Flexural strength of denture bases repaired with metal wires★

Comparison among different amounts of metal wires

Lin Ying-hui, Sun Gui-lan

Department of Prosthodontics, the Affiliated Hospital of Qingdao University Medical College, Qingdao 266003, Shandong Province, China

Lin Ying-hui★, Studying for Master's degree, Department of Prosthodontics, the Affiliated Hospital of Qingdao University Medical College, Qingdao 266003, Shandong Province, China

Correspondence to: Sun Gui-lan, Professor, Master's supervisor, Chief physician, Department of Prosthodontics, the Affiliated Hospital of Qingdao University Medical College, Qingdao 266003, Shandong Province, China

Received: 2009-11-23
Accepted: 2009-12-29
(20091123001/M)

Lin YH, Sun GL. Flexural strength of denture bases repaired with metal wires: Comparison among different amounts of metal wires. Zhongguo Zuzhi Gongcheng Yanjiu yu Linchuang Kangfu. 2010;14(8): 1504-1507.

[http://www.crter.cn http://en.zglckf.com]

Abstract

BACKGROUND: Poly methyl methyacrylate (PMMA) has been widely used as a denture base material in dental field for a long time. However, the fracture of acrylic resin dentures is an unresolved problem in prosthodontics. Therefore, how to improve the flexural strength of repaired denture seems to be extremely important.

OBJECTIVE: To study the effect of embedding different amounts of metal wires on the flexural strength of repaired denture bases.

METHODS: Twenty-five rectangular specimens (50 mm × 30 mm × 2.5 mm) were fabricated using heat-cured acrylic resins and randomly and evenly divided into five groups: A, B, C, D, and E. All specimens were fractured through the use of universal testing machine, and the flexural strengths were tested. Following preparation of fracture surfaces, one to four metal wires were separately embedded in the groups B, C, D, and E. No metal wires were embedded in the group A. All fractured specimens were repaired using self-curing resins. The flexural strengths were measured again using the same testing machine, and the percentages of strength recovery were calculated.

RESULTS AND CONCLUSION: After repair, the flexural strengths were obviously reduced (P < 0.01). Compared to group A, the percentages of strength recovery were significantly increased in groups C, D, and E (P < 0.05). There was no significant difference in the percentage of strength recovery among groups C, D, and E (P > 0.05). These results indicate that embedding two to four metal wires can improve the flexural strength of denture bases.

INTRODUCTION

Since 1940s, poly methyl methyacrylate (PMMA) has been widely used in dental field as denture bases material[1]. The fracture of acrylic resin dentures is an unresolved problem in prosthodontics because of its lower toughness and strength[2-3]. In order to improve the repair strength, many different approaches have been applied on broken dentures, such as modifying the denture material itself (high-impact resins)[4-7] or reinforcing the strength[8-12]. Gregory *et al*[13] reported that the most common reinforcing technique was the use of metal wires or metal nets embedded in the prostheses[13]. In this study, the common heat-cured acrylic resin was used to make specimens. When the specimens were repaired, different amount of metal wires with a diameter of 1.0 mm were embedded. The flexural strengths were measured, and the percentage of strength recovery was calculated in order to provide reasonable guidance for clinical application.

MATERIALS AND METHODS

Design

A controlled observation study.

Time and setting

This experiment was performed at the Prosthodontics Laboratory, Affiliated Hospital of Qingdao University Medical College from August to October 2009

Materials

Primary materials and equipment used are listed as follows.

Material/equipment	Source
Denture base resin (type Ⅰ) powder	Nisshin Dental Material Co., Ltd., Japan
Denture base resin (type Ⅰ) liquid, denture base resin (type Ⅱ) powder	Shanghai Dental Material Factory, China
Denture base resin (type Ⅱ) liquid	Shanxi Changzhi Dental Instrument Co.,Ltd.,China
Base plate wax (for general use)	Shanghai Dentistry Factory, China
Metal wires (for dental use)	Shanghai Kangqiao Dental Instrument, China
Waterproof abrasive paper (600#)	Shanghai Grinding Wheel Factory, China
Vernier caliper (precision 0.01 mm)	Beijing Xingao Tongchuang Science and Technology Co., Ltd., China
Universal testing machine (AGS-J)	Daojin, Japan

