

Original Article

Effect of electrical spot welding on load deflection rate of orthodontic wires

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ABSTRACT

Background: One of the methods used for joining metals together is welding, which can be carried out using different techniques such as electric spot welding. This study evaluated the effect of electric spot welding on the load deflection rate of stainless steel and chromium-cobalt orthodontic wires.

Materials and Methods: In this experimental-laboratory study, load deflection rate of 0.016×0.022 inch stainless steel and chromium cobalt wires were evaluated in five groups ($n = 18$): group one: Stainless steel wires, group two: chromium-cobalt wires, group three: stainless steel wires welded to stainless steel wires, group four: Stainless steel wires welded to chromium-cobalt wires, group five: chromium-cobalt wire welded to chromium-cobalt wires. Afterward, the forces induced by the samples in 0.5 mm, 1 mm, 1.5 mm deflection were measured using a universal testing machine. Then mean force measured for each group was compared with other groups. The data were analyzed using repeated measure analysis of variance (ANOVA), one-way ANOVA, and paired *t*-test by the SPSS software. The significance level was set as 0.05.

Results: The Tukey test showed that there were significant differences between the load deflection rates of welded groups compared to control ones ($P < 0.001$).

Conclusion: Considering the limitation of this study, the electric spot welding process performed on stainless steel and chromium-cobalt wires increased their load deflection rates.

Key Words: Elastic modulus, orthodontic wires, welding

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INTRODUCTION

Tooth movement is the result of force application on it and tissue response. Orthodontic wires produce biomechanical forces which lead to tooth movement.^[1] Favorable treatment results require wires with appropriate size and ideal alloys. An ideal archwire should have an acceptable amount of stabilization, hardness, formability, resiliency, biocompatibility, and weldability.^[2] Stainless steel is the primary alloy for orthodontic wires.^[3] Stainless

steel and chromium-cobalt wires are the favorite wires for the last stages of treatment, where the stability of the arch form is required.^[4,5]

The required forces for tooth movement, function through different systems such as coil springs, power arms, and attachments welded on wires and also different forms of loops either made from the wire or welded. Welding attachments on the wire help to apply forces along the center of resistance of teeth.

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Therefore, it is favorable among orthodontists.^[6]

Welding is a method for joining metals, which has different types such as laser welding and electric spot welding.^[7] Nowadays, using laser as a method for welding in orthodontic practice is reduced. The different composition of orthodontic wires can affect on the penetration depth of laser into metal wires, therefore having an effect on the joint strength of welded parts. Electric spot welding is a process in which two or more surfaces are joined by the heat produced by current electric flow. Rapid welding, easy laboratory process, low expense, and good hygiene are the advantages of this technique.^[8]

Nascimento *et al.*^[8] investigated the effect of electric spot welding on the tensile strength of wires. Results showed that stainless steel wires welded to stainless steel ones have more tensile strength in comparison with other combinations. Krishnan *et al.*^[6] investigated the strength of stainless steel wires after welding process and mentioned that “nugget formations” that were produced in welding point during welding process and micro structural modification that happened because of heat generated in welding area, can have effect on the mechanical characteristics of these wires.

The load deflection rate of the wire is the most important factor in determining the biologic behavior of tooth movement. According to Burstone's^[9] study, the major factor in selecting a wire is its load deflection rate. Regarding that there has been no study on the comparison of electric spot welding effect on the mechanical features of stainless steel and chromium-cobalt wires therefore in this study, we evaluated the effects of electric spot welding on the load deflection rate of stainless steel and chromium-cobalt wires.

MATERIALS AND METHODS

In this experimental-laboratory study, two different types of straight wires, stainless steel (3M, Unitek, Monrovia, CA, USA) and chromium-cobalt (Blue Remaloy, Dentarum, Pforzheim, Germany) with 0.016 inch × 0.022 inch diameter were used. The samples were divided into two groups: Case and control. The control groups had two subgroups: A group of 18 stainless steel wires (30 mm) and a group of 18 chromium-cobalt wires (30 mm). These two subgroups were not welded. The case groups had three subgroups:

1. 18 samples which 30 mm of chromium-cobalt wire was welded with two 8 mm pieces of chromium-cobalt wires (R + R).

2. 18 samples which 30 mm of chromium-cobalt wire was welded with two 8 mm pieces of stainless steel wires(S + R).
3. 18 samples which 30 mm of stainless steel wire was welded with two 8 mm pieces of stainless steel wires(S + S).

Electric spot welding was performed 2 times by the Master 2000 machine (Dentaram, Pforzheim, Germany), which was set at 30W power, after joining its two electrodes.^[10] The distance between the two welding spots was 20 mm.

Afterward, all the samples underwent three-bracket bending test. The process was designed to be similar to tooth movement in the oral environment. The designed model was made of two rectangular cubes which were placed 12 mm far from each other. Two maxillary central incisor edgewise brackets (0.018 inch × 0.025 inch) were attached on the cubes so that the midpoint of the brackets had a 14 mm distance from each other. Each sample was placed in the brackets and tied with elastomeric rings. The welding points were placed outside the interbracket region. The third bracket was attached to the head of a cylinder and placed on the moveable vertical part of the testing machine. When the device was set at the unload stance, the third bracket was exactly in the middle of the two welded spots, and the three brackets were in one line. The universal testing machine (Walter+bi AG, Löhningen, Switzerland) was used for the load deflection test. The moveable part velocity was set at 1 mm/min.^[11] The load value was measured at 0.5 mm, 1 mm, and 1.5 mm deflections^[12] on the 0.022 inch dimension of the wire [Figures 1 and 2]. The machine traced the load deflection curve for each sample.

At the end, data were analyzed by repeated measure analysis of variance (ANOVA), one-way ANOVA, paired *t*-test, and Tukey test using SPSS software version 13 (SPSS, Chicago, IL, USA). The significance level was set at 0.05.

RESULTS

The mean load values for 0.5 mm, 1 mm, and 1.5 mm deflections for each sample are represented in Table 1 and Chart 1. According to the significant interaction between load changes and weld type and also to the wires, proved in the repeated measure ANOVA, the one-way ANOVA test revealed that in each group, the load values measured for the 0.5 mm, 1 mm,



Figure 1: Universal testing machine set up while wire deflected 1.5 mm in anterior view.

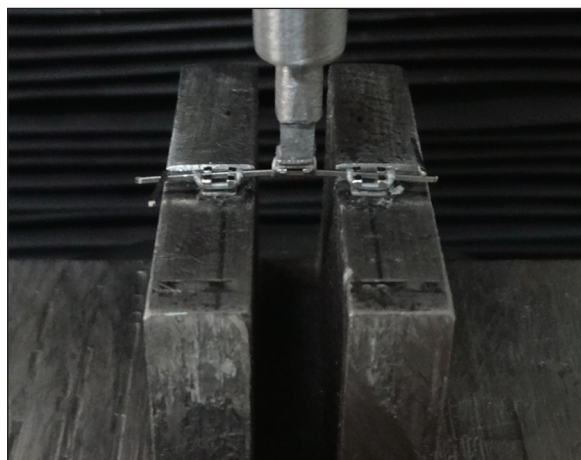


Figure 2: Universal testing machine set up while wire deflected 1.5 mm from above view.

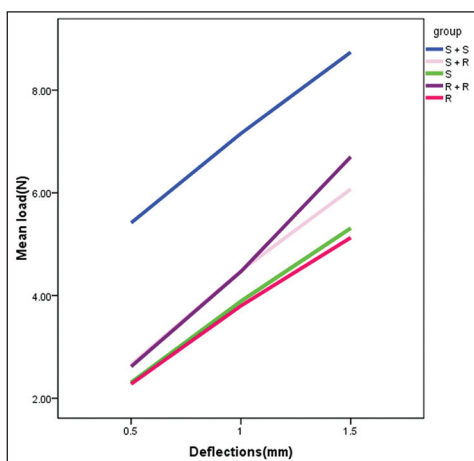


Chart 1: Linear chart of the mean loads in different deflections in each group.

and 1.5 mm deflections were significantly different ($P < 0.001$ in all groups). The difference between the load values measured in 0.5 mm, 1 mm, and 1.5 mm

Table 1: Mean and SD and CI of the loads measured in study groups ($n = 18$).

