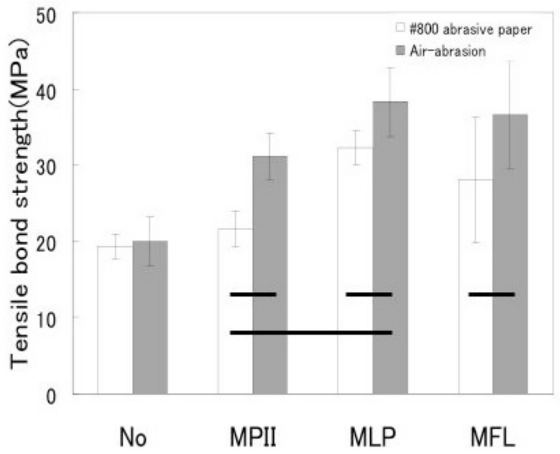



**Fig. 2.** Pre-thermocycling bond strength.

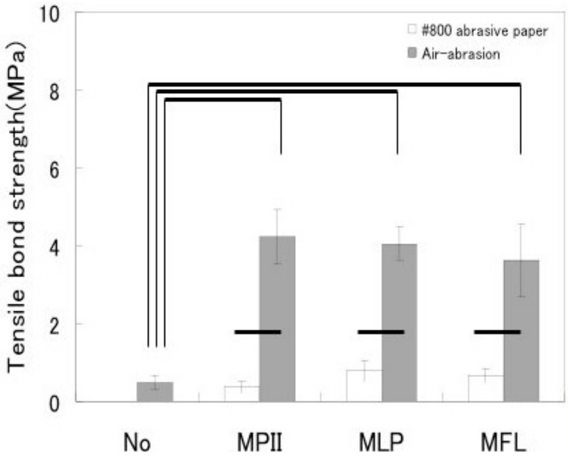
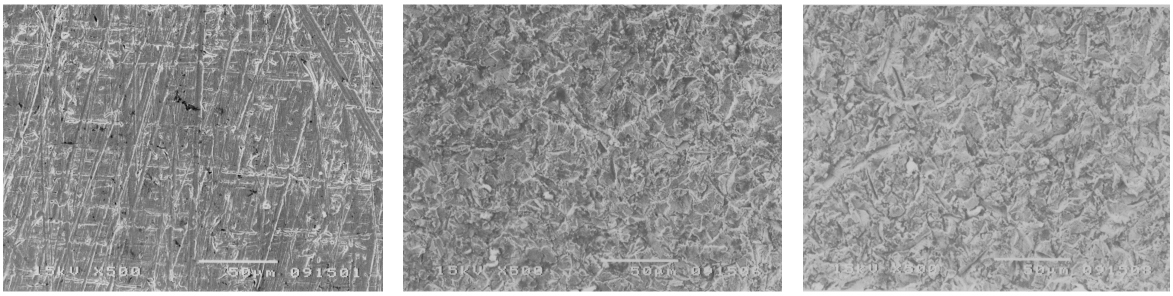



**Fig. 3.** Post-thermocycling bond strength.



a: sanding with #800 SiC paper b: air-abrasion with 50 µm alumina c: alumina abrasion + priming (MPII)

**Fig. 4.** Scanning electron micrographs of the AUM 20 steel after surface preparations.

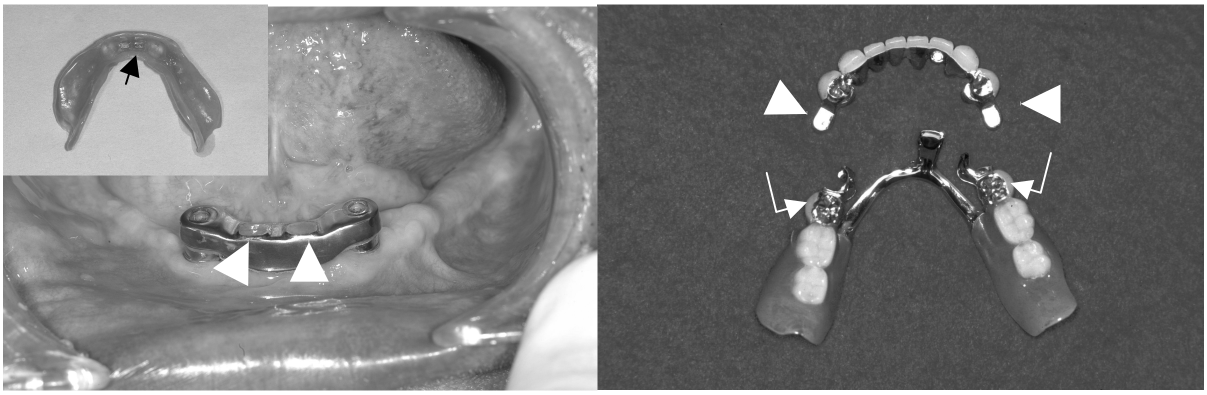
Fig. 3 shows the tensile bond strength between the magnetic stainless steel (AUM 20) and auto-polymerizing resin before thermocycling. The tensile bond strength in air abraded surfaces without primer treatment was 19.9 MPa and the value was not significantly different from that without both air abrasion and primer treatment. The bond strength of sanded surfaces with primer treatment varied from 21.6 to 32.2 MPa and the value increased significantly for primers other than MPII. The bond strength of air abraded surfaces with primer treatment varied from 31.1 to 38.3 MPa and the value increased significantly with all primer treatments.

