# A Comparison of Hydrogen/Oxygen and Natural Gas/Oxygen Torch Soldering Techniques

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The tensile strength of connectors joining bars of palladium-silver alloy and formed using hydrogen/oxygen flame soldering was compared to those formed using conventional gas/oxygen soldering. As-cast specimens served as the control. No significant differences were found between the as-cast, hydrogen/oxygen flame soldered, or the natural gas/oxygen flame soldered specimens. *Int J Prosthodont 1994;7:258–263.*

A fixed partial prosthesis may be either cast in one piece or in sections to be joined by soldering. The soldering method has the advantage of permitting each individual retainer to be fitted to its abutment instead of fitting the entire prosthesis to multiple abutment teeth.[1]

Soldering techniques have not changed in many years. Traditionally, hand-held gas/air or gas/oxygen torches have been used to heat the components.[2] Little information has been published regarding the joining of metals by methods other than conventional torch soldering or oven soldering techniques.[3–5]

In aeronautics, oxidation of similar alloys is reduced by soldering parts in protective atmospheres such as helium, argon, or hydrogen gas, or in high-power vacuums.[6] Hydrogen gas is a strong reducing agent that ignites at 574°C.[7,8] It is readily absorbed into the surface of certain metals, including palladium.[7] Hydrogen torch soldering has been reported to have been used in dental laboratory procedures for over 50 years,[9] but its use has been rarely reported.[10,11] The most practical use in dentistry was for orthodontic soldering where the parts to be joined were small. Although the strength of orthodontic connectors formed using a hydrogen flame and torch was found to be equal,[10] hydrogen soldering apparently never gained significant acceptance in fixed prosthodontic procedures.

The purpose of this investigation was to evaluate the tensile strength of soldered connectors of test specimens formed using a hydrogen/oxygen torch flame and natural gas/oxygen flame and compare these to as-cast specimens.

## Materials and Methods

Thirty specimen rods, 41 mm long and 3 mm in diameter, were made from prefabricated wax tensile test patterns (J.M. Ney, Bloomfield, CT). Each specimen had enlarged ends that could be gripped in a universal testing machine (Fig 1).

All specimens were individually invested in 2-inch-diameter steel casting rings (J.M. Ney) using a noncarbon phosphate bonded investment (Hi Temp casting investment, Whip Mix, Louisville, KY) with the manufacturer's recommended liquid/powder ratio of 14.5 mL of special liquid concentrate to 90 g of powder. The patterns were cast using 50% new and 50% used alloy (± 10%) (Fig 2). The metal, a 60% palladium/28% silver alloy (PD 60, Five Stars Alloys, Hackensack, NJ), was heated in a new large-fused silica casting crucible (Kerr, Romulus, MI). Castings were made with a hydrogen/oxygen flame torch (Hydrogen Flame

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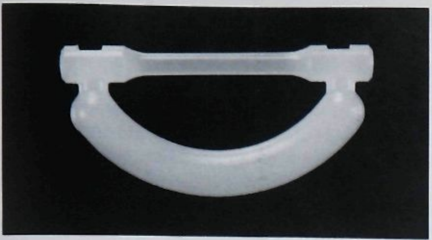


