

Micro Hardness Difference After Stainless Steel Bracket Heat Treatment Using a Mini Torch at Different Durations (Laboratory Test)

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Abstract : Stainless Steel (SS) brackets are the most widely used brackets in fixed orthodontic treatment because they have advantages, including being strong, inexpensive, and resistant to corrosion, and can be repeated several times. Bracket recycling is an option for orthodontists when brackets need to be reattached to the tooth. The advantage of bracket recycling is that it is more economical. The most common and easily used by clinicians is heat treatment. The mini torch was used in the bracket recycling process at the Orthodontic Clinic, Dental and Oral Hospital, University of Indonesia. This study aims to determine the differences in the microhardness of the SS brackets after burning using a mini torch at different durations. **Objective:** To find out the difference in the hardness level of the SS bracket with a burning duration of 5, 7, and 10 seconds. **Methods:** Laboratory experiment in September 2022 at the Mechanical Engineering Thermodynamics Laboratory, Faculty of Engineering, the University of Indonesia for bracket heat treatment and the micro hardness test stage was carried out at CMPFA (Center for Materials Processing and Failure Analysis), consisting of 15 brackets with a control group of 1 bracket. **Results:** One-way ANOVA test with a value of $P < 0.05$ indicates a difference in the micro hardness of the bracket with a heat treatment duration of 5, 7, and 10 seconds. The highest average bracket hardness was found in 10 seconds of heat treatment, with an average value of 347.46 HV. **Conclusion:** There are differences in bracket hardness with different heat treatment durations.

Keywords: Heat treatment, micro hardness, duration

INTRODUCTION

Brackets are one of the essential medical tools used in orthodontic treatment.¹ SS brackets are the most widely used in fixed orthodontic treatment because they have advantages, including being strong, cheap, and resistant to corrosion, and can be repeated several times compared to ceramic brackets.² Bracket failure is due to lack of fracture resistance. Fracture often occurs on the wing and happens when cutting ligature wire or engaging rigid wire in the bracket. Sometimes, the torque applied to the wire can also cause a fracture.³

Stainless steel is an alloy that is resistant to corrosion. A Sheffield metallurgist named Brearley was working on steel for ordnance construction. Brearley later observed that steel did not rust in wet weather. Its high chromium content causes this. It was recognized and patented in 1917. The addition of chromium to carbon steel increases the metal's corrosion resistance by forming a protective surface layer of chromium oxide. For this to be fully effective, alloy's chromium content must exceed 11%.⁴

Several SS bond classifications divided into several groups, namely ferritic, martensitic, and austenitic. Ferritic stainless steel is a chromium steel used to manufacture instruments or other desired parts. The material consists of carbon, silicon, and molybdenum, with a chromium content of 12% -29%. Martensitic steel is a chromium steel with a lower chromium content (12%-18%). While austenitic steel contains 18% chromium and 8% nickel so it referred to as SS 18-8.⁵

Bracket recycling is an option for orthodontists when brackets must be reattach to teeth.⁶ Many techniques are used to clean residual adhesive material on brackets, including burs, sandblasting using spray alumina, and burning using Bunsen or torch. The most common and accessible recycling used by clinicians is incineration.⁷

Several studies carried out to evaluate the condition of the bracket, namely the dimensions of the slot, the thickness of the base of the bracket, and the base of the surface of the bracket several times after recycling.⁸ Repeated recycling of the bracket can result in residual adhesive material used previously in the retentive area of the bracket. The remaining material decreases the contact area between the bracket mesh and the adhesive material used next, resulting in a decrease in adhesive strength. This condition results in the movement of the bracket against the teeth being less effective.⁹

The mini torch is used in bracket recycling at the Orthodontics Clinic, Dental and Oral Hospital, University of Indonesia. This research aims to determine the differences in microhardness of SS brackets after burning using a mini torch for different durations, especially in the wing bracket because this is the part with the smallest size. This is needed to provide torque to the wire. It makes the author interested in researching the hardness of the bracket.

METHODS

This research carried out in September 2022. The bracket burning stage at the Mechanical Engineering Thermodynamics Laboratory, Faculty of Engineering, University of Indonesia. The hardness level test stage was at CMPFA (Center for Materials Processing and Failure Analysis). The research was carried out after obtaining a letter of passing an ethical test from the Ethics Commission of the Faculty of Dentistry, University of Indonesia, with number:20/Ethical Exempted/FKGUI/IX/2022, and having obtained a research permit from the

Faculty of Engineering, University of Indonesia with number: ND-0961/UN2.F4.DTM/PDP.04.04/2022.