Fig. 4 shows the tensile bond strength between the magnetic stainless steel (AUM 20) and the auto-polymerizing resin after thermocycling. Bond strengths of all groups were significantly reduced by the application of thermal cycling ($p<0.05$). The bond strength of bonded surfaces with and without primer treatment varied from 0 to 0.78 MPa and the bond strength was reduced by thermal stress. The bond strength of air abraded surfaces with primer treatment varied from 3.6 to 4.2 MPa and the bond strength was significantly ($p<0.05$) larger than those in the other groups.

Cohesive failure regions were observed on a large area of debonded surfaces in most specimens before thermocycling, whereas no cohesive failed resin regions were observed in specimens without primers after thermocycling. Cohesive failure regions were observed on a part of debonded surface in specimens with air abrasion and primer treatment after thermocycling.

## Discussion

It is a conventional procedure to fix magnets to denture bases in the mouth using auto-polymerizing resin (Fig. 5). This procedure is easy to fix and it is possible to position the magnet into the denture base with minimum error. There are two categories of magnet fixation method: the chemical method and the mechanical method. Bond strength of magnets either with a projection of 0.2 mm or with reverse tapered form of 15 degree in the mechanical method shows high values of 186.82 and 353.92 N, respectively. Although these in vitro values are satisfactory, it often happens in the long term that the magnet detached from the denture base due to the hygrothermal effect of the denture resin. In addition, it is important to enhance the bond strength between the magnet and denture base to prevent a fracture of the denture base.



a: bar-type attachment of implants b: extracoronal attachment

**Fig. 5.** Application of magnetic attachment. Arrows; magnetic keepers. Arrowheads; magnets.

A push out test is commonly used as an evaluation of the bond strength between the auto-polymerizing resin and the magnet, because this test simulates a clinical situation. In the present study, the tensile bond strength test was used to clarify the influence of a chemical primer on bond strength.

In the literature, air abrasion with alumina has been mentioned as a standard laboratory procedure to enhance bond strength between resin and metal.[6] However the present results show that no difference between air abrasion and paper abrasion were found. In pouring auto-polymerizing resin onto the bonded metal surface, air abrasion treatment affects the bond strength less than the paper abrasion treatment.

On the other hand, it is well known that metal primer chemically enhances bond strength.[7] Although the same result was shown in the present study, it is reported that the effect of MEPS application has about 40-50 MPa after thermocycling,[8] i.e., thermal stress drastically decreased the strength except for those specimens that underwent air abrasion treatment. Thermal cycling revealed that the reduction in bond strength between stainless steel (SUS 316) and auto-polymerizing resin after 20,000 cycles ageing was significant for all specimens and the rate of reduction varied from 65.2% to 100%.[5] The combination of air abrasion and primer application is the most effective procedure to fix the magnet. Thermal cycling stress reduced less the bond strength of specimens using both air abrasion and primer together less than any other procedure.

The mechanical effect of air abrasion with alumina is produced by the following factors: cleaning of bonded surface, increase of bonded area, and interlocking of rough surface. The surface produced by abrasive paper is monotonically scratched, whereas the surface produced by air abrasion with alumina is rough with complicated morphology. The mutually potential effect of this surface morphology with primer application may prevent the resin detaching from the metal surface.

## Conclusion

It was concluded that the alumina air abrasive treatment with primer was effective for strengthening the tensile bond strength of magnetic assemblies to auto-polymerizing resin.

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