Methods

Preparation of specimens

Twenty-five wax sheets (50 mm × 30 mm × 2.5 mm) were prepared with denture base plate wax. The wax sheets were flasked and boiled-out as regular methods. The heat-cured acrylic resins were mixed, packed, and processed as recommended by the manufacturer. The water-bath heat polymerization process is as follows: polymerized at 70 ℃ for 90 minutes, remained at 100 ℃ for 30 minutes, and finally naturally cooled to ambient temperature. The specimens were roughly grinded with dental bur, and polished with 600# waterproof abrasive paper. The sizes of these specimens were accurately measured with a vernier caliper. All the specimens were randomly and evenly divided into five groups: A, B, C, D, and E. Each group contained five specimens. Specimens were stored in a distilled water bath at (37±1) ℃ for 24 hours, and then the flexural strengths were tested.

Flexural strength test

All specimens were tested in air at 21 ℃ through the use of universal testing machine. The span was 40 mm, and the crosshead speed was 1 mm/min. The flexural strength (σ) was measured by three-point bending test and calculated by the following equation:

$$\sigma = 3FL/2bh^2$$

Where F stands for the breaking load (N), L is the test span (mm), b is the width of specimen (mm), and h represents the thickness of specimen (mm).

Repair procedure

Group A was the control group and had no metal wire repair. The specimens of group B, C, D, and E involved 1, 2, 3 or 4 metal wires, respectively. The length of each metal wire was 10 mm, and the diameter was 1.0 mm. All groups were repaired using self-curing resins.

The fractured specimens were restored and the two fractured sections were kept on the original level. The fractured surfaces were adhered with gel, and the specimens were fixed in the dental stone[4]. A dental grinding bur was used to move apart resin to leave a 5 mm gap along the fractured line and to create one to four channels which were perpendicular to the fractured line for placement of wires. The metal wires were separately placed with proportional spacing in different groups according to experimental design. Self-curing resins were mixed as usual and the specimens were repaired. At 60 minutes after polymerization process at room temperature (21 ℃), the specimens were trimmed to their original dimensions with 600# waterproof abrasive paper and kept in distilled water at (37±1) ℃ for 24 hours. The flexural strengths were tested again and the percentage of strength recovery was calculated.

Main outcome measures

The original flexural strengths test and the flexural strengths test of repaired specimens, and then the percentages of strength recovery were calculated.

Design, enforcement and evaluation

The first and second authors designed this study. The first author collected data and performed all experiments. The first and second authors also evaluated experimental data using a blind method.

Statistical analysis

All data were statistically processed using SPSS 11.5 and PPMS 1.5[14] software. Paired t test was used to compare the flexural strength between prior to and after repair. One-way analysis of variance was employed to compare the percentage of strength recovery between groups. A value of $P < 0.05$ was considered statistically significant.

RESULTS

After repair, the flexural strengths were obviously reduced ($P < 0.01$). Compared to group A, the percentage strength recovery was significantly increased in groups C, D, and E ($P < 0.05$). The group D yielded the highest percentage of strength recovery, being 66.74%. There was no significant difference in the percentage of strength recovery among groups C, D, and E ($P > 0.05$; Table 1).

Table 1 Comparison on original and repaired flexural strength of specimens and the percent age of strength recovery in different groups ($\bar{x}\pm s$, n =5)

Group	Original flexural strength (MPa)	Repaired flexural strength (MPa)	Percentage of strength recovery (%)
A	91.08±8.34	42.16±9.55	46.18±8.12
B	91.07±9.19	51.25±8.88	56.15±6.60
C	83.19±8.91	53.55±6.47	64.70±8.70[a]
D	85.20±7.03	57.42±5.31	67.58±6.40[a]
E	85.14±9.23	54.93±8.95	64.58±7.65[a]

[a]$P < 0.05$, *vs.* group A; Group A had no metal wire repair; Groups B, C, D, and E involved 1, 2, 3 or 4 metal wires, respectively; The length of each metal wire was 10 mm, and the diameter was 1.0 mm.

