Original Article

Effect of 4-META on Transverse Strength of Metal-Reinforced Denture Base Acrylic Resin

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Abstract

The objective of this study was to investigate the effect of 4-META application on transverse strength of metal-reinforced denture base acrylic resin. 5% 4-META acetone solution, sandblasting and combination of both were treated on either 18 gauge stainless steel wire or brass mesh, and then embedded in acrylic resin specimen. Denture base acrylic resin without metal insert was prepared as a control group. Ten specimens for each of seven groups were in water storage at 37 C for 48 hours. The specimens were tested by the universal testing machine using a three-point flexure test at a crosshead speed of 5 mm/min until fracture. The results indicated that stainless steel wire significantly enhanced the fracture resistance of acrylic resin ($p < .05$). However, no significant differences in transverse strength were found between groups of stainless steel wire with 5% 4-META acetone solution, sandblast, or sandblast plus 5% 4-META acetone solution application and group of stainless steel wire without surface application ($p > .05$). The brass mesh did not strengthen acrylic resin no matter if surface was treated with 5% 4-META acetone solution or not.

Key words: 4-META; acrylic resin; denture base; metal reinforcement

Introduction

The most common material used for complete denture fabrication is polymethyl methacrylate (PMMA). It has been widely used; despite it is still far from ideal requirements for material of choice of prosthesis materials. The primary problem is its poor strength characteristics.[1] Some studies reported that more than 60% of acrylic resin dentures broke within a few years after fabrication.[2,3] Most of denture fractures were caused by a combination of fatigue and impact.[2, 4] The common fracture occurs at the midline of the denture base.[5,6] The prevalence of fracture occurs more often in maxillary dentures than in mandibular dentures.[5]

Many attempts have been made to enhance the mechanical properties of acrylic denture base.[7-12] The most common reinforcing technique is the use of metal wire or mesh embedded in the acrylic denture base although their benefit remains questionable. The major problem of using metal-reinforcement is poor adhesion and lack of chemical bond between metal and acrylic resin. Due to the different coefficient of thermal expansion between metal and resin, a gap occurs at the interface leading to microleakage of oral fluids and microorganism. This may result in the discoloration and deterioration of the denture base and finally fracture along this space.[13,14] The damage of the denture base would dramatically increase under functional loading. Although several methods have been used to improve the adhesion between these components such as sandblasting or silanization of the wire surface with different techniques, the enhancement in mechanical properties was not significant.[10,15,16]

4-META (4-Methacryloxyethyl trimellitate anhydride) is a well-known synthesized adhesion-promoting monomer. It is successfully used for several applications to bond metal, especially base metal to resin.[13,14,17-19] Examples of commercial products for 4-META application are Meta Fast® or Meta Dent® (Sun Medical Co. Ltd., Kyoto, Japan). The materials are produced in the form of self-curing acrylic resin. 4-META is incorporated in methyl metacrylate (MMA) liquid, aiming for several advantages of the bonding for removable prosthesis.[20] However, those products were not applicable for denture base.

Therefore, the objective of this study was to investigate the effect of 4-META on the enhancement of transverse strength of metal-reinforced denture base acrylic resin.

Materials and methods

4-META-acetone solution (5% weight) the same as commercial product (META FAST®) was prepared from 4-META powder (Lot no. 01001, Sun Medical, Osaka, Japan) that was dissolved in acetone.

18 Gauge stainless-steel wire (1 mm. in diameter x 62 mm. long), and brass round mesh strip, 3 mm. x 62 mm. (stahl-Netzeinlage, Germany), were used as metal insertions. Stainless steel wire was surface-treated either by sandblasting with 50 micron aluminum oxide at 4 bars pressure, sandblasting and then painted with 4-META-acetone solution for 3 times, or painted only with 4-META-acetone solution for 3 times. The wire without any surface modification was used as within group control. Brass mesh strip was surface-treated only by painting with 4-META-acetone solution for 3 times. The strip without any surface modification was used as within group control. Acrylic resin without metal insertion was prepared as between group control.

