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Effect of CO2 laser irradiation on the surface of the polycrystalline ceramic bracket and the rate of canine movement with sliding mechanic

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ABSTRACT

Introduction: Metal brackets are the most commonly used brackets in clinical orthodontics, but the sight of color of the metal bracket can be unpleasant for some patients. Ceramic brackets offer the desired beauty but they have higher frictional resistance. Considering that in vitro studies suggest that CO2 laser reduces the friction between the wire and slot of the bracket in the sliding mechanics, the aim of this study was to evaluate the clinical effect of CO2 laser on the speed of tooth movement using the sliding mechanics.

Materials & Methods: This randomized double-blind clinical trial was performed on 7 patients and a total of 13 half jaws in each group. These patients were candidates for bilateral extraction of the first premolars due to lack of space or dentoalveolar protrusion. After alignment and leveling, the ceramic brackets were passively bonded. The ceramic brackets of the experimental group irradiated with the CO_2 laser and the brackets of the control group were bonded unchanged. The brackets were examined with an atomic force microscope (AFM) before and after irradiation. Statistical data were analyzed paired t-test to compare the rate of gap closure between the two groups at one-month intervals. ANOVA was used to examine the reduction in spacing at three-month intervals. A value of $p<0.05$ was considered statistically significant.

Results: The rate of gap closure between the two groups was compared at one-month intervals, which was not statistically significant in either month. Furthermore, in the comparison between the study and control groups, the decrease in the distance between the canine and second premolars was not statistically significant after a total of three months ($p=0.0918$).

Conclusion: According to the results of this study, CO_2 laser irradiation of the bracket surface has no effect on the speed of movement of the canine when sliding on the wire.

Keywords: Friction, Tooth, Movement

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Introduction

As the number of adults seeking orthodontic treatment increases, so does the need for appliances that fulfill the patients' desire for greater beauty. Metal brackets are the most commonly used brackets in clinical orthodontics, but the metal color may be unpleasant for some patients. Ceramic brackets provide the desired beauty. [1-5] They are monocrystalline or polycrystalline and both are made of alumina. [6] These brackets have many advantages over other esthetic appliances. Some of these advantages include greater strength, greater resistance to erosion and deformation, greater color stability, and most importantly, greater beauty. Ceramic brackets are available in a variety of shapes and systems. [7] All ceramic brackets available today are made of alumina or zirconia. The manufacturing process of alumina ceramic brackets is divided into two groups: Single-crystal ceramic brackets or monocrystalline and polycrystalline ceramic brackets. The manufacturing process plays a crucial role in the clinical properties of ceramic brackets. Since the manufacturing process of polycrystalline brackets is less complex, these brackets are more commonly available nowadays. [8] Ceramic brackets have been found to have higher frictional resistance than metal brackets under all conditions tested, which is due to the higher surface roughness of these brackets. This can be easily seen by comparing the two brackets microscopically at scanning electron microscope (SEM). [9, 10] Brackets manufactured by milling or machining with a diamond tool have greater roughness than injection-molded brackets and generate more friction. Injection-molded brackets produce a smooth surface, decreasing the friction coefficient of the bracket. [7, 10]

Polycrystalline brackets are manufactured by both methods and have a rough or smooth surface, depending on the manufacturing process. However, these brackets have a higher roughness than stainless steel brackets. [11, 12] In addition, the friction coefficient of monocrystalline ceramic brackets is comparable to that of stainless steel brackets, but significant frictional properties are not seen in monocrystalline brackets. [13] Lasers are used as useful tools to modify alumina surfaces in structural, microstructural, and chemical developments. In this regard, modifying the surface of an alumina ceramic bracket with a CO2 laser to convert the γ metastable phase to the α equilibrium phase is very useful in reducing the frictional resistance of the bracket surface and facilitating the sliding of the wire in the bracket during orthodontic treatment. The CO2 laser was used to decrease the roughness and frictional resistance of polycrystalline ceramic brackets. [4, 5] The CO2 laser is one of the oldest lasers used in medicine, developed in the early 1970s. The active intermediate element of the CO2 laser is carbon dioxide gas and usually produces an invisible laser with a wavelength of 10600nm in the infrared region. This laser has the highest absorption rate in dental hydroxyapatite of all lasers. [14] Since the CO2 laser reduces the friction between the wire and bracket slot in in vitro sliding mechanics studies [5], the aim of the present study was to examine the clinical effect of the CO2 laser on the speed of tooth movement with sliding mechanics.

