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Is laser conditioning a valid alternative to conventional etching for aesthetic brackets?

ABSTRACT

Aim *ER:Yag lasers have been described as a more conservative alternative to conventional acid-etching enamel conditioning technique, when bonding conventional metallic orthodontic brackets. Since the use of aesthetic orthodontic brackets is constantly increasing, the purpose of the present report has been to test laser conditioning with different aesthetic brackets.*
Methods *Study Design: Five different aesthetic brackets (microfilled copolymer, glass fiber, sapphire, polyoxymethylene and sintered ceramic) were tested for shear bond strength and Adhesive Remnant Index scores using two different enamel conditioning techniques (acid etching and ER:Yag laser application). Two hundred bovine incisors were extracted, cleaned and embedded in resin. Specimens were then divided into 10 groups with random tables. Half of the specimens were conditioned with conventional orthophosphoric acid gel, the other half with ER:Yag laser. Different aesthetic brackets (microfilled copolymer, glass fiber, sapphire, polyoxymethylene and sintered ceramic) were then bonded to the teeth. Subsequently all groups were tested in shear mode with a Universal Testing Machine. Shear bond strength values and adhesive remnant index scores were recorded. Statistical analysis was performed.*
Results *When considering conventional acid etching technique, sapphire, polyoxymethylene and sintered ceramic brackets exhibited the highest SBS values. Lowest values were reported for microfilled copolymer and glass fiber appliances. A significant decrease in SBS values after laser conditioning was reported for sapphire, polyoxymethylene and sintered ceramic brackets, whereas no significant difference was reported for microfilled copolymer and glass fiber brackets. Significant differences in ARI scores were also reported.*
Conclusions *Laser etching can significantly reduce bonding efficacy of sapphire, polyoxymethylene and sintered ceramic brackets.*

Keywords *Aesthetics; Bracket; Etching; Laser; Orthodontics; Shear bond strength.*

Introduction

When bonding an orthodontic bracket to a tooth, 37% phosphoric acid conditioning of the enamel prior to adhesive application is the standard procedure [Zhu et al., 2014]. The etchant application however results in a loss of mineralised surface of 10–15 µm approximately, with a consequent unintentional demineralisation of the enamel [Nanjannavar, 2012]. As these surface changes are slight but irreversible, other etching methods are claimed to minimise enamel loss. An alternative method for enamel conditioning is laser application [Karandish et al., 2014]. By stimulated emission of photons from excited atoms or molecules, Er:YAG laser generates an intense beam of monochromatic and coherent light at a wavelength of 2,940 µm. This wavelength matches the absorption peaks of water [3,000 nm] and hydroxyapatite [2,800 nm], thus allowing Er:YAG laser to be indicated for the treatment of hard and soft tissues [Yassaei et al., 2014].

The use of Er:YAG lasers for enamel conditioning has been firstly described in conservative dentistry for cavity preparation, smear layer removal, endodontic debridement of canal systems and enamel conditioning before adhesive application [Karandish, 2014]. This last use has been tested also for orthodontic purposes in order to bond conventional metallic brackets [Akin et al., 2016].

With the increased awareness of cosmetic dentistry, aesthetic orthodontic treatment requests are rapidly growing from both adult and adolescent patients [Giannattasio et al., 2015]. The most used aesthetic orthodontic appliance consists in clear brackets, which serve as a cosmetic alternative to traditional metal braces by mimicking the natural colour of the teeth [Waring et al., 2013].

Group	Company	Name	Material	Conditioning	Code
1	Leone	DB Logic Line	Microfilled Copolymer	Acid	MC-A
2	Leone	DB Logic Line	Microfilled Copolymer	Laser	MC-L
3	Leone	DB Fibra	Glass Fiber	Acid	GF-A
4	Leone	DB Fibra	Glass Fiber	Laser	GF-L
5	Ormco	Ice	Sapphire	Acid	S-A
6	Ormco	Ice	Sapphire	Laser	S-L
7	Forestadent	Brillant	Polyoxymethylene	Acid	P-A
8	Forestadent	Brillant	Polyoxymethylene	Laser	P-L
9	Forestadent	Glam	Sintered Ceramic	Acid	SC-A
10	Forestadent	Glam	Sintered Ceramic	Laser	SC-L

TABLE 1 Materials tested.