Acrylic resin bar specimens (3 mm. x 5 mm. x 60 mm.) modified from the ISO 1567:1999(E)[21] with central metal insertion were prepared by conventional flasking technique. A wax sheet (1.5 mm. x 5 mm. x 60 mm.) was sandwiched overlapping for 1 mm. at both ends on a 1.5 mm. x 5 mm. x 62 mm. sheet. The sheet was then embedded in lower flask of plaster mold with longer sheet faced to upper flask mold. Then upper mold was poured with stone. After the mold was prepared and wax was run out, the step at the both end mold was seen. Semicircular groove (1 mm. in diameter) was prepared at the step of mold ensuring the central alignment of the round wire insertion in wire-reinforced acrylic specimen. For other specimens such as control and brass mesh reinforced specimens, this groove was not prepared. The brass mesh was centrally aligned on the step of the both ends of the mold. The schematic and mold picture is shown in Fig. 1.

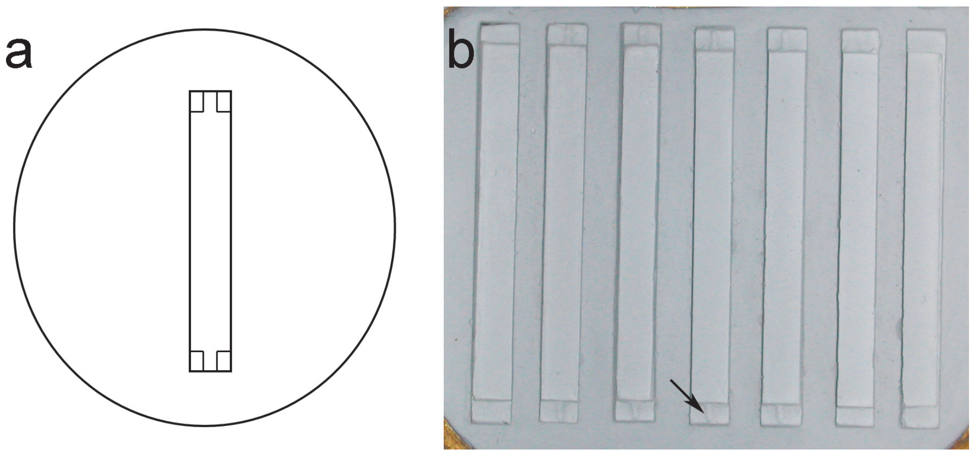

Fig. 1 *(a) A schematic of a mold for acrylic resin specimen and (b) a photograph of a flask for the specimens. An arrow shows a groove at a step for a 18 gauge stainless steel wire*

Heat-cured acrylic resin (Rodex, Rodent, Italy) was mixed according to the manufacturer's instruction and packed into the mold. Metal was inserted in acrylic by placing on the prepared step to ensure the central insertion. The processing flask was closed, and a final packing was performed. After polymerization, the resin specimens were removed and finished with 600 grit silicon carbide paper. The final dimension of finished specimens was 3 mm. x 5 mm. x 60 mm. The specimens were stored in distilled water at 37 C for 48 hours before testing. Ten specimens of each of seven groups were tested. The specimen treatments are summarized in Table 1.

All specimens were subjected to 3-point flexure test at a crosshead speed of 5 mm/min with 50 mm. supporting span using a universal testing machine (Instron model 5566, Instron, England). Testing condition was prepared according to the International Standard (ISO 1567:1999(E))[21]. The transverse strength was calculated from the value of the first cracked load with the original specimen dimension and support span length. Data were analyzed using one-way ANOVA and post hoc comparison using Games-Howell test at a significance level (α) of 0.05.

Table 1 *Metal insertion, and surface modification of acrylic resin specimens in this study*

Group	Metal insertion	Surface modification
1	none	none
2	brass mesh strip	none
3	brass mesh strip	4-META painting
4	steel wire gauge 18	none
5	steel wire gauge 18	sandblasting
6	steel wire gauge 18	sandblasting + 4-META painting
7	steel wire gauge 18	4-META painting

Results

One-way ANOVA revealed significant differences in transverse strength ($p < .05$) among groups. Table 2 shows transverse strength of the specimens with statistical comparison (Games-Howell test, α =0.05). The control specimen without metal insertion showed its transverse strength approximately 70 MPa. The strength of the control group was not significant difference from those of brass mesh strengthening groups, either with 4-META application or none ($p > .05$). The transverse strength of the 18-gauge stainless steel wire strengthening groups showed no significant difference from each other, either with surface treatment or none ($p > .05$). The transverse strength of metal wire strengthening groups was approximately 100 MPa. The strength was significantly different from the controlandbrass mesh strengthening groups ($p < .05$).