Materials & Methods

This double-blind randomized clinical trial was conducted under the code of ethics of MUBABOL.HRI.REC.1396.216 on 7 patients with a total of 13 half-jaws in each group. The sample size of the clinical trial was calculated using the Altman nomogram. delta (δ) or difference was considered to be 2mm, δ_α or standard deviation of differences was considered to be 0.57). [4] Patients were candidates for bilateral extraction of the first premolars due to the lack of space or dentoalveolar protrusion. Exclusion criteria included all patients in whom the canine or first premolars had fallen completely out of the arch, the canine had a curved root and a

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periodontal pocket was present. First, 26 ceramic brackets without canine hooks were randomly divided into two groups (A and B) (each group contained brackets) using the MBT Slot 022 system (Korean Hubit Company, made of polycrystalline alumina). The bracket slots of group A were irradiated at Noshirvani University of Babol with continuous CO_2 laser irradiation (Sahand Laser, Isfahan, Iran) with a wavelength of 10600 nm and a power of 90 J/cm^2 (20 mA and constant voltage) [5] and group B was considered as a control group. Before laser irradiation, the samples were washed in 96% ethanol. The laser parameters were as follows:

Focal length: 30 mm

Laser spot: 3mm

Traverse speed: 60 rpm

The distance of the specimens from the laser, the speed at which the laser scanned the surface, and the angle of laser irradiation were constant for all specimens. Irradiation was performed at 24 ° C (room temperature) and under argon gas. [5] In patients in whom the first premolars were extracted bilaterally and primary alignment and leveling was performed with a 0.018 steel wire, the laser-irradiated bracket was placed on the canine of one side, which was randomly selected and the ceramic bracket of the control group was fixed on the canine of the opposite side of the same jaw. The brackets were passively bonded by placing the wire at the gingival margin to eliminate the difference of wire play in the brackets. It should be noted that patients and therapists did not know on which side the laser-exposed bracket would be bonded. The brackets were bonded by a third person using coins. The other teeth were treated with the same conventional metal brackets to reduce costs. For one month, the 0.017*0.025 Niti wire (Orthotechnology ,Carlsbad,USA)was used for further leveling, then the 0.018 steel wire (Orthotechnology ,Carlsbad,USA) was used again and the retraction began. [15] Before closing the space, the distance between the canine and the second premolar was measured with a digital caliper(CNC Qualitat,Dresden,Germany) with an accuracy of 0.01 mm. [16] A Niti coil spring (Yahung,Anji, China) with the same activation force of approximately 150 g was used on both sides to close the space. [17] The distal part of the coil was inserted into the hook of the first molar and its mesial part was ligated to the ceramic bracket of the canine with a ligature wire. The second premolars and the first molar were connected with a ligature wire on each side. Patients were examined at 4-week intervals for 3 months or until the gap was closed, whichever came first, and the distance between the second canine and the second premolar was recorded at each session.

The effect of the CO_2 laser beam on the surface roughness of nanoscale samples was investigated using atomic force microscopy (AFM) (Nanosurf, Liestal, Switzerland). AFM images of size 10 µm× 10 µm were acquired in non-contact mode and under ambient conditions with a scanning speed of 0.5 lines. Statistical data were analyzed using SPSS software, paired t-test was used to compare the degree of spatial closure between the two groups at one-month intervals and ANOVA was applied to examine the reduction in spacing over a total of three months. The statistical significance level was set at 0.05.

Results

The degree of space closure was compared between the two groups at one-month intervals (Chart 1), which was not statistically significant in any of the months ($p_{month1} = 0.725$, $p_{month2} = 0.420$, $p_{month3} = 0.823$). In addition, the reduction in the distance between the canine and second premolar after three months was not statistically significant when comparing the two study groups and the control group ($p = 0.918$).

AFM analysis: Based on the results of AFM analysis for orthodontic brackets before and after CO2 laser irradiation, the mean roughness before laser radiation was 46.5nm and after radiation was 30.3nm. Accordingly, the mean surface roughness decreased for the specimens imaged with a size of 10µm × 10µm after laser irradiation. Figure 1 illustrates the topography and linear profiles of the surface of the samples before and after CO2 laser irradiation.