Nowadays manufacturers produce aesthetic brackets with different materials: microfilled copolymer, glass fiber, sapphire, polyoxymethylene and sintered ceramic. To our knowledge in Literature only ceramic brackets have been tested for bond strength after Er:YAG laser etching [Yassaei et al., 2014]. Therefore the purpose of the present investigation was to evaluate and compare shear bond strength (SBS) and adhesive remnant index (ARI) for aesthetic brackets of different materials bonded after conventional and Er:YAG enamel conditioning. The null hypothesis of the present report was that there is no difference in SBS values and ARI scores among the different groups.

Materials and methods

The present study has been approved by the Unit Institutional Committee Board. Two hundred bovine permanent mandibular incisors were collected. Teeth were stored in a solution of thymol 0.1% (weight/volume) immediately after extraction.

Inclusion criteria were: no caries, no cracks and intact enamel. The teeth were cleaned, embedded in acrylic resin (Leocryl, Leone, Sesto Fiorentino, Italy) and placed in metal rings. Each tooth was oriented so that its labial surface would be parallel to the force applied during shear test [Scribante et al., 2013]. All specimens were then assigned to one of 10 groups using random number tables.

Half of the specimens (Groups 1,3,5,7 and 9) were conditioned with conventional etching technique using 37% orthophosphoric acid gel (Orthophosphoric acid gel, 3M Unitek, Monrovia, California, USA) for 30 seconds and then washed and dried. The other half of the teeth (Groups 2,4,6,8 and 10) were conditioned with Er:YAG laser (AT Fidelis Er:YAG, Fotona, Ljubjana, Slovenia) at wavelength 2940 nm, short pulse mode (100µsec, 120 mJ, 10Hz, 1,2W) and then washed and dried.

After conditioning, different aesthetic brackets were bonded to the tooth (Table 1): microfilled copolymer (DB Logic Line, Leone, Sesto Fiorentino, Italy), glass fiber (DB Fibra, Leone, Sesto Fiorentino, Italy), sapphire (Ice, Ormco, Glendora, USA), polyoxymethylene (Brillant, Forestadent, Pforzheim, Germany) and sintered ceramic (Glam, Forestadent, Pforzheim, Germany).

A thin layer of primer (Transbond XT Adhesive Primer, 3M, Glendora, USA) was applied to the enamel surface with a microbrush, then the brackets were bonded with a resin (Transbond XT Adhesive Paste, 3M, Glendora, USA) near the centre of the facial surface of the tooth. Sufficient pressure was applied to express excess adhesive, which was removed with a scaler. Brackets were then light cured (Ortholux XT, 3M, Glendora, USA) for 20 seconds.

All specimens were then secured in the lower jaw of an universal testing machine (Model 4301, Instron, Canton, MA, USA) and then tested in shear mode (head speed: 1mm/min) [Abu Alhaija et al., 2012; Sfondrini et al., 2013].

The maximum load necessary to debond bracket was recorded in newtons (N). Subsequently, values were converted into megapascals (MPa) as a ratio of newtons to surface area of the bracket.

Enamel surfaces and bracket bases were examined under optical microscope (Stereomicroscope SR, Zeiss, Oberkochen, Germany) at 20x magnification, and the adhesive remnant index (ARI) score was recorded to assess the amount of adhesive left on the enamel surface [Artun and Bergland, 1984]. The ARI score was used to define bond failure site among the enamel, the adhesive, and the bracket base. ARI scale ranges from 0 to 3 (0:no resin remaining on tooth; 1:less than 50% resin remaining on tooth; 2: more than 50% resin remaining on tooth; 3: 100% resin remaining on tooth).

Statistical analysis was performed with a software (R version 3.1.3, R Development Core Team, R Foundation for Statistical Computing, Wien, Austria). Descriptive statistics (mean, standard deviation, minimum, median, and maximum values) were calculated for all groups.