The population of this study was orthodontic brackets made from SS material, which were treated with adhesive and exposed to a light cure. Each sample group requires five brackets from each treatment, so the total sample required is 15 brackets with a control group of 1 bracket new 0.022" SS slot premolar bracket with the Ormco brand produced by Ormco Cooperation, USA.

The researchers grouped the brackets into two groups, the treatment group and the control group. The treatment groups divided into three categories based on burning duration, namely 5 seconds, 7 seconds, and 10 seconds. Each group was sampled using purposive sampling. The first six brackets were taken for 5 seconds of burning, followed by six brackets for 7 seconds of burning, and following six brackets for 10 seconds of burning, as well as a control group of 1 bracket (without treatment). Adhesive material was applied to each bracket (5 second, 7 second, and 10 second groups) using a spatula at the base of the bracket, then continued with irradiation using light cure for 10 seconds. The group burned for 5 seconds. Each bracket was taken using a bracket holder. Then, the bracket is burned with a mini torch in the outer zone, dipped in water, and dried using a three-way syringe. The group burned for 7 seconds. Each bracket was taken using a bracket holder. Then, the bracket is burned with a mini torch in the outer zone, dipped in water, and dried using a three-way syringe. The group burned for 10 seconds. Each bracket was taken using a bracket holder. Then, the bracket is burned with a mini torch in the outer zone, dipped in water, and dried using a three-way syringe. Before conducting the microhardness test, the Vickers Microhardness Tester was calibrated to the ASTM E384 standard for testing material microhardness standards. Both groups of brackets were tested for hardness using a Vickers Microhardness Tester with a load of 50 gf for 10 seconds. Each sample measured at five bracket points. The hardness value is calculated from the average value of the diagonal of the diamond pyramid in each sample and then described using the Vickers Hardness (HV) measuring unit.

RESULT

This research was carried out using the Microvickers test method with the ASTM E384 standard, carried out at CMPFA, ISO 9001 certified. The results of measuring the microhardness of SS brackets based on burning time at various temperatures for each group are descriptively shown in Table 1 below.

Table 1. Microhardness of SS brackets based on different firing times and temperatures

Bracket Group	Microhardness	Average Hardness	Standard Deviation	Temperature (°C)	Average Temperatur	n
5 second		285.06	14.05		242 °C	6
A	291 HV			152°C		

B	304.4 HV			260 °C	
C	269.6 HV			260 °C	
D	271.6 HV			240 °C	
E	295.6 HV			230 °C	
F	278.2 HV			310 °C	
7 second		312.53	14.56	295 °C	6
A	326.8 HV			350 °C	
B	306.2 HV			275 °C	
C	334 HV			325 °C	
D	297.8 HV			275 °C	
E	301.2 HV			275 °C	
F	309.2 HV			270 °C	
10 Second		347.46	11.78	302.5 °C	6
A	331 HV			270 °C	
B	362 HV			240 °C	
C	347 HV			360 °C	
D	349.2 HV			350 °C	
E	358 HV			320 °C	
F	337.6 HV			275 °C	
Control	262.80 HV				1
Total					19

Table 1 shows that the group of brackets burned for 10 seconds had the highest average level of microhardness compared to the group of brackets burned for 5 seconds and 7 seconds, namely 347.46 HV with an average temperature resulting from burning of 302.5°C. The bracket group with a burning duration of 7 seconds and 5 seconds had an average value of 312.53 HV and 285.06 HV, respectively, with an average resulting temperature of 295°C and 242°C. The control group had a hardness level value of 262.80 HV. Figure 5.1 shows the differences in levels of hardness and temperature for each burning group.