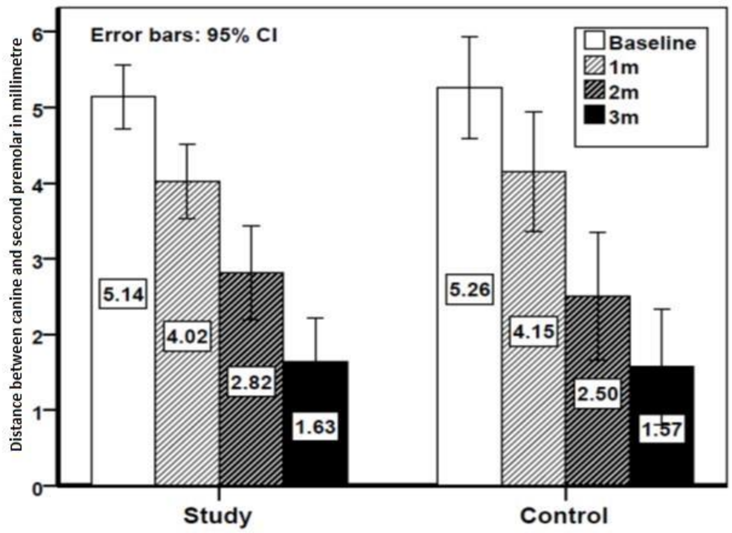

Chart 1. Space closure at one month intervals

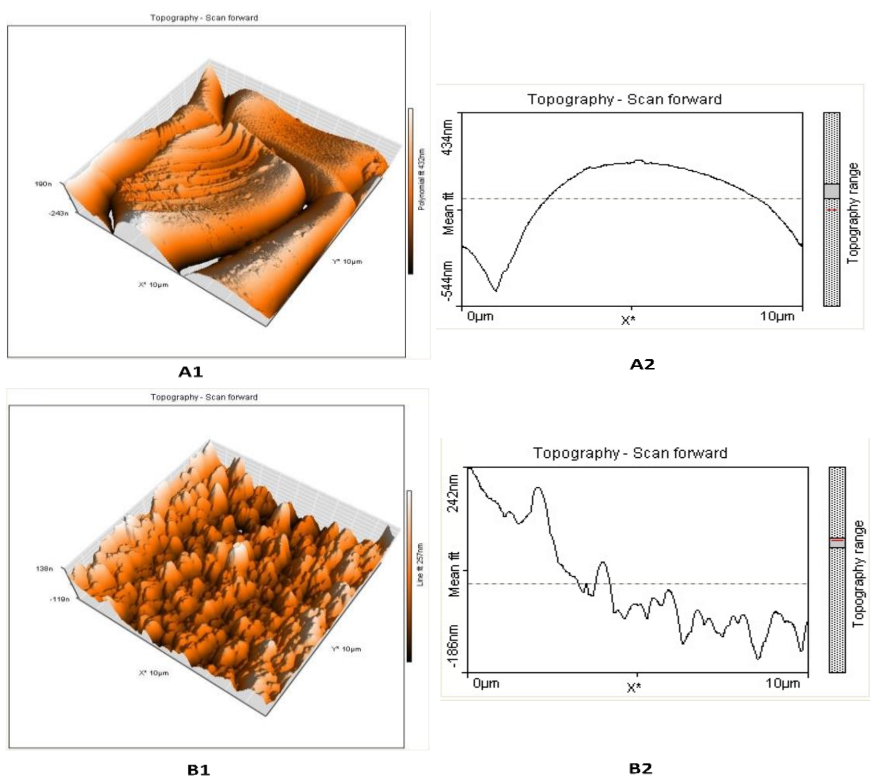

Figure 1. Topography and linear profile of surface of samples before laser irradiation (A1, A2) and after laser irradiation (B1, B2)

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Discussion

In the present study, irradiation of CO2 laser on the ceramic brackets caused homogenization of the surface of the ceramic brackets but had no effect on the clinical speed of movement of the canine during sliding on the wire. As various factors that can counteract tooth movement, the binding force can be considered an important factor in preventing tooth movement, although it reduces the friction between the wire and the bracket. When the angle between the bracket and the wire is zero, the resistance to sliding of the bracket along the wire results entirely from friction. Given the play of the wire in the bracket, this angle can be greater than zero and this rule applies until the wire no longer touches the corners of the bracket. This angle naturally varies due to the combination of different types of brackets and different wire sizes. Once the wire touches the corners of the bracket, the resistance to sliding depends on the elastic and non-elastic bond (notching), and the role of the frictional force decreases sharply. [18]

To confirm the role of bonding in inactivating changes in the bracket surface and its friction with the wire, Jones et al studied static frictional resistance in polycrystalline ceramic brackets with conventional, glazed and metallic slots. In this study, the glazed ceramics showed a decrease in static friction in the samples where the angle was zero and no bonding occurred, like the ceramics with the metal slot, but with an increase in the contact angle, they showed similar behavior to conventional ceramic brackets. [19] Based on the results of the present study, the application of 90J / cm2 CO2 laser radiation to ceramic brackets had no positive effect on tooth movement speed. One of the most important factors affecting the friction between two surfaces is their surface roughness. Many studies have been conducted to decrease friction by reducing the surface roughness. The research results obtained by Er: YAG laser irradiation with different powers on the surfaces of ceramic bracket showed that as the power of the laser increased, the rounding of the surface angles and the reduction of friction increased and the properties of the ceramic surface improved. In the mentioned study, the friction reduction was significant when the angle between the brackets and the wire was considered zero. When the angle became larger, the bond reduced the effect of friction reduction and the resistance to movement increased due to the bond, and no significant difference was found between the samples. [4] In addition, glazing the ceramic surface with a CO2 laser increases the smoothness of these surfaces by homogenizing them through melting the surface structure. The use of higher laser power is more successful in improving this surface property. [20] The CO2 laser also reduced surface roughness in the current study. According to some studies [4, 5, 20], laser irradiation, especially at high powers, improves the surface texture of ceramic brackets and reduces their friction with other surfaces. However, since various factors affect tooth movement during orthodontic treatment, resistance to sliding is due to friction only in the early stages of tooth retraction. However, as the wire contacts the bracket edges, friction becomes almost negligible and resistance to sliding is almost entirely due to elastic bonding. [21] The studies using angle application in wires to simulate laboratory conditions have shown that the application of angles greater than zero reduces the supportive role of the laser in improving sliding movement, and glazed and conventional brackets show similar behavior. [4, 19, 22, 23] These results confirm and justify the findings of the ongoing study regarding the lack of difference in the speed of tooth movement in the case and control groups despite the improvement in the surface properties of ceramic brackets. In a study conducted by Osorio et al to investigate the effect of Nd: YAG on In-Ceram Alumina blocks and analyze the AFM results, the changes induced by the 141J / cm^2 laser did not cause a significant difference in surface roughness. [24] Studies similar to the present study [5, 25] have reported only on the statistics of the AFM images. By conducting a separate study to comprehensively analyze the AFM, the difference resulting from laser irradiation of the surface and the reduction in surface roughness might not be statistically significant. Hence, to achieve accurate results in this area, it is necessary to use laser and AFM data analysis to investigate the significance of the differences that have arisen. Moreover, the use of artificial saliva as a lubricant has a positive effect on reducing the friction between the wire and the bracket [10, 26-30], but the application of an angle between the brackets and the wire reduced this effect. Although the current study was conducted in the clinic and oral saliva played a role in reducing friction, the difference in the speed of tooth movement in the two groups was not statistically significant, which is in line with the results of mentioned studies. To minimize the anatomical and structural differences between patients, our clinical study used each patient as a case and a control and compared them. The limitation of this study was to find the subjects who met the inclusion criteria. To increase the reliability of the results, it is suggested to use more patients, which requires the use of patients in clinics other than faculty.

Conclusion

In general, according to the results of this study, CO2 laser irradiation had no effect on the movement of the canines during sliding, although it had a significant effect on the homogenization of the surface of the ceramic brackets. It seems that increasing the study time and the number of samples may enhance the reliability of the results.

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Conflicts of Interest

There is no conflict of interest.

Authors' Contribution

Mirzaie M. and Ghorbanipour R. designed the study and accomplished manuscript editing and review. Ebrahimi M. performed literature search, clinical studies, manuscript preparation, editing and review. Ghasemi T. accomplished clinical and experimental studies. Bijani A. accomplished data acquisition, data and statistical analysis.

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