DISCUSSION

PMMA has been widely used as a denture base material in the clinic. It has many good properties, such as beautiful color and easy to operate[15-16]. However, PMMA resin matrix is a linear polymer, and the molecular chain has greater stiffness, less crosslinking degree, so acrylic resin exhibits lower toughness and strength, which easily leads to fracture[17-18]. In addition, the mechanical property of acrylic resin is relevant to polymerization method[19-21]. The stress of the denture base is restricted during the polymerization shrinkage process of heat-cured acrylic resins, and the stress is released in function. The process results in the change of base dimension, so the microcrack occurs[22]. In the clinic, denture fracture occurs because of many different reasons which happened outside or inside the mouth[23-24]. According to a survey, midline fracture is the most common problem. It is the result of flexural fatigue failure caused by cyclic deformation of the base[25]. If PMMA denture base adapts to the oral cavity, and the patient felt comfortable, then old denture should be repaired. Regardless of the reason for the fracture or the method of repair, satisfactory repairs must have adequate strength, be easily and rapidly completed, match the original color of the material, and retain its dimensional accuracy. However, these criteria cannot always be achieved[26]. Many different approaches have been applied in broken dentures.The most common reinforcing technique is presently the use of metal wires or casted metal nets in the prostheses[27]. However, there are different opinions as to the amount, dimension, space, and effect of embedded metal wires. In this study, 1.0 mm round metal wires was used to repair the broken specimens. According to the design, different amount metal wires were embedded in different groups, but the repair method and the testing condition remained essentially the same. The metal wires were placed perpendicular to the fractured line, and were kept proportional to the space, in order to reduce stress concentration as much as possible.

The experiment results are shown as follows: ① After repair, the flexural strengths were obviously reduced ($P < 0.01$). This occurs possibly due to a fact that the newly filled self-curing resins have lower density and higher brittleness. The resins and the smooth surface of metal wires cannot fit together tightly, so the adhesive property is decreased[28]. The incorporation between resins and metal wires plays a dominant role in the overall mechanical behaviors of the repaired specimens. Furthermore, there is a bonding interface between self-curing resins and heat-curing resins. Metal wires can only increase the inside strength of bases, but the adhesive property of bonding interface cannot be increased[29]. ② Compared to group A, the percentage of strength recovery was significantly increased in groups C, D, and E. These results indicate that the incorporation of metal wires allows greater deflection of specimens prior to fracture occurs. It suggests that more forece is necessary for breaking the denture. In addition, metal wires can disperse stress and resist stress transference. Vallittu *et al*[30] reported that round and half-round metal wires thicker than 1 mm had a significant reinforcing effect on denture resins when compared to unreinforced ones. These findings are in consistent with results from this study. ③ The percentage of strength recovery was highest in group D. Compared to groups C, D, E, the percentage of strength recovery increased initially and then decreased. These results are not significantly different from each other (P > 0.05). In conclusion, embedding two to four metal wires whose diameter is 1.0 mm can improve the repair flexural strength of denture base. It is worth nothing that metal wires should be placed perpendicular to the fractured line, and kept several millimeter spacing between wires for improving the repair effect.

