Evaluation of Soldered Joints of Two Base Metal Ceramic Alloys: Supercast and Minalux

Farshad bajoghli[1], Ehsan Ghasemi[2], Saeed Sahafi[3]

[1]Associate Professor, Dental Implant Research Center and Department of Prosthodontics, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
[2]Assistant Professor, Dental Materials Research Center and Department of Prosthodontics, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
[3]Dentist

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Abstract

Background: Different soldering techniques have a variety of applications in dentistry. One of the most important uses of soldering is to join multiple-unit fixed partial dentures together. In this Study, two base metal alloys (Supercast and Minalux) were soldered and their tensile, compressive and flexural strengths were measured and compared to each other. **Materials and methods:** In this in-vitro study, an aluminum pattern was made by a milling machine according to ASTM (American Society for Testing Material). Eighteen acrylic resin Patterns were duplicated by flasking using putty indices according to the original aluminum pattern. Acrylic resin patterns were divided into two groups of nine and each group was cast with two different alloys named Supercast and Minalux. All eighteen metal rods were separated by 0.008-inch disc and soldered with Vera-solder by means of gas-oxygen torch. Three patterns of each alloy were selected for each of the compression, tensile and flexural tests. Tensile strength was measured by Instron a universal machine and flexural and compression strengths were measured by Dartec machine. Statistical analysis was done by Mann - Whitney test. **Results:** The mean tensile, flexural and compressive strengths for supercast alloy was 347.6, 44.01 and 1014.8MPa respectively and the mean for tensile, flexural and compressive strengths for Minalux alloy was 350.03, 51.70 and 938.17 MPa respectively. Statistical analysis showed no significant differences between the two alloys in all the three mentioned tests. ($p>0.05$) **Conclusion:** Tensile, flexural and compressive strengths of the two soldered alloys, Minalux and supercast, showed no significant differences. Minalux is an alloy manufactured in Iran with the advantage of not including Beryllium, a cariogenic element, as one of the ingredients of the alloy; therefore, it is suggested that Minalux be used instead of supercast in soldering procedures in fixed prosthodontics.

Keywords: Alloy, Minalux, Soldering, Solder joint, super cast**.**

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Introduction

As defined by the Glossary of Prosthodontic Terms, connectors are a component of a fixed partial dental prosthesis (FPD) “that unite retainers and pontics (1). Soldering is the process of joining two pieces of metal by fusing an intermediate alloy (Solder) with a melting point lower than the parent metal. Joining or fusion of a metal or an alloy is required for assembling bridges in prosthodontics, uniting component parts of bridges for establishing esthetics, to develop harmony and also for uniting wrought clasps to a cast metal framework in removable prostheses (2). This procedure was conventionally done using methods like soldering, brazing and welding. Newer techniques such as laser fusion, infrared fusion and electron beam fusion have been recently introduced (2,3). Numerous investigations on accuracy and strength of various materials as connectors in dental brazing have been done with various methods.

Different soldering techniques have been used in dentistry especially in fixed prosthodontics. Accuracy of multiple-unit fixed partial dentures is a basic issue in prosthetic treatments. Generally, as the length of one piece casting increases, the potential for inaccuracy of fit also increases. To assure the fit of metal frameworks on abutments, a trial insertion is generally performed in a clinic. If any inadequacy is detected, sectioning and soldering of metal frameworks are required (4). Alloys that are used in crown and Bridge work include a wide range of precious, semi-precious and non-precious alloys, each of which has advantages and disadvantages. A steep rise in the cost of precious metals in 1973-1974 led to widespread use of more economical non-precious alloys, referred to as Base-metal alloys. These include Nickel-Chromium (Ni-Cr) and Chromium-Cobalt (Cr-Co) and have suitable mechanical and physical properties such as increased strength and hardness, higher fusion temperature and less distortion during porcelain firing compared to precious metals. Disadvantages of base metal alloys are higher excess oxide formation during casting and soldering, difficulty in finishing and polishing and questionable biocompatibility (5). Consequently, a change in the technique of soldering is necessary for joining base metal alloys. Although many favorable properties of joints have been mentioned in literature, no definitive technique has been proven to produce the ideal properties (6). When base metal alloys are used, solders which match the parent alloy both in color and strength is required. Therefore, in such cases, nickel chromium alloy solders are used to fabricate joints, especially in metal ceramic bridges (2,7,8).