Group	Material	Conditioning	Code	Mean	SD	Min	Mdn	Max	Tukey*
1	Microfilled Copolymer	Acid	MC-A	10.01	3.32	3.22	9.43	14.40	A
2	Microfilled Copolymer	Laser	MC-L	8.21	2.66	4.22	7.88	13.06	A
3	Glass Fiber	Acid	GF-A	3.32	0.66	2.49	3.13	4.90	B
4	Glass Fiber	Laser	GF-L	3.11	0.63	2.37	2.97	4.42	B
5	Sapphire	Acid	S-A	19.59	4.88	12.38	19.25	28.80	C
6	Sapphire	Laser	S-L	11.17	4.83	5.62	9.72	21.81	A
7	Polyoxymethylene	Acid	P-A	15.41	3.86	7.12	14.46	21.36	C,D
8	Polyoxymethylene	Laser	P-L	9.88	4.61	2.32	9.63	20.28	A
9	Sintered Ceramic	Acid	SC-A	16.70	6.55	4.35	17.11	27.19	C
10	Sintered Ceramic	Laser	SC-L	11.65	4.36	7.07	10.40	24.43	A,D
*Tukey Grouping: means with the same letters are not significantly different.									

TABLE 2 Shear bond strength values of the different groups tested.

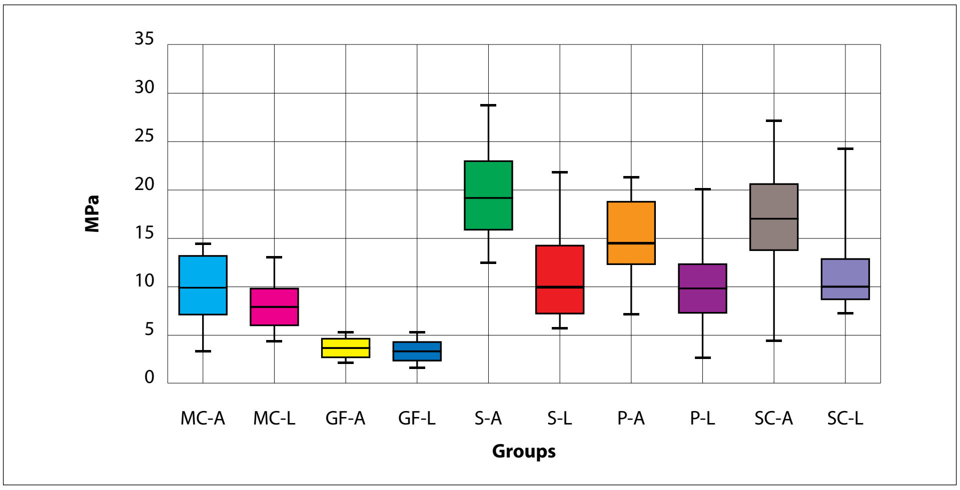

FIG. 1 Box plot of shear bond strengths (MPa) of the different groups tested.

The normality of the data was calculated using the Kolmogorov-Smirnov test. Analysis of variance (ANOVA) and Tukey tests were applied for debond strength values. The chi-square test was used to determine significant differences in the ARI scores among the different groups. Significance for all statistical tests was predetermined at $P < 0.05$.

Results

The descriptive statistics for the shear bond strengths (MPa) of the 10 groups tested are presented in Table 2. ANOVA showed the presence of significant differences ($P<0.0001$). Post-hoc Tukey test reported that with conventional orthophosphoric acid application, the highest shear bond strength values were recorded with sapphire, polyoxymethylene and sintered ceramic brackets, that showed no significant differences among them ($P>0.05$) (Fig. 1). Significantly lower bond values were reported with microfilled copolymer brackets ($P<0.05$), whereas the lowest shear bond strength values were reported with glass fiber brackets ($P<0.0001$). On the other hand, after Er:YAG laser conditioning no significant differences were reported among microfilled copolymer, sapphire, polyoxymethylene and sintered ceramic brackets ($P>0.05$). Significantly lower bond values were recorded with glass fiber brackets ($P<0.0001$).

When evaluating the effect of acid versus laser treatments, Er:YAG conditioning significantly reduced shear bond strength values of sapphire, polyoxymethylene and sintered ceramic brackets ($P<0.05$). On the other hand no significant difference between acid etching and Er:YAG conditioning was reported for microfilled copolymer and glass fiber brackets ($P>0.05$).