The specimen fracture characteristics are shown in Fig. 2. All specimens in control group were totally separated when fractured, while the other groups, fracture pieces were held together by the metal insertions.

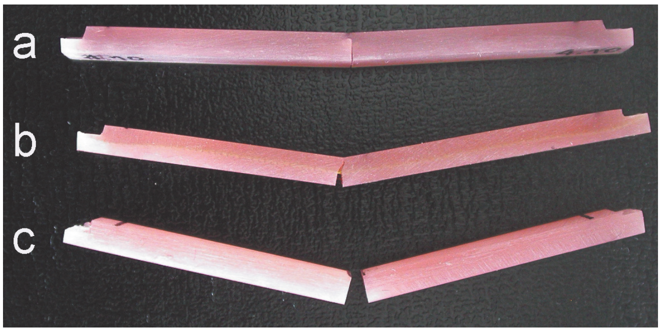

Fig. 2 *A photograph of fractured specimens (a) with a stainless steel wire insert (b) with a brass mesh insert and (c) without metal insertion*

Discussion

Metal insertion has been widely used to reinforce a denture base, and it significantly improved the transverse strength of denture base resin.[7-12] However, failure occurred around embedded materials due to stress concentration and the net effect is actually to weaken the resin.[22,23] This may be because of poor adhesion between acrylic resin and the metal inserts. In this study, we evaluated the effect of 5% 4-META acetone solution in combination with surface modifications and different kinds of metal insertion on the transverse strength of acrylic resin.

The results in Table 2 shows that only strengthening by stainless steel wire improved the transverse strength of the acrylic resin, while the brass mesh strengthening did not show any improvement. This may be due to the rigidity of inserted materials compared with that of acrylic resin. The rigidity of the materials are depend not only the strength but also the configuration of materials. Stainless steel wire in this study has higher strength (200 MPa, Yield Strength) and round configuration which show more rigidity compared to brass mesh which has lower strength (70 MPa, Yield Strength) and thin plate configuration. Both metal inserted specimens showed no complete separation of specimen, and the both fracture pieces were hold by the metal insertion, while the control specimen was completely separated into two pieces (Fig. 2). This could be also both advantage and disadvantage. The advantage is that the fractured pieces are held together, and patient may use it until dental visit. The disadvantage is the difficulty of repairing the fracture pieces due to the interruption of the metal inserts.

In this study, 5% 4-META acetone solution with or without sandblasting did not improve the transverse strength of the acrylic resin reinforced with metal insertion. This result was controversy to several studies which showed the improvement of transverse strength of acrylic resin by sandblasting, metal adhesive painting or combination to metal insertion.[16,24] This may be because of small surface contact between metal and acrylic resin in this study that led to small scale of the bonding between metal and acrylic resin. Theoretically, the bonding improvement either by sandblasting or chemical bonding on larger surface may help to transfer the force from one material to another material, leading to improvement of the transverse strength of those sandwiched specimens. However, mechanical enhancement in this study may be too small compared with the metal and acrylic strength in order to show their effect. However, we found the difference of the detached distance of acrylic resin from metal insertion in metal wire group. Fig. 3 shows the comparison of the detached distance of acrylic resin from metal wire. Although this phenomenon could not scientifically explained due to the uncontrolled deflection of the specimens, the tendency of the differences in the detached distance confirmed the effect of metal surface modification on the transverse strength of acrylic resin. From this phenomenon, the chemical bonding between metal and resin reduced the gap between them, leading to reduced

Table 2 *Mean transverse strength [SD] of acrylic resin specimen with different conditions. Groups with the same superscript are not significantly different (SS* = stainless steel).*

Group	Condition	Transverse strength (MPa)
1	No metal insertion	70.8 [3.9][a]
2	Brass mesh	71.6 [2.4][a]
3	Brass mesh + 4-META painting	72.6 [2.6][a]
4	Gauge 18 SS* wire	108.4 [15.4][b]
5	Gauge 18 SS wire + sandblast	104.1 [13.1][b]
6	Gauge 18 SS wire + sandblast + 4-META	106.0 [13.3][b]
7	Gauge 18 SS wire + 4 META	101.1 [8.4][b]