Other more recent techniques such as soldering by infra– red machine can be used; however, no difference in strength and porosity has been found between infra-red and torch soldering (9) Several methods, including an infrared heating method and laser welding, have been investigated to join different metals such as high-palladium, cobalt-chromium and titanium alloys (10,12). Although these methods fulfill the need for mechanical strength, torch and oven soldering are still standard techiques for joining dental alloys. Although microwave technology is well known in industrial settings for it’s faster heating rate, shortened processing time, improved microstructure and energy efficiency, the application of microwave technology in dentistry has been limited to polymeric materials and dental ceramics and application of microwave technology to dental brazing alloys has not yet been reported (13,15).Pre-veneer soldering is a more popular technique compared to post-veneer soldering because it is easier; however, some investigators found post-veneer soldering to be stronger (16)

Multi-unit dental restorations are usually cast in small sections and then soldered by a gas-torch technique (17). Supercast is a non- precious alloy most commonly used in crown and bridge work, this alloy contains beryllium, which has been identified as a potential carcinogen and also has to be bought from foreign countries (8). On the other hand, Minalux is also a non - precious alloy with no beryllium made in our home-country, Iran. The goal of this study was to compare the strength of soldered joints of Supercast and Minalux alloy.

Materials and methods

Preparation of specimens for the tests

The alloys used in this study were Supercast (Vera bond dental alloy Albadent, California, USA) and Minalux (mavadkaran co. Iran). A recommended Solder by the manufacturer, Vera – solder (Vera-solder Albadent. California. USA) was used for both alloys. Eighteen specimens were used and divided in two groups of nine (simple randomization). First, an aluminum model according to ADA/ISO 9693 specifications was made for tensile test, made of a 3-mm diameter bar which was cut and soldered in the middle (Fig. 1) (18). The processing flask was used, upper and lower half of the flask was ½ filled with type II dental plaster (Pars Dandan, Tehran, Iran). After stone was set, the other half of the lower half of the flask was filled with condensation silicone (Speedex, Coltene, Switzerland) before putty was set, the aluminum model was ½ sank into it. After putty was set, it was lubricated by Vaseline. The upper half of the flask was filled with Speedex putty, similar to the lower half. Before putty was set, upper and lower halves of the flask were placed together under pneumatic press machine (KAVO EWL, Germany). After tightening the screws on the machine, pressure was raised to 2000

N/cm^2 for 5minuts. After 5minutes, pressure was released and excess resin removed. By removing the aluminum model from the flask, the impression was left on the Speedex putty. Auto polymerizing acrylic resin (Duralay, Reliance Dental Mfg. Co., USA) was placed into an already made impression of the aluminum mold. Before acrylic resin was set, upper and lower halves of the flask were placed together under pressing machine at 2000 N/cm^2 for five minutes. Then, upper and lower halves of the flask were separated, in this way a duplicate acrylic pattern from an aluminum pattern was made. Eighteen acrylic patterns were made this way. These patterns were invested in a circular casting rings lined with one layer of ring liner with phosphate-bonded investment (Hi Temp II, whip mix Corp, Louisville, ky). The rings were then placed in burnout furnace. Temperature was raised to 30 $^{\circ}C$ and held for 30 min at this temperature, followed by an automatically raise to 860 $^{\circ}C$ keeping for 30 minutes. Rings were cast by use of gas/oxygen torch and a manually controlled centrifuge machine (Degutron, Degussa, Germany). The castings were then bench cooled for 1 hour, divested, sandblasted and cleaned ultrasonically.

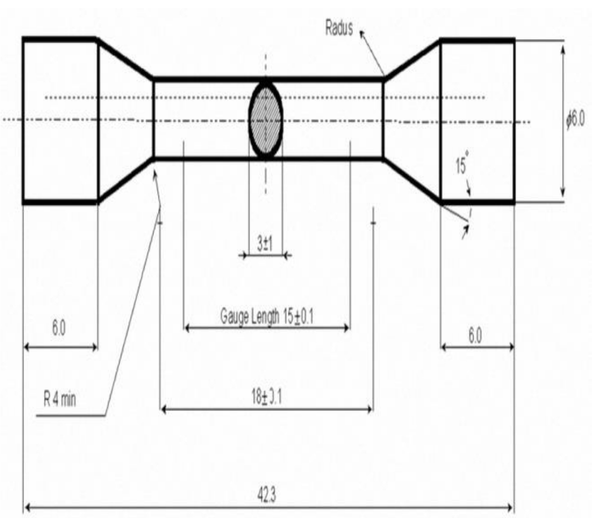

Figure 1 ADA/ISO 9693 model for tensile strength test

Preparation for soldering procedures

A mounting jig was made by filling a cup with stone (plaster) and sinking one half of each specimen into it, each specimen was cut in half by an ultra-thin disc (Dedeco International, long eddy, N, Y) perpendicular to them.

The thickness of the disc was .00٨ inches (0.2٠mm), which approximated a thickness of a business card. The specimens were joined with chemically activated acrylic resin (Duralay, Illinois, U.S.A) .The specimens were removed from plaster and invested in a block of soldering investment (Hi Temp II, whip mix Corp, Louisville, ky) with one inch thickness. For the gas-oxygen torch soldering, the soldering block was pre-heated in a burnout furnace at 350ºc for 30 minutes. The soldering gaps were fluxed before the soldering procedure, Vera solder which was used in this study was also dipped into flux before soldering. After soldering, specimens were allowed to bench cool. Joint areas were finished and polished by disc and polishing stones so that the thickness of these areas was 3.1mm. Joint areas were evaluated radiographically to ensure a porosity free joint. All Specimens were positioned 12.5cm (5 inches) from the focal point of the radiographic unit which was set at 0.35 seconds, 15 ma and 90 kVp.