Groups	Mean \pm SD	95% CI for mean	
		Lower bound	Upper bound
Load (N) (0.5 mm)			
S + S	5.41 \pm 0.65 ^a	5.09	5.74
S + R	2.65 \pm 0.10 ^d	2.60	2.71
S	2.30 \pm 0.26 ^g	2.17	2.43
R + R	2.61 \pm 0.15 ^d	2.53	2.69
R	2.27 \pm 0.16 ^g	2.19	2.36
Load (N) (1 mm)			
S + S	7.15 \pm 0.49 ^b	6.91	7.40
S + R	4.48 \pm 0.09 ^e	4.43	4.53
S	3.88 \pm 0.33 ^h	3.72	4.05
R + R	4.46 \pm 0.19 ^e	4.37	4.56
R	3.80 \pm 0.24 ^h	3.68	3.91
Load (N) (1.5 mm)			
S + S	8.73 \pm 0.59 ^c	8.44	9.03
S + R	6.07 \pm 0.16 ^f	5.99	6.15
S	5.31 \pm 0.34 ⁱ	5.13	5.48
R + R	6.70 \pm 0.14 ^f	6.62	6.77
R	5.12 \pm 0.29 ⁱ	4.98	5.27

Different superscripts (a-j) indicate mean values that are significantly different. S: Steel wire; R: Remaloy wire; S + R: Steel weld to Remaloy; R + R: Remaloy weld to Remaloy; S + S: Steel weld to Steel; CI: Confidence interval; SD: Standard deviation.

deflections was significant in all groups ($P < 0.001$). The Tukey test showed that in 0.5 mm, 1 mm, and 1.5 mm deflections, the loads measured for the S + S group were significantly different from other groups. Also, the difference between the load values of the S + R group and the S and R groups were significant (S + R group had higher amounts) but the difference between the S + R and R + R group was not significant (except in 1.5 mm deflection in which the amounts in R + R were significantly higher), and also there was a significant difference between R and S groups and R + R group (in all deflections the mean load in R + R group was higher in comparison with R and S groups).

DISCUSSION

Orthodontic wires which enforce biomechanical forces are the main point of interest in clinical practice.^[13] Until 1920, the sole orthodontic wire available was made of gold. Stainless steel was introduced in 1929.^[2] Today, austenitic stainless steel is the primary alloy used in orthodontic wires. After stainless steel, other alloys with acceptable features such as chromium-cobalt were introduced to orthodontics.^[4] The rationale for using a wire for a specific treatment should be based on a wide

range of mechanical features such as elastic modulus (stiffness or load deflection rate).^[3] Biomechanical considerations claim that wire stiffness is an important feature which is defined as the correlation between orthodontic force and deflection in the elastic range.^[14] Our results showed that increasing in deflection (in these type of wires) significantly ($P < 0.001$) increased the force applied by the wire, which was predictable.^[15]

According to Kusy and Greenberg,^[4] although stainless steel and chromium-cobalt have different compositions, their modulus of elasticity is similar, and when the heat hardening and torsional strength of chromium-cobalt are not needed, they can be replaced with each other. Our study also showed that differences in measured loads between nonwelded stainless steel and nonwelded chromium-cobalt wires in these three deflections were not significant ($P = 1, 0.93, 0.54$). This result is similar to the study of Meling and Odegaard,^[6] which reported that 0.016×0.022 inch chromium-cobalt wire has similar stiffness with the same-sized stainless steel wire. Kusy^[17] reported that Elgiloy (Chromium-cobalt, Rocky Mountain Orthodontics, Denver, Colo, USA) had a similar stiffness with stainless steel. Stainless steel and blue Elgiloy are high stiff wires.^[5]