**Fig 1** Prefabricated wax pattern for tensile test rod.

**Fig 2** Specimen cast in palladium-silver alloy.

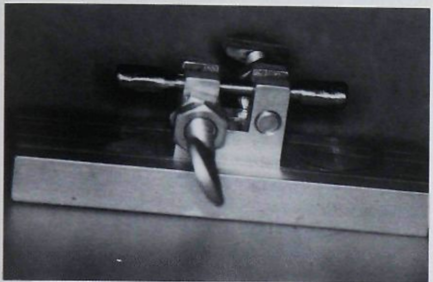


**Fig 3** Aluminum jig.

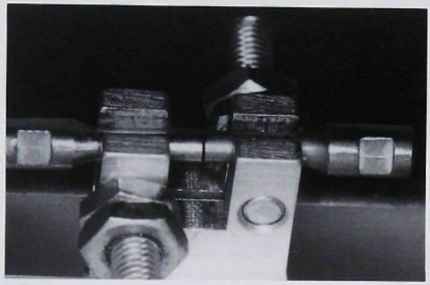


**Fig 4** Aluminum jig with casting parts aligned and 0.005-inch gap set.

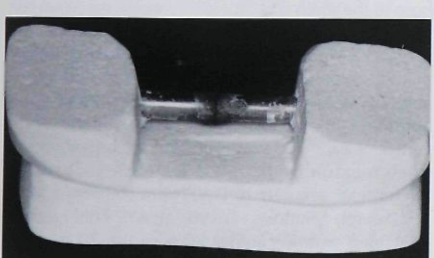


**Fig 5** Specimen invested for soldering.

model Heraeus HT-150, Technical Industrial Products, Philadelphia, PA) used to heat the alloy in the crucible that was held in an open, broken arm, centrifugal casting machine. Each casting was allowed to cool to room temperature, devested, and airborne particle–abraded (Comco MB102 microblaster, Sun Valley, CA) using 50-μm nonrecycled aluminum oxide.

Ten randomly selected castings were reserved for testing without sectioning or soldering. Each of the 20 remaining castings was placed in a custom jig (Fig 3) and cut in half with a #5178 double-sided, 7/8 inch, 0.015-inch-thick carborundum "wafer thin" disc (Dedeco, Long Eddy, NY) using a straight handpiece held parallel to each casting. The cut ends were not subjected to any polishing procedures but were cleaned ultrasonically using distilled water. Further contact with the interfaces to be soldered was avoided.

Cut specimens were aligned and stabilized in the previously mentioned mounting jig, and 0.005-inch shim stock was used to set the gap distance (Fig 4).[12] Specimens were then joined with an autopolymerizing acrylic resin (GC Pattern Resin, G-C America, Chicago, IL). Each assembly was placed in a silicone mold to standardize the size and shape of the investment block. Soldering investment (Biovest, Dentsply) was vibrated into the mold and allowed to set overnight before separation (Fig 5). The time between investing and soldering varied from 5 to 10 days.

### *Soldering*

The resin was eliminated by placing the samples into a cold oven, raising the temperature 100° F/min to 1300°F, and maintaining that temperature for 20 minutes. Ten specimens were soldered using a natural gas/oxygen flame and 10 using a hydrogen/oxygen source.


**Fig 6** Hydrolysis machine (source of hydrogen and oxygen gases).

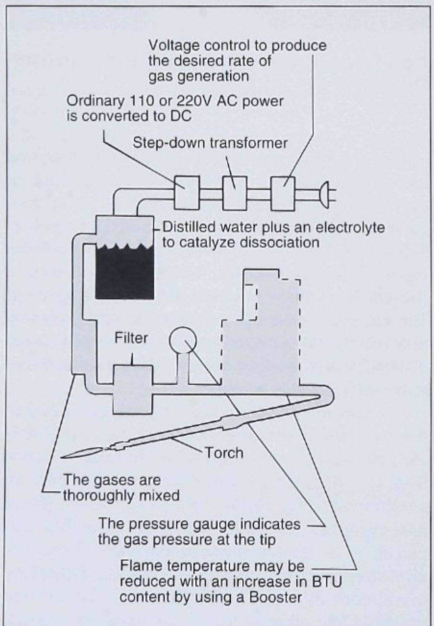



**Fig 7** Diagram of hydrolysis-generator functions.

Immediately upon removal of the sample from the oven, a preceramic flux (Ney Soldering Flux, J.M. Ney) was placed in position, and a strip of solder (High-fusing ceramic solder, Ivoclar, North America) was held against the joint ends until the gap was filled. The listed composition of the solder was 45% gold, 41.5% silver, and 12.5% palladium.