Chi squared test showed significant differences among frequency distributions of various groups (Fig. 2). Microfilled copolymer brackets showed a significant

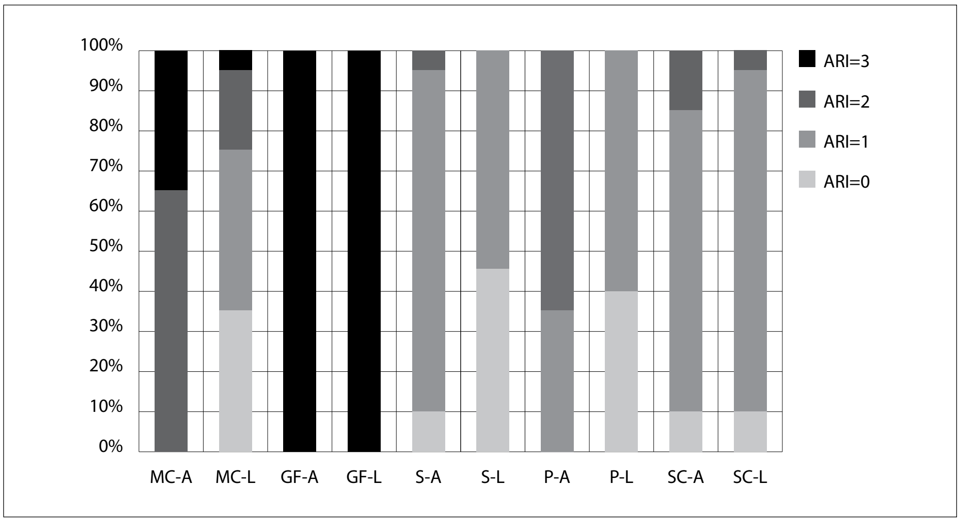

FIG. 2 Frequency distribution of adhesive remnant index scores of the different groups tested.

Group	Bracket	Condition-ing	Code	ARI=0	ARI=1	ARI=2	ARI=3
1	Microfilled Copolymer	Acid	MC-A	0 (0%)	0 (0%)	13 (65%)	7 (35%)
2		Laser	MC-L	7 (35%)	8 (40%)	4 (20%)	1 (5%)
3	Glass Fiber	Acid	GF-A	0 (0%)	0 (0%)	0 (0%)	20 (100%)
4		Laser	GF-L	0 (0%)	0 (0%)	0 (0%)	20 (100%)
5	Sapphire	Acid	S-A	2 (10%)	17 (85%)	1 (5%)	0 (0%)
6		Laser	S-L	9 (45%)	11 (55%)	0 (0%)	0 (0%)
7	Polyoxymethylene	Acid	P-A	0 (0%)	7 (35%)	13 (65%)	0 (0%)
8		Laser	P-L	8 (40%)	12 (60%)	0 (0%)	0 (0%)
9	Sintered Ceramic	Acid	SC-A	2 (10%)	15 (75%)	3 (15%)	0 (0%)
10		Laser	SC-L	2 (10%)	17 (85%)	1 (5%)	0 (0%)

TABLE 3 Frequency distribution of adhesive remnant index scores of the different groups.

higher frequency distribution of ARI=2 and ARI=3 after acid etching application, whereas an higher frequency of ARI=0 and ARI=1 was recorded after Er:YAG laser application (P<0.05). Also with polyoxymethylene brackets was observed a significant decrease in frequency distribution of ARI scores (from ARI=2 to ARI=0 and ARI=1) when comparing acid etch versus Er:YAG laser conditioned group (Table 3).

On the contrary ARI scores distributions of glass fiber (ARI=3), sapphire (ARI=1) and sintered ceramic brackets (ARI=1) reported no significant difference between acid etching and Er:YAG laser conditioned groups (P<0.05).

Discussion

Then null hypothesis of the study has been rejected. After conventional orthophosphoric acid application the lowest values were reported with glass fiber brackets, whereas higher strengths were observed with microfilled copolymer brackets, and the highest shear bond strength values was recorded with sapphire, polyoxymethylene and sