TENSILE STRENGTH OF FLAME SOLDERED & LASER WELDED JOINTS OF STAINLESS STEEL WIRES WITH BAND

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ABSTRACT

Objectives: To compare the tensile strength of flame soldered joints and laser welded joints formed with stainless steel wires and band materials. Also to determine the tensile strength of various types of joints site preparations (Round wire, Flattened wire, Sandblasted wire).

Methods: Sixty joint specimens were prepared using 50mm length 0.036 round RemaniumTM (Dentaurum) stainless steel wires and 50mm length 0.180 x 0.005 TruChrome (RMO) band materials. They were assigned in two groups for flame soldering and laser welding of 30 specimens each and divided into three sub-groups of 10 specimens each. Sub group A comprised of round wire. Sub group B comprised of flattened wire. Sub group C comprised of sand blasted stainless steel wire and band material. Tensile testing was conducted with a Universal Testing Machine at a crosshead speed of 2.5 mm/min. The means and standard deviations of the tensile strengths per unit joint length were determined.

Results: The laser welded joints were found to be stronger than the flame soldered joints at a statistically significant level (P < 0.05). The laser welded joints of sandblasted wire and band material was found to be stronger than the other subgroups but there is no statistically significant difference between them.

Significance: Laser welding can be an alternative to flame soldering of stainless steel wires and band materials. Increasing the surface area by flattening or by sandblasting does not influence the strength of the joint.
Keywords: Laser welding, Soldering, Strength, Stainless steel wire, Band material, Space

1. INTRODUCTION

A number of metallic components are used in dental practice for construction of orthodontic appliances including space maintainers. The frequently employed processes to join two or more metal parts are soldering and welding. Susceptibility to corrosion and low strength of soldered joints are commonly encountered problems arising from soldering [1]. The most critical part of any orthodontic appliance and space maintainers is the strength of the stainless steel silver solder joints when they are employed. The appliance must be able to withstand the intra oral forces generated while in function. Broken appliances may lead to local complications like soft tissue irritation, lost orthodontic anchorage, untoward movement of teeth to life threatening emergencies like swallowing or aspiration [2,3]. Many indications for the use of space maintainers are suggested but very little evidence exists regarding their efficiency [4,5]. The major factor affecting the efficiency of space maintainers is length of service. Therefore the mean survival time is a valuable parameter in the indication and evaluation of space maintainer.

Various studies have shown that low mean survival rate of a space maintainer [4-7], and the common cause for failures of the appliance were due to solder breakage [6,7].

Another method of joining metals is by laser welding and can be an alternative to soldering [8]. The laser welding process was introduced into dentistry by the end of the 1980's, resulting on a great impulse to that area with the development of cheaper and smaller equipment, using simpler technique. The heat source for the laser welding process is a concentrated light beam of high power, which minimizes distortion problems [9]. Various studies have compared the performance of laser welding with the other means of joining metals used in orthodontics, prosthodontics and implantology and have found that laser welding to be superior or comparable to other means. Therefore, it is assumed that laser welding of stainless steel orthodontic wires and stainless steel orthodontic band materials is most advantageous method. The purpose of this study was to compare the tensile strength of flame soldered joints and laser welded joints formed with stainless steel wires and band materials. Also to determine the tensile strength of the flame soldered and laser welded joints on increasing the surface by flattening the end of the wire and sand blasting the ends of the wire and band materials.

2. Materials and methods

A total of 60 joint specimens were prepared using 50mm length 0.036 round Remanium™ (Dentaurum®) stainless steel wires and 50mm length 0.180 x 0.005 TruChrome (RMO®) band materials. They were assigned in two groups for flame soldering and laser welding of 30 specimens each. Each of the 30 specimens of Group I and Group II was divided into three sub-groups of 10 specimens each (Fig.1). Sub group A comprised of round stainless steel wire. Sub group B comprised of flattened stainless steel wire. A 2mm length of the stainless steel wire end to be joined was flattened in order to increase the metal to metal contact area to 0.6mm from the original diameter of wire i.e. 0.9mm, with an acrylic trimmer mounted on a micromotor straight hand piece. A stainless steel custom block was used to check the amount of wire reduction. The custom block had a grove 50mm long 0.9mm in depth, a 2mm length of the groove reduced to a depth of 0.6mm served to cross check wire reduction after flattening.

Sub group C comprised of both the stainless steel wire and the stainless steel band material sand blasted to a 2mm length at the end where the joint site was made. A 2mm Surface of each stainless steel wire and band material was treated with aluminium oxide particles [100-110 microns] directed from the sand blaster (Delta dental equipment) under four bar psi of air pressure. Sand blasting was considered complete when the entire 2mm surface of the band material and stainless steel wire took on a uniform frosty white appearance [10]. Typically this required 7 to10 seconds [11].