The heat from the torch was directed at each specimen in a back and forth motion until solder flowed into the 0.005-inch gap. A hydrogen/oxygen torch (Hydrogen Flame model Heraeus HT-150, Technical Industrial Products) at a temperature of about 4,500°F and a gas/oxygen torch (Niranium, Long Island City, NY) with natural gas were used for alternate specimens (Fig 6). The hydrogen/oxygen machine uses a 120-volt current to separate hydrogen and oxygen from a solution of electrolyte and distilled water by hydrolysis. A single unit can supply up to 300 liters of combined gases per hour, sufficient to cast and/or solder any fixed prosthodontic alloy. It is reported to produce a flame of 6,000°F, which can be reduced to 4,500°F by passing the gases through a canister of alcohol.[13] The generator of the hydrogen/oxygen unit is about 12 × 12 × 10-inch deep in size. The gases are generated naturally in the 2:1 ratio needed for efficient flame combustion.[13] The hydrogen and oxygen are mixed, and the mixture is sent through a single hose to the torch (Fig 7).

All specimens were bench cooled. After devesting and airborne particle–abrading using 50-µm aluminum oxide at 90 pounds pressure, all excess solder was removed using a handpiece and green abrasive stone at low speed. The diameter at the center of each rod was recorded as the average of three measurements made for each rod using a micrometer accurate to 0.001 mm (Mitutoyo MDC 293 Sevrei, Mitutoyo, Tokyo, Japan). This location coincided with the solder joint for the 20 soldered specimens.

### *Testing*

Specially designed grips were used to hold the 30 samples in a universal testing machine (Model TTB, Instron, Canton, MA). The tensile load required to fracture each specimen was recorded.

## Results

Strength values were calculated from the maximum load recorded before tensile failure divided by the computed cross-section area to give the maximum stress (force/unit area). All soldered specimens fractured at the solder joint and strength values ranged from 3,040 to 5,805 kg/cm². As-cast test specimens fractured at a mean value of 4,706 kg/cm² (SD = 754 kg/cm²). Ultimate tensile strength, mean, and standard deviations of the three groups are shown (Table 1, Figs 8 and 9).

The three groups were compared using a one-way ANOVA with pairwise comparisons using the Scheffe procedure. No significant differences were

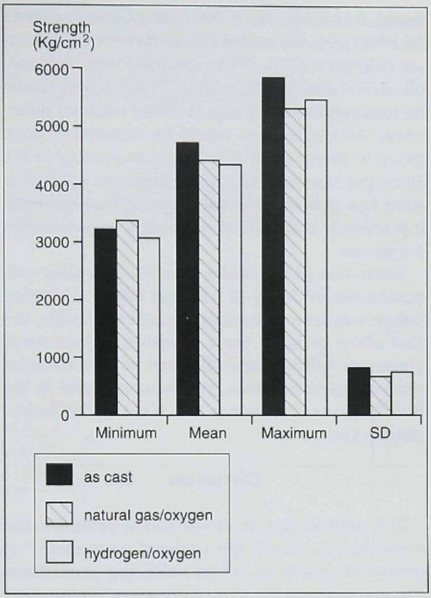
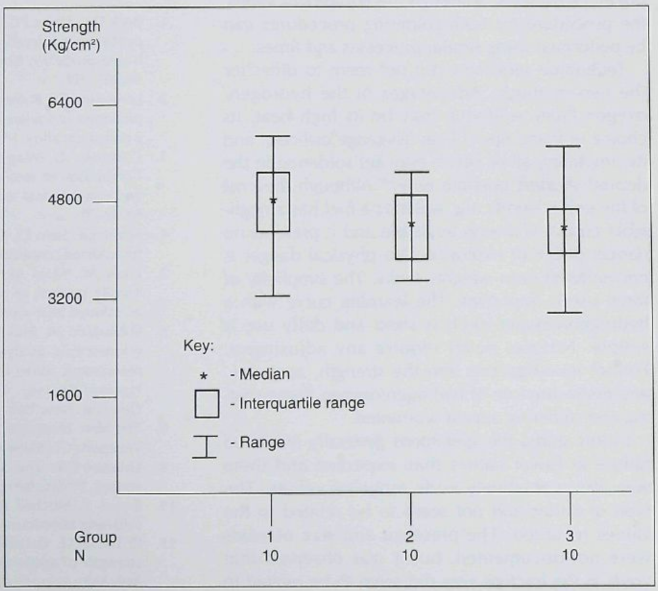