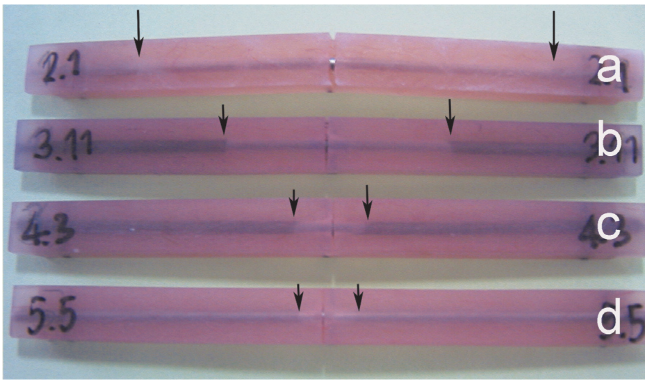

Fig. 3 *A photograph of fracture specimens with a stainless steel wire insert and varying surface modifications (a) without surface modification (b) sandblast (c) sandblast and 4-META application and (d) 4-META application. Arrows demonstrate detached distance of acrylic resin from stainless steel wire*

microleakage of oral fluids and micro-organisms, and resulted in less discoloration and deterioration of the denture base. The further study, however, need to be done to actually evaluate this phenomenon.

Conclusion

With the limitations of this study, the following conclusions were drawn:

1. The use of 18-gauge stainless steel wire improved the transverse strength of acrylic resin, while brass mesh strip did not improve the transverse strength of acrylic resin.

2. The surface treatment of metal insert using sandblast, 5% 4-META acetone solution or both did not show any effect on the transverse strength of acrylic resin

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บ ท วิ ท ย า ก า ร
Original Article

ผลของโฟร์เมตาต่อกำลังแรงดัดขวางของเรซินอะคริลิกสำหรับทำฐานฟันเทียมที่เสริมความแข็งแรงด้วยโลหะ

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบผลของการใช้สารละลาย 5 เปอร์เซนต์โฟร์เมตาในอะซิโตนทาโลหะสองชนิดคือลวดโลหะไร้สนิมขนาด 18 และตะแกรงทองเหลืองที่ใช้เสริมความแข็งแรงฐานฟันเทียมที่ทำจากเรซินอะคริลิกต่อค่ากำลังแรงดัดขวางของเรซินอะคริลิก เตรียมชิ้นตัวอย่างโดยทาสารละลาย 5 เปอร์เซนต์โฟร์เมตาในอะซิโตนบนผิวโลหะโดยตรงหรือการเป่าทรายด้วยผงอะลูมินาบนผิวโลหะ หรือการใช้ทั้งสองวิธีร่วมกัน นำโลหะดังกล่าวไปเสริมบริเวณกึ่งกลางของชิ้นงานตัวอย่างเรซินอะคริลิกขนาด 3 มิลลิเมตร x 5 มิลลิเมตร x 60 มิลลิเมตร แบ่งกลุ่มทดลองออกเป็น 7 กลุ่ม กลุ่มละ 10 ชิ้นตัวอย่าง โดยกลุ่มควบคุมเป็นกลุ่มไม่เสริมด้วยชิ้นโลหะ นำชิ้นตัวอย่างมาทดสอบค่ากำลังแรงดัดขวางโดยเครื่องทดสอบสากล ความเร็วหัวกด 5 มิลลิเมตรต่อนาที ผลการวิเคราะห์ทางสถิติใช้การวิเคราะห์ความแปรปรวนแบบทางเดียวและเปรียบเทียบเชิงซ้อนโดยใช้สถิติเกมส์-โฮเวล ที่ระดับนัยสำคัญ 0.05 พบว่าค่าเฉลี่ยกำลังแรงดัดขวางของชิ้นตัวอย่างเสริมด้วยลวดโลหะไร้สนิมมีค่าสูงกว่าอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับกลุ่มควบคุม ($p < .05$) ส่วนการเสริมด้วยตะแกรงทองเหลืองไม่มีผลต่อค่ากำลังแรงดัดขวางเมื่อเปรียบเทียบกับกลุ่มควบคุม ($p > .05$) และการทาผิวโลหะด้วยสารละลาย 5 เปอร์เซนต์โฟร์เมตาในอะซิโตนหรือการเป่าทรายอย่างเดียวกับการเป่าทรายร่วมกับการทาสารละลาย 5 เปอร์เซนต์โฟร์เมตาในอะซิโตนไม่มีผลต่อค่ากำลังแรงดัดขวางของเรซินอะคริลิกสำหรับทำฐานฟันเทียมที่เสริมชิ้นโลหะ