For flame soldering procedure, a stainless steel jig was prepared in order to stabilize the stainless steel wire and band material with a uniform amount of overlap of 2mm[2,12] and to provide an adequate air space of about 0.3mm [13,14] to the joint site while soldering. The total length of the jig was 96mm. It had a groove of 48mm long and 0.9mm depth for the stainless steel wire specimen and 48mm long for the band material specimen with 4mm x 6mm groove, at the intersection to provide adequate air space for the joint site

[12]. The specimens were stabilized in the stainless steel jig prior to soldering using plaster of paris custom blocks. Care was taken to cover areas other than the joint site with plaster of paris custom blocks in order to avoid unnecessary exposure to heat from the flame soldering torch (Microtorch, GS). Adequate amount of flux was placed at the joint site. Antiflux (lead pencil) was used to restrict the flow of solder beyond 2mm of the desired joint length [13].For each specimen the amount of solder used was kept uniform of about 4mm of the silver solder (American Orthodontics®). The joint site was adequately heated after application of the soldering flux (American Orthodontics®) within the reducing zone of the flame and as soon as the site reached solder flow temperature, a 4mm of solder was held in a tweezer and introduced at the joint site [2]. The flame was kept approximately three fourths inch long throughout the flame soldering procedure [13]. The flame was withdrawn when the solder had flowed evenly over the joint site in a feather edge configuration [12] and immediately quenched in water.

The laser welding was done utilizing cw Nd:YAG laser unit (JK 2000, GSI group Inc., UK). The parameters were set as 300-350 watts for 0.2 seconds. The specimens were stabilised in the welding platform such that 2mm overlap was kept uniform for all the specimens and laser welding was carried out with argon shielding. Tensile testing for all the 60 Specimens was conducted with a Universal Testing Machine (Unitek 94100, FIE-Blue Star, India) at a crosshead speed of 2.5 mm/min. The load of failure was recorded in Kilo Newton (KN), and the tensile strength value in Kg/mm of the joint length were then determined using the formula given in Fig.2. The statistical analyses were done using SPSS software. The means and standard deviations of the tensile strengths per unit joint length for each of the two groups and each of the six subgroups were determined. Analysis of variance (ANOVA) and students't' test were used to determine the statistical differences within the groups and subgroups. The level of significance to reject the null hypothesis was $p \leq 0.05$

3. Results

The mean tensile strengths per unit joint length of the various groups and subgroups are shown in the Table 1. The mean tensile strength per unit joint length of the flame soldered joints (n = 30) was 6.631 (SD 0.40) Kg/mm and the mean tensile strength per unit joint length of the laser welded joints (n = 30) was 7.239 (SD 0.47) Kg/mm. The laser welded joints were found to be stronger than the flame soldered joints at a statistically significant level ($P < 0.05$). Among the strengths of various types of joints site preparations (Round wire, Flattened wire, Sandblasted wire), the laser welded joints of sandblasted wire and band material was found to be stronger than the other subgroups but there is no statistically significant difference between them.

4. Discussion

The fabrication of a space maintainer typically involves wires and band materials joined by soldering. However there was no data regarding the comparisons between the laser welded and conventional flame soldered joints of stainless steel orthodontic wire and band materials. In this study, the mean tensile strength of laser welded joints was found to be significantly higher than the mean tensile strength of soldered joints. The probable reason for decreased tensile strength for flame soldered joints may be because the bond created by soldering is strictly mechanical and no alloying occurs at the stainless steel silver solder interface [13]. The fusion of the parent metal parts does not usually occur during soldering process. More over the strength of the soldered joint was reduced as the parent alloys are soldered with different types of alloy solder. Laser welding produces joints in which actual fusion of the parent metals occur and thereby these laser welded joints exhibit the similar strength as that the parent metals [15,16].

With regard to the effect of increasing the surface area by flattening the stainless steel wires and sand blasting at the joint site, the sand blasted specimens of laser welded Remanium (Dentaurum) stainless steel wire-TruChrome (RMO) band material joints showed higher tensile strength values. Although not significant, the higher tensile strength values for sand blasting may be attributed to the increased surface area for chemical and mechanical bonding. Sand blasting also reduces the thickness of the oxide layer leaving a more firmly attached layer for bonding [11].

Hence it can be concluded that laser welded joints had higher tensile strength than flame soldered joints. Increasing the surface area of the joint site by either flattening the wire or by sandblasting the wire and band materials does not influence the strength of the joint obtained. Evaluation of tensile strength of the metal joints is one of the methods of evaluating and comparing their performance. The joint characteristics determined by these tests do not necessarily reflect the behavior of them under clinical conditions. Future studies with more detail laboratory findings and long term clinical data may demonstrate laser welding as a means of joining stainless steel wires with band materials that can produce stronger joints with improved clinical performance of orthodontic appliances.

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