Preparation of specimens for the tests

The specimens were secured in an optimum horizontal and vertical position for testing compression and tensile strengths respectively. A universal testing machine (Instron; Zwick 20, Germany) was used for testing tensile strength and Dartec machine (HC10, England) was used to test compressive and flexural strengths. Force was applied at a speed of 0.5 mm/min for all three tests and mega pascal was used as the unit of force. Statistical analysis was computed by SPSS software (IBM SPSS statistics 22) and Mann - Whitney test was used for comparison between groups (significant level =0.05).

Results

The mean compressive strength for soldered supercast alloy was 1014.018 MPa and for soldered Minalux was 938.17. The mean flexural strength for soldered supercast alloy was 44.01 MPa and for soldered Minalux alloy was 51.70. The mean tensile strength for soldered supercast alloy was 347.46 MPa and for soldered Minalux alloy was 350.03 (Table.1). It was concluded that there were no statistical differences between compressive, flexural and tensile strengths of supercast and Minalux alloys (p=0.27, 0.38 and 0.18).

Table 1 Comparison between strength of soldered joint of supercast and minalux alloy (MPa)

groups	Supercast		Minaux		P -value
	Mean±SD	Median	Mean±SD	Median	
Compressive strength	1014.18±63	1021.78	938.17±48	965.54	0.27
Flexural strength	44.01±12	48.60	51.70±14	53.20	0.38
Tensile strength	347.47±21	332.89	350.03±33	342.41	0.18

Discussion

El – Ebrashi et al stated that clinical failure of FPDS occurred at the point of maximal tensile stress, thus measuring the tensile strength of a soldered connector is an appropriate method of comparing fracture resistance (19). On the other hand, Morse et al used flexural strength in their study, stating that flexural strength is a combination of several kinds of stresses and therefore is recommended to measure the strength of a soldered joint (20). In this study, tensile, compressive and flexural strengths of two soldered joint alloys, namely Supercast and Minalux, were measured. Lautenschlager et al. demonstrated that changes in cross head speed of the Instron testing machine affect the strength of soldered joints. Studies on base metal alloy solder joints have used a wide range of cross head speeds with no apparent influence on the results (21, 22). In this study, a cross head speed of 0. 5 mm/min was selected. The soldering technique used in this study was pre-veneer soldering using gas/oxygen torch. All joints in this study were fluxed before soldering to minimize oxide formation. A disadvantage of preceramic soldering is the risk of parent alloy melting and also micro porosity or pitting as a result of volatilization of base metal alloy constituents (23). Porosity in solder joints may be produced by flux entrapment due to over-fluxing and under-heating, in addition to the wetting ability of molten solder in solder gap space (24,26)..All materials and instruments used such as stone, the investment ring, etc were the same for both alloys. There are controversies regarding gap size to be soldered, but it is recommended to be between .005-.0012 inches .[8] In this study, a gap size of .009 inches was chosen. Willis et al, in contrast to the present study, suggested using a minimum gap distance without contact (25).Our results indicated that, there were no statistical differences between mean tensile, compressive and flexural strengths of soldered Supercast and soldered Minalux alloys. However, the mean tensile strength of soldered joint of Supercast alloy was slightly lower than Minalux alloy, but as noted earlier, this was not statistically significant. Another point is that the mean flexural strength for soldered joints was lower than the mean for tensile and compressive strengths. This is probably due to the fact that flexural strength is a combination of several kinds of strengths. As stated by morse et al, the strength of solder joints is related to five general factors: wetting, strength of metals to be joined, geometry of the joint, flux inclusions and voids and thickness of soldering alloy in the gap (20).They concluded that different alloys will show different results, which is consistent with the results of this study (27).Minalux is an alloy made in Iran, which is devoid of beryllium; this is of importance, because Beryllium is known to have carcinogenic potentials. Therefore, as far as soldering procedures are concerned, Minalux solder joints have the same strength as supercast solder joints. It is recommended to compare other properties of these two alloys together i.e. porcelain bond to these two alloys and their solder joints. If the results show same characteristics in Minalux and Supercast, then we can be confident in using Minalux instead of Supercast which is an alloy containing beryllium, and also has to be bought from foreign countries.

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Corresponding Author
Ehsan Ghasemi
Assistant Professor, Dental Materials Research Center and Department
of Prosthodontics, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
Tell: 03137925562
Email: ehsann.ghasemi@gmail.com