REFERENCES

[1] Nagai E, Otani K, Satoh Y, et al. Repair of denture base resin using woven metal and glass fiber: effect of methylene chloride pretreatment. J Prosthet Dent. 2001;85(5):496-500.
[2] Zhang T, Mo AC. Research progress of provisional denture materials. Guoji Kouqiang Yixue Zazhi. 2008;35(4):289-291.
[3] Leskinen K, Salo S, Suni J, et al. A practice-based study of the sealant treatment effectiveness in Finns. J Dent. 2007;35(4):338-342.
[4] Guo YJ, Cheng H, Li XR, et al. Effect s of surface-modified Nano-titanium dioxide on mechanical properties of denture base resin. Fujian Yike Daxue Xuebao. 2009;43(2):129-132.
[5] Cheng YT, Sun JP, Weng JB, et al. Preparation and properties of PMMA/TiO2 nanocomposite. Huaxue Fanying Gongcheng Yu Gongyi. 2007;23(5):435-440.
[6] Wang XJ, Zhang YM, Sun Y, et al. Test of function of resin base with added nanometer titania. Yati Yasui Yazhou Bing Xue Zazhi. 2007;17(4):192-194.
[7] Jagger DC, Jagger RG, Allen SM, et al. An investigation into the transverse and impact strength of "high strength" denture base acrylic resins. J Oral Rehabil. 2002;29(3):263-267.
[8] Zhang XY, Wu WS, Tian AF, et al. The effect of whisker fraction on flexural strength of whisker-PMMA composite reinforced with potassium titanate whiskers. Linchuang Kouqiang Yixue Zazhi. 2009;25(3):151-153.
[9] Karacaer O, Polat TN, Tezvergil A, et al. The effect of length and concentration of glass fibers on the mechanical properties of an injection- and a compression-molded denture base polymer. J Prosthet Dent. 2003;90(4):385-393.
[10] Tjong SC, Meng YZ. Properties and morphology of polyamide 6 hybrid composite containing potassium titanate whiskers and liquid crystalline copolyester. J Polymer.1999;40(5):1109-1117.
[11] Xu HH, Martin TA, Antonucci JM, et al. Ceramic whisker reinforcement of dental resin composites. J Dent Res. 1999;78(2):706-712.
[12] Xu HH. Whisker-reinforced heat-cured dental resin composites: effects of filler level and heat-cure temperature and time. J Dent Res. 2000;79(6):1392-1397.
[13] Gregory L, Panagiotis E. Acrylic resin denture repair with adhesive resin and metal wires: Effects on strength parameters. J Prosthet Dent. 1996;75(4):381.
[14] Zhou XB, Ji XQ, Xu L. The composition and application of PPMS 1.5 medical statistical software. Qilu Yixue Zazhi. 2009;24(1):29-32.
[15] Lu Y, Yao YL, Zhao XY. An experimental study on denture base roughness. Zhongguo Meirong Yixue. 2007;16(4):492-493.
[16] KawaraM, Komiyama O, Kimoto S. Distortion behavior of heat-activated acrylic denture-base resin in conventional and long, low-temperature processing methods. J Dent Res. 1998;77(6):1446-1453.
[17] Gao H, Zhang ZT. Study on modification of PMMA denture base resin. Beijing Kouqiang Yixue. 2006;14(2):92-94.
[18] Yan HL. Study on the fracture of denture bases. Shiyong Yiji Zazhi. 2006;13(22):4012-4013.
[19] Lv YH, Mo SX. Experiment research of microwave radiation to polymerize denture base resin. Junyi Jinxiu Xueyuan Xuebao. 2008;29(5):413-414.
[20] Li H, Yu HL, Lian W. The clinical application and study of Polymerization method on complete denture bases of the heat reactive resin. Shiyong Yiji Zazhi. 2006; 13(9):1531.
[21] Chai TI, Stein RS. Porosity and accuracy of multiple-unit titanium castings. J Prosthet Dent. 1995;73(6):534-541.
[22] Lv YH, Mo SX. Effects of microwave radiation polymerization on the porosity of the denture base resin. Henan Yixue Yanjiu. 2008;17(2):131-136.
[23] Fang SL. Analysis of the cause of repeated damage on complete denture. Zhongguo Meitan Gongye Yixue Zazhi. 2006;9(12):1297.
[24] Liu H. The clinical analysis of the fracture of 60 upper complete denture bases. Xiandai Yiyao Weisheng. 2007;23(4):534.
[25] Bai BJ, Zhang ZT. Effect of palatal vault, cusp inclination and position of artificial teeth on the stress distribution in the base of the maxillary complete dentures. Kouqiang Hemian Xiufuxue Zazhi. 2005;6(1):62-64.
[26] Johnston EP, Nicholls JI, Smith DE. Flexure fatigue of 10 commonly used denture base resin. J Prosthet Dent. 1981;46(5):478-483.
[27] Ruffino AR. Effect of steel strengthener on fracture resistance of the acrylic resin complete denture base. J Prosthet Dent. 1985;54(1):75-78.
[28] Berry HH, Funk OJ. Vitallium strengthen to prevent lower denture breakage. J Prosthet Dent. 1971;137(6):532-536.
[29] Minami H, Suzuki S, Ohashi H. Effect of surface treatment on the bonding of an autopolymerizing soft denture liner to a denture base resin. Int J Prosthodont. 2004;17(3):297-301.
[30] Vallittu PK, Lassila VP. Reinforcement of acrylic resin denture base material with metal or fibrestrengtheners. J Oral Rehabill. 1992;19(3):225-230.

