



The effects of tack welding and increasing surface area on the tensile strength of silver electric and flame soldered stainless steel joints

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Abstract

The purposes of this study were: 1) to compare silver solder joint strength using flame and electric soldering techniques, and 2) to determine the effect of tack welding and increasing metal-to-metal contact area prior to tack welding, on the tensile strength of silver solder joints. Six methods: (flame soldered; tack welded and flame soldered; increased contact area, tack welded, and flame soldered; electrosoldered; tack welded and electrosoldered; and increased contact area, tack welded, and electrosoldered) were used to produce 15 solder joints in each group. The tensile strength of the joints were tested with Instron Universal Testing Machine.TM Flame soldering resulted in joints with significantly higher tensile strength ($P \leq 0.001$). Tack welding had no significant effect on the tensile strength of the joints. Increasing the contact area had no significant effect on the tensile strength of tack welded electric soldered joints, but significantly weakened the flame soldered joints ($P \leq 0.05$). (*Pediatr Dent* 18:215–18, 1996)

The strength of stainless steel silver solder joints used to fabricate orthodontic appliances and space maintainers is critical. The appliance must be able to withstand the forces generated while eating—or the force of a patient's curious finger. Broken appliances are a common source of unscheduled office visits. Complications of broken appliances include soft tissue irritation, lost orthodontic anchorage, untoward movement of teeth, and swallowing or aspiration of broken parts (Fig 1).

A 10-year review of the literature failed to reveal new materials or methods to help technicians fabricate stronger stainless steel silver solder joints. A number of studies^{1–5} compared silver solder joints produced by several techniques differing in the method of heat application. Results are inconclusive as to which technique produces the strongest joints. Gardiner and

Aamodt² and Brown, Mitchell, and Barenie³ found that the strongest joints were produced by flame soldering techniques and the weakest joints were produced by electric soldering methods. Laird and von Fraunhofer⁴ found no significant difference in tensile strength between silver solder joints produced using electric- or flame-solder techniques. These investigators evaluated similarly designed butt-ended stainless steel wire or rod solder joints.

O'Toole, Furnish, and von Fraunhofer⁵ recently compared the tensile strength of overlapping joints of orthodontic stainless steel wire to stainless steel band material using a traditional gas-air blowpipe, an electrochemically generated hydrogen-oxygen flame, and an electric soldering unit. In this study, the gas-air flame produced significantly stronger joints than electric soldering and the hydrogen-oxygen flame.

Electric welding utilizes electric impulses that generate significant heat over a small area to fuse the metal of two objects. Lightly welding or tack welding stainless steel parts prior to silver soldering produces weak bonds between metal parts that can be broken with fin-

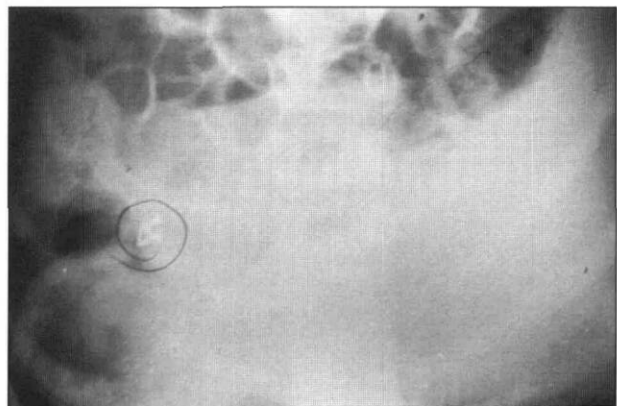


Fig 1. KUB (kidney, urethra, bladder) radiograph showing section of habit appliance in patients intestine. The appliance failed at the solder joints.

ger pressure. The tack welds are used for the sole purpose of holding the parts together prior to soldering.¹ The effect of tack welding on joint strength has not been investigated.

The effect of increasing the surface contact area prior to tack welding and soldering has not been studied. Flattening round wire allows for a less bulky solder joint. Also, the increased metal-to-metal contact area may improve the strength of the solder joint.

The purposes of this study were to: 1) compare the strength of solder joints fabricated using flame and electric soldering techniques, and 2) determine the effects of tack welding and increasing contact area on the tensile strength of soldered joints.

Methods and materials

Six soldering methods were tested: (group F) flame soldered; (group FW) tack welded then flame soldered; (group FWD) wire flattened to increase contact area at the joint, tack welded, then flame soldered; (group E) electrically soldered; (group EW) tack welded then electrically soldered; and (group EWD) wire flattened, tack welded, then electrically soldered. Fifteen solder joints were prepared for each group.

Orthodontic 50-mm-long, stainless steel wires (size 0.036, standard round wire, Unitek/3M, Monrovia, CA) were soldered to stainless steel strips (Ion Brand Ni-Chro/3M, Dental Products Division, 3M Health Care, St Paul, MN), 50 mm x 10 mm x 0.18 mm. All joints were 2.20 ± 0.35 mm in length as measured with a micrometer (Ultra Cal II,TM Fowler Inc, Newton, MA). Preformed silver solder rectangles (Rocky Mountain Orthodontics, Denver, CO) and soldering flux (ORMCO, Glendora, CA) were used as the soldering media. All joints were completely covered with solder (Fig 2). The wire for samples FWD and EWD was flat-

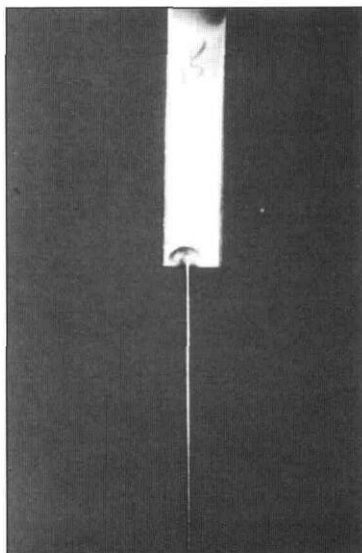


Fig 2. Standard 0.036 round wire with 2-mm solder to stainless steel strip.

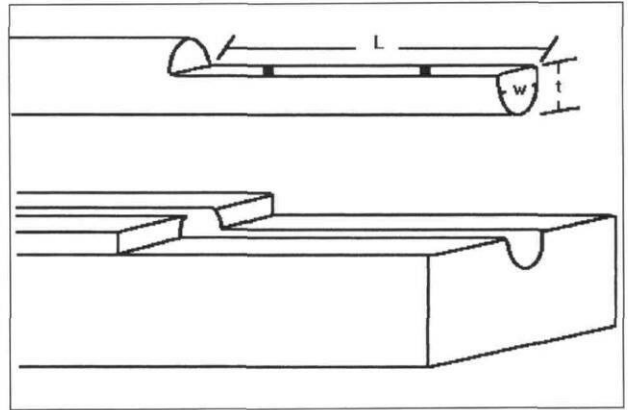


Fig 3. Schematic of flattened 0.036 round wire, tack weld locations, and custom block used to standardize amount of wire reduction. ($L = 2$ mm, $w-t = 0.28 \pm 0.03$ mm).

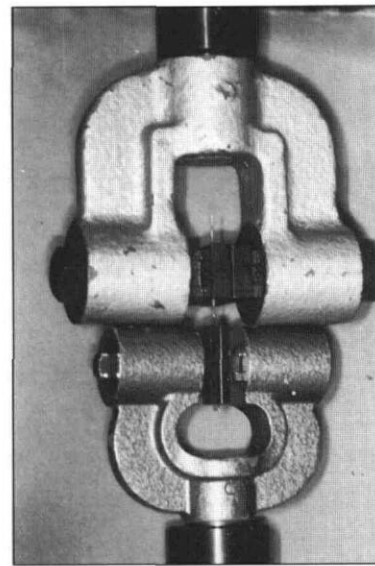


Fig 4. Testing tensile strength of solder joints with Universal Testing MachineTM (Instron Corp, Canton, MA).

tened on one side with a 2-mm green stone. The decrease in diameter was 0.28 ± 0.03 mm for the length of the solder joint, as measured with the same micrometer (Fig 3). Joints tack welded prior to soldering (groups FW, FWD, EW, and EWD) were prepared with two tack welds, spaced 1 mm apart, on each 2-mm joint with a portable electric welder unit (Model No. 660, Rocky Mountain Orthodontics, Denver, CO) set on the #2 weld position. Flux was placed at the joint site, a silver solder rectangle was placed over the joint, and the solder joints were prepared either with the reducing area of a flame (OrthoflameTM soldering torch, Rocky Mountain Orthodontics, Denver, CO) for groups F, FW and FWD, or with the electric welder set on the soldering position for groups E, EW, and EWD. The specimens were immediately quenched in cold water as recommended by Phillips.¹

Tensile strength measurements were made of joints using a Universal Testing Machine (Instron Corp, Canton, MA) at a crosshead speed of 2.0 mm/min (Fig 4). The load at failure was recorded. The broken joints were examined visually to determine where the failure had occurred, within the solder joint or outside the solder joint (wire or metal strip failures). All laboratory procedures, measurements, and testing were done by the primary author.

Means and standard deviations of the tensile strengths, and tensile strengths per unit length, for each of the six test groups were determined. Analysis of variance (ANOVA, $P \leq 0.05$) and the Scheffe multiple comparison test were used to determine statistical differences within groups E and F. Students *t*-test ($P \leq 0.05$) was calculated to compare all flame groups to all samples in electro soldered groups.

TABLE 1. MEAN TENSILE STRENGTH PER UNIT LENGTH (KG/MM)

Solder Group	kg/mm (SD)	
F	41.48	(3.98)
FW	40.41	(5.05)
FWD	35.85	(4.73)
E	29.04	(5.82)
EW	28.00	(3.37)
EWD	28.84	(3.18)
Combined F groups	39.24	(5.13)
Combined E groups	28.63	(4.22)

Results

Mean tensile strengths per unit joint length (kg/mm) of soldered joints produced by the six techniques are shown in Table 1. Brackets indicate statistically significant differences. Flame soldered joints (groups F, FW, and FWD combined) were found to be stronger than electro soldered joints (groups E, EW, and EWD combined) at a statistically significant level ($P \leq 0.001$). Within the flame soldered group, F and FW were found to have statistically significant ($P \leq 0.05$) higher mean tensile strengths per unit length than group FWD. No statistically significant differences were found within the electro soldered groups.

TABLE 2. SITE OF FRACTURE

Solder Method	Within Joint	Wire Fracture	Strip Fracture
F	7	8	0
FW	13	2	0
FWD	12	3	0
E	13	1	1
EW	14	1	0
EWD	15	0	0

Table 2 shows where the joints failed. Seventy-four of the sample test strips failed at the joint. Sixteen of the strips failed outside of the joint itself. Fifteen of these were wire failures and one was due to the stainless strip tearing. The flame soldered samples had 13 wire failures as opposed to two for the electro soldered samples. There was no significant difference in tensile strength between samples with wire fractures and samples that fractured within the solder joint.

Discussion

Silver soldering of stainless steel wires for the fabrication of appliances typically involves overlap of wires with crowns, bands, or other wires. In stainless steel soldering, it is important that the solder wraps around the wires so that the relatively weak solder has sufficient mass to strengthen the joint.⁶ Evidence indicates that no alloying occurs at the stainless steel-silver solder interface and that the bond is strictly mechanical.^{1,3,7}