The welding process is widely used for helping tooth movement.^[18] Welding can be performed using electric spot weld or laser weld.^[7] Both stainless steel and chromium-cobalt can be welded to construct complex appliances.^[19] The effects of welding on wire properties are important. Our result showed that spot welding process increased the stiffness of the wire. In this study, welding was performed outside the test region to eliminate the effects of increased length on stiffness. One of the major factors in electric spot welding is the heat produced by electrodes in the joining area.^[20] Some studies claim that the low resistance of copper electrodes causes the heat to remain only in the welding spot.^[8,9] Other studies have reported that the increased temperature in the welding spot can cause significant alterations in the features of the wire adjacent to the welding point.^[20]

We can say that the effects of the increased temperature caused by electric spot welding maybe similar to heat treatment effects because nowadays orthodontic spot welders are used for heat treatment.^[21,22] Metallurgy references consider stiffness as a structure with insensitive feature, but researchers have shown that

heat treatment can affect the stiffness of orthodontic wires.^[23,24] Reduced inner stress during heat treatment in low temperature is considered as a recovery mechanism in stainless steel and Elgiloy.^[24] Various studies have evaluated heat treating different sizes of chromium-cobalt wires and reported that their stiffness increases for 10-20%.^[24] Other studies, however, claim that more than 15% increase in modulus of elasticity is very rare.^[25] Analyzing straight chromium-cobalt wires showed that a slight increase in the modulus of elasticity is predictable.^[24,26] Heat treating stainless steel wires is shown to increase its stiffness.^[27,28] The amount of the increase in modulus of elasticity of stainless steel wires after heat treatment is usually 2-5% but 15% has also been reported.^[25] On the other hand, Ingerslev^[29] reported that wire stiffness is not affected by heat treatment. Watanabe *et al.*^[19] stated that laser welding has less heat effects on the adjacent regions, therefore, is the preferable method in clinic.

Comparing the S + S and R + R groups showed that welded stainless steel loading amounts (in all three deflections) were significantly higher than welded Remaloy ($P < 0.001$). Different combinations of Co, Fe, Mb between the wires can probably be the cause of this difference. Comparing the load deflection rate of the S + R group with the S + S group showed that the S + S group had significantly higher stiffness in all three deflections ($P < 0.001$). Watanabe *et al.*^[19] also showed that heterogenous welded combination have lower load deflection rates compared to homogenous ones, maybe because of different heat transmission in weld point in heterogenous combination compared to the homogenous ones. In S + R group samples, the base wire was Remaloy, so it might be predictable that their load deflection rates were mostly similar to the base wire and lower than S + S group. The results showed that although the loading amounts in S + R group were more than R + R in 0.5 mm and 1 mm deflection, their difference was not statistically significant ($P = 0.99, 1$).

CONCLUSION

Within the limitations of this laboratory study, it is concluded that electric spot welding process done on stainless steel and chromium-cobalt wires can lead to an increase in their load deflection rates.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