DISCUSSION

In general, the brackets used in orthodontics are austenitic and martensitic SS brackets.²² The composition of austenitic SS has a lower amount of carbon than martensitic, but the chromium content in austenitic is higher than martensitic.²³ Martensitic SS has a body-centered tetragonal crystal structure with a high level of chromium. Low and high carbon levels obtaining an austenitic structure at high temperatures and then cooling suddenly to change the austenitic phase to martensite.²⁴

In this study, the bracket used was SS precipitation hardening martensitic type 17-4 PH with a composition of 0.07 carbon, 1.00 Mn, 1.00 Si, 0.17 chromium, 8.0 Nickel, and Fe. The research carried out by burning for 5, 7, and 10 seconds. The average temperature resulting from each combustion group has a different value. The 5 second group had an average temperature of 242°C, the 7 second group 295°C, and the 10 second group 302.5°C. Then, the level of microhardness was measured using a Vickers microhardness tester with a load of 50 grams for 10

seconds. The research results showed differences in microhardness in the brackets that burned for a duration of 5, 7, and 10 seconds. The highest average level of microhardness in this study found in the bracket burned for 10 seconds with a value of 347.46 HV.

In stainless steel precipitation hardening, nickel formed an intermetallic composition that can increase strength. Manganese (Mn) is usually used to increase the elasticity of stainless steel. Silicon (Si) increases resistance to oxidation at both high and low temperatures. This also increases the ferritic microstructure and strength.²⁵ This study's microhardness increase is thought to occur due to the secondary hardening phenomenon. The secondary hardening phenomenon generally occurs at tempering temperatures up to 700°C. The atomic structure in SS metal at high temperatures will increase atomic diffusion due to increased internal energy.^{22,26} The chromium element dissolved in the matrix diffuses with the carbon element to form a carbide compound in the matrix.²⁷ A layer of chromium oxide (Cr₂O₃) due to combustion can create protection from the effects of contaminants.²⁸

The secondary hardening phenomenon is related to the martensitic matrix phase and a large concentration of primary carbide after combustion.²⁹ Carbide deposition can occur if there are Mo and Carbon elements that produce Mo₂₃C₆ or other carbide-forming elements such as (Cr,Fe)₂₃C₆ or (Cr,Fe, Mo,Ni)₂₃C₆.³⁰ Microstructurally, metal forming with an increase in combustion temperature below 700°C results in an increase in the martensite matrix phase in stainless steel metal. The increase in the amount of martensite matrix phase occurs due to changes in the austenitic microstructure to martensitic after combustion.^{29,31}

A decrease in the level of microhardness occurs at temperatures over 700°C. This is because the higher temperature used in burning results in a decrease in the amount of martensitic phase, thereby reducing the hardness level. The decrease in the amount of martensitic phase is caused by composing of the martensitic phase into an austenitic phase structure again due to too high temperatures.^{24,31,32} Low hardness in the bracket wings can inhibit the transfer of torque from the wire to the bracket because it prevents full engagement of the wire with the slot wall. And allows slot deformation in the wing brackets.³³ The biocompatibility of metal oxide coatings is often better than that of the base metal used as the substrate because the oxides usually suppress the release of toxic ions. Many authors state chromium oxide as the most biocompatible oxide, which forms on the surface of SS.³⁴

Research shows differences in the level of microhardness in combustion carried out at durations of 5, 7, and 10 seconds. In laboratory tests, recycling new brackets carried out by burning using a mini torch will increase the level of microhardness if carried out at temperatures below 700°C for 5 to 10 seconds. In clinical application, various factors influence the level of microhardness in the bracket, such as the length of time the bracket worn on the patient before recycling, so further research needs to be done using the burning method.

CONCLUSION

There is a statistically significant difference in hardness level of SS brackets burned with a burning duration of 7 seconds, which is greater than 5 seconds with an average hardness value of 312.53 HV and 285.06 HV with a calculated p value of 0.003. There is a statistically significant difference in hardness level of SS brackets burned with a burning duration of 10 seconds, which is greater than 5 seconds with an average hardness value of 347.46 HV, and 285.06 HV with a calculated p value of 0.000. There is a statistically significant difference in the hardness level of SS brackets burned with a burning duration of 10 seconds which is greater than 7 seconds with an average hardness value of 347.46 HV and 312.53 HV with a calculated p value of 0.000. There is a statistically significant difference in the SS bracket's hardness level based on the burning duration of 5, 7, 10 seconds with the highest hardness value at the burning duration of 10 seconds with a calculated p value of 0.000.

RECOMMENDATIONS

Research carried out by considering the consequences for the orthodontist of differences in hardness with burning durations of 5 seconds, 7 seconds, and 10 seconds. Research carried out by considering the occurrence of corrosion with differences in combustion duration of 5 seconds, 7 seconds, and 10 seconds. Further research can be carried out to create innovative bracket protective materials for burning brackets.

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