金属加强丝与义齿基托修理后弯曲强度：不同数目影响的差异★

林映辉，孙桂兰(青岛大学医学院附属医院口腔修复科，山东省青岛市 266003)

林映辉★，女，1983年生，山东省烟台市人，汉族，青岛大学医学院在读硕士，主要从事口腔修复科工作。

通讯作者：孙桂兰，教授，硕士生导师，主任医师，青岛大学医学院附属医院口腔修复科，山东省青岛市 266003

摘要

背景：聚甲基丙烯酸甲酯长期以来作为义齿基托材料在牙科领域得到了广泛应用，然而义齿折裂是修复学至今尚未解决的难题。因此，如何增强义齿修理后的弯曲强度显得尤为重要。

目的：研究加入不同数目的金属加强丝对义齿基托修理后弯曲强度的影响。

方法：用聚甲基丙烯酸甲酯热凝树脂制作25个50 mm×30 mm×2.5 mm的长方体试件，将试件在万能试验机上压断，测得其弯曲强度。各组试件断面经预备后分别加入1~4根不锈钢丝，未加入钢丝组为对照组，并用自凝树脂修理裂缝，测定修理后试件的弯曲强度，计算强度恢复率。

结果与结论：各组试件修理后的弯曲强度均明显低于修理前($P < 0.01$)。除加入1根钢丝组外，其余各组强度恢复率均高于对照组($P < 0.05$)。加入2，3，4根钢丝各组间强度恢复率比较，差异无显著性意义($P > 0.05$)。结果证实加入2~4根金属加强丝可增强义齿基托修理后的弯曲强度。

关键词：金属加强丝；义齿修理；弯曲强度；聚甲基丙烯酸甲酯；口腔生物材料

doi:10.3969/j.issn.1673-8225.2010.08.042

中图分类号：R318 文献标识码：A

文章编号：1673-8225(2010)08-01504-04

林映辉，孙桂兰.金属加强丝与义齿基托修理后弯曲强度：不同数目影响的差异[J].中国组织工程研究与临床康复，2010，14(8):1504-1507.

[http://www.crter.org http://cn.zglckf.com]

(Edited by Zhang Y, Luo XB/Song LP/Wang L)

关于生物材料研究有价值的近期新闻回顾：本刊学术部

内容简介	网站点击更多
通常，人们只见过蚕丝被用来制作成各种款式的衣服，但浙大妇院妇科盆底学科的邹晓晖博士却独具匠心地把蚕丝用到妇科疾病的治疗上。“和现有的人工合成材料比起来，以蚕丝为原料的生物材料更容易被人体所吸收，而且一旦运用到临床上，可以帮患者大大降低医疗费用。”2009年11月2日，在浙大妇院举行的“浙江省第三届妇科泌尿及盆底功能障碍性疾病诊治新进展”的论坛上，邹晓晖这样向与会者介绍这项研究的意义。	http://cn.zglckf.com/Html/2009_11_27/2_65764_2009_11_27_83607.html
在国家自然科学基金重点项目的支持下，由中科院理化技术研究所唐芳琼研究员带领的纳米材料可控制备与应用研究组在纳米增强的酶生物传感器研究方面取得重要进展。这一研究成果近期发表在国际电化学与传感器领域影响因子排名第一的杂志《生物传感器与生物电子学》上（Biosensors and Bioelectronics,2009,25,889-895），引起审稿人的兴趣，评价该文章“工作细致，并得到了很好的实验结果”。	http://cn.zglckf.com/sites/MainSite/Detail.aspx?StructID=88874
2009年11月中旬，美国科研人员宣布，已经在实验室中成功研制出了人工雄性兔子生殖器，而且可以通过从动物身上提取细胞，再使用这种人工生殖器即可培育出小兔子。据报道，美国科研人员在最近发表的美国《国家科学院院刊》（Proceedings of the National Academy of Sciences）中表示，这项研究的成功将使科学家们向使用患者的细胞培养出其他诸如肝脏等更复杂的器官的技术迈近一步。	http://cn.zglckf.com/Html/2009_12_26/2_65764_2009_12_26_88873.html
2009年7月,科学家首次用木头制造了假肢材料。科学家称，该材料最适合填补骨肿瘤移植或严重的骨折等医疗领域留下的空白，同时也可在工程和太空领域大展拳脚。相关研究发表在最新出版的《材料化学》杂志上。	http://cn.zglckf.com/Html/2009_07_23/2_65764_2009_07_23_66229.html