Other than joint strength, considerations for choosing soldering methods are convenience and characteristics of the work site. Laird and von Fraunhofer⁴ reported that electric soldering was the most rapid and convenient method of producing a soldered joint. Phillips¹ recommended that parts be tack welded to hold them in alignment during soldering. When tack welding, the resistance of the material to the flow of a large electric current produces intense localized heating and fusion of the overlapped metals.¹ Rogers⁸ found that excessive current led to concavity, pitting, or burning of the surfaces in apposition to the electrodes, resulting in a reduction of the metal thickness in the weld area and destruction of the grain structure of the stainless steel. Flattening wire to be soldered to crowns and bands is a way of increasing metal-to-metal contact and also decreasing the overall bulk of the solder joint. However, techniques that simplify the soldering procedure should not be used if they affect the joint strength.

In our study, neither tack welding nor adjusting the wire to increase the contact surface area with the metal strip and then tack welding had a significant effect on the tensile strength of electro soldered joints. Tack welding had no significant effect on the tensile strength of the flame-soldered joint. Adjusting the wire to increase the contact surface area prior to tack welding significantly weakened the flame soldered joint.

Flame soldering resulted in stronger solder joints than did electric soldering, which coincides with previous studies. Flame soldering appeared to weaken the wire more than electric welding in our study. The majority of wire failures (13 of 16) occurred in samples that were flame soldered. There was no statistically significant difference in tensile strengths between wire fracture samples and those that fractured within the solder joints. The clinical significance of this finding is not

certain. It may be due to the difficulty of controlling flame temperature and the resulting overheating of the wire. Overheating stainless steel wire destroys its temper and resiliency, which can contribute to wire failure.

Recently Tehini and Stein⁹ compared gas flame and a new infrared heating technique on gold alloys. They showed that infrared and torch soldering produced joints with similar strengths. The infrared unit provides a more precise temperature control according to the manufacturer's operating manual. Future study of this technique using silver solder and stainless steel may demonstrate a means of soldering that is less technique sensitive and produces consistently stronger joints.

Conclusions

For silver stainless steel solder joints (between 0.036-in. stainless steel orthodontic wire and stainless steel crown material with about 2 mm of overlap) tested for tensile strength:

1. Flame soldering, compared with electric soldering, resulted in joints with significantly higher tensile strength.
2. Flame soldering resulted in more wire fractures outside of the solder joint.
3. Tack welding had no significant effect on the tensile strength of either electric or flame soldered joints.
4. Increasing the contact area at the solder joint by adjusting the wire prior to tack welding and soldering had no significant effect on the tensile strength of tack welded electrosoldered joints, but weakened the flame soldered joints.

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Teen pregnancy rate rises

RATES OF ADOLESCENT PREGNANCIES AND BIRTHS HIGHER IN U.S. THAN OTHER DEVELOPED COUNTRIES

Pregnancy rates among 15- to 19-year-old girls increased by 9% from 1980 to 1990, according to a study published in a recent issue of *The Journal of the American Medical Association*.

Alison M. Spitz, MS, MPH, from the Centers for Disease Control and Prevention (CDC), Atlanta, Ga., and colleagues studied the numbers of teenage pregnancies, births and abortions using data from the CDC, the National Survey of Family Growth, and the National Center for Health Statistics.

The authors write: "Pregnancy rates among 15- to 19-year-old teenagers remained fairly stable from 1980 to 1985 but increased by 9% during the last

half of the decade, reaching 95.9 pregnancies per 1,000 teenaged girls 15 to 19 years old by 1990."

Birth rates among teenagers 15 to 19 years old declined by 4% between 1980 and 1985, but increased by 18% between 1985 and 1990, reaching 59.9 births per 1,000 teenage girls 15 to 19 years old in 1990.

Rates of abortions among teenagers 15 to 19 years old remained stable during the 1980s, with 35.8 abortions per 1,000 teenaged girls 15 to 19 years old in 1980 and 36.0 abortions in 1990.

The authors warn that despite similar rates of sexual experience, rates of adolescent pregnancies and births are higher in the United States than in other developed countries, and an estimated 95% of pregnancies among teens are unintended.