**Fig 8** Ultimate tensile strengths (minimums, means, maximums, and SDs) of specimens.

**Table 1** Ultimate Tensile Strengths of Each Specimen

| | As cast | Natural gas/oxygen | Hydrogen/ oxygen |
|---|---|---|---|
| | 5805 | 5382 | 5625 |
| | 5515 | 5126 | 4844 |
| | 5320 | 4843 | 4782 |
| | 5182 | 4758 | 4418 |
| | 4642 | 4618 | 4382 |
| | 4416 | 4159 | 4306 |
| | 4378 | 4144 | 4214 |
| | 4314 | 3984 | 4048 |
| | 4216 | 3665 | 3668 |
| | 3272 | 3412 | 3040 |
| Mean | 4706 | 4409 | 4333 |
| Standard Deviation | 754 | 639 | 695 |

**Fig 9** Ultimate tensile strengths of (median, interquartile range, and range) specimens.



found, F (2,27) = .7649, NS. Using Cohen's criteria for effect size, the probability of detecting a moderate difference (25% of the variance) with this sample size is about 60%. About 70 specimens would be required in each group to detect medium differences; 600 specimens would be required in each group to detect small differences at a power of 80. Since the observed differences between conditions were less than the standard error of measurement, it is unlikely that clinical differences exist between the groups.

Separation of the solder from the cast alloy was considered evidence of adhesive failure. Cohesive failure was seen as fracture through the solder, the cast alloy, or both. Both adhesive and cohesive connector failures were observed in both soldered groups. Seven cohesive failures were found in the natural gas/oxygen group and eight in the hydrogen/oxygen group.

## Discussion

The weakest part of a fixed partial denture metal framework is usually the soldered connection.[14] A connector made by sound soldering procedures can approximate the strength of a cast connector.[15] A connector that is soldered by either hydrogen/oxygen or natural gas/oxygen flame can be successfully fabricated and used for fixed prosthodontic procedures. Although the equipment varies, the procedure for both soldering procedures can be performed using similar processes and times.

Technique sensitivity did not seem to differ for the two methods. Advantages of the hydrogen/oxygen flame soldering may be its high heat, its choice of flame tips (14- to 30-gauge orifices), and its simplicity, all of which may aid soldering in the desired shortest possible time.[16] Although the cost of the unit is significant, water as a fuel has a negligible cost. It is always available and it presents no danger of fire or explosion. No physical danger is encountered from weighty tanks. The simplicity of torch use is important. The learning curve with a hydrogen/oxygen torch is short and daily use is simple. Nozzles never require any adjustment. Further investigations into the strength, accuracy, and microstructure of hydrogen/oxygen flame casting and soldering appear warranted.

In this study, the specimens generally exhibited failure at lower values than expected and there was also a relatively wide range of values. The type of failure did not seem to be related to the values recorded. The presence and size of voids were not documented, but it was observed that voids at the fracture sites did seem to be related to the recorded values. Even when care is exercised in all procedures, a small sample size, voids typical of palladium silver castings, soldering voids, irregular cross-sections, and testing apparatus variability may yield less than ideal results.

## Conclusions

As-cast and soldered palladium-silver rods were fabricated and tested in tension. Under the conditions of the study, the following conclusions may be made:

1. Specimens soldered by natural gas/oxygen or hydrogen/oxygen torch showed no significant difference in ultimate tensile strengths.
2. The ultimate tensile strength of specimens soldered using natural gas/oxygen torch or hydrogen/oxygen torch was not significantly different from that of as-cast specimens.

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