- Juvvadi SR, Kailasam V, Padmanabhan S, Chitharanjan AB. Physical, mechanical, and flexural properties of 3 orthodontic wires: An *in-vitro* study. *Am J Orthod Dentofacial Orthop* 2010;138:623-30.
- Vijayalakshmi RD, Nagachandran KS, Kummi P, Jayakumar P. A comparative evaluation of metallurgical properties of stainless steel and TMA archwires with timolium and titanium niobium archwires — An *in vitro* study. *Indian J Dent Res* 2009;20:448-52.
- Drake SR, Wayne DM, Powers JM, Asgar K. Mechanical properties of orthodontic wires in tension, bending, and torsion. *Am J Orthod Dentofacial Orthop* 1982;82:206-10.
- Kusy RP, Greenberg AR. Effects of composition and cross section on the elastic properties of orthodontic wires. *Angle Orthod* 1981; 51:325-41.
- Kapila S, Sachdeva R. Mechanical properties and clinical applications of orthodontic wires. *Am J Orthod Dentofacial Orthop* 1989;96:100-9.
- Krishnan V, Kumar KJ. Weld characteristics of orthodontic archwire materials. *Angle Orthod* 2004;74:533-8.
- Madhan Kumar S, Sethumadhava JR, Anand Kumar V, Manita G. Effects of conventional welding and laser welding on the tensile strength, ultimate tensile strength and surface characteristics of two cobalt-chromium alloys: A comparative study. *J Indian Prosthodont Soc* 2012;12:87-93.
- Nascimento LE, Santos RL, Pithon MM, Araújo MT, Nojima MG, Nojima LI. The effect of electric spot-welding on the mechanical properties of different orthodontic wire alloys. *Mater Res* 2012;15:409-14.
- Burstone CJ. Variable-modulus orthodontics. *Am J Orthod* 1981;80:1-16.
- Chunduri R. Welding characteristics of variable cross section beta titanium wires. *J Indian Orthod Soc* 2011;45:24-8.
- Basafa M, Zebarjad SM, Jahanbazee H. Evaluation of load-deflection rate of stainless-steel orthodontic wires available in Iran's commercial market. *J Mashhad Dent Sch* 2006;30: 15-24.
- Nakano H, Satoh K, Norris R, Jin T, Kamegai T, Ishikawa F, *et al.* Mechanical properties of several nickel-titanium alloy wires in three-point bending tests. *Am J Orthod Dentofacial Orthop* 1999;115:390-5.
- Iijima M, Muguruma T, Brantley WA, Mizoguchi I. Comparisons of nanoindentation, 3-point bending, and tension tests for orthodontic wires. *Am J Orthod Dentofacial Orthop* 2011; 140:65-71.
- Oltjen JM, Duncanson MG Jr, Ghosh J, Nanda RS, Currier GF. Stiffness-deflection behavior of selected orthodontic wires. *Angle Orthod* 1997;67:209-18.
- Proffit WR, Fields HW Jr, Sarver DM. *Contemporary Orthodontics*. 5th ed. St. Louis: The C.V.Mosby Co.; 2013. p. 313.
- Meling TR, Odegaard J. The effect of cross-sectional dimensional variations of square and rectangular chrome-cobalt archwires on torsion. *Angle Orthod* 1998;68:239-48.
- Kusy RP. A review of contemporary archwires: Their properties and characteristics. *Angle Orthod* 1997;67:197-207.
- Santos RL, Pithon MM, Nascimento LE, Martins FO, Romanos MT, Nojima MC, *et al.* Cytotoxicity of electric spot welding: An *in vitro* study. *Dent Press J Orthod* 2011;16:57-63.
- Watanabe E, Stigall G, Elshahawy W, Watanabe I. Deflection load characteristics of laser-welded orthodontic wires. *Angle Orthod* 2012;82:698-702.
- Darwish SM, Ghanya A. Critical assessment of weld-bonded technologies. *J Mater Process Technol* 2000;105:221-9.
- Cuoghi OA, Kasbergen GF, Santos PH, Mendonça MR, Tondelli PM. Effect of heat treatment on stainless steel orthodontic wires. *Braz Oral Res* 2011;25:128-34.
- Durr DP, Vargas R, Ward K. Evaluation of stress-relief methods on cobalt-chromium orthodontic wires. *Pediatr Dent* 1988;10:205-9.
- Goldberg AJ, Vanderby R Jr, Burstone CJ. Reduction in the modulus of elasticity in orthodontic wires. *J Dent Res* 1977;56:1227-31.
- Asgharnia MK, Brantley WA. Comparison of bending and tension tests for orthodontic wires. *Am J Orthod* 1986;89:228-36.
- Backofen WA, Gales GF. The low-temperature heat-treatment of stainless steel for orthodontics. *Angle Orthod* 1951;21:117-24.
- Khier SE, Brantley WA, Fournelle RA. Structure and mechanical properties of as-received and heat-treated stainless steel orthodontic wires. *Am J Orthod Dentofacial Orthop* 1988; 93:206-12.
- Kemler EA. Effect of low temperature heat treatment on the physical properties of orthodontic wire. *Am J Orthod* 1956; 42:793.
- Howe GL, Greener EH, Crimmins DS. Mechanical properties and stress relief of stainless steel orthodontic wire. *Angle Orthod* 1968;38:244-9.
- Ingerslev CH. Influence of heat treatment on the physical properties of bent orthodontic wire. *Angle Orthod* 1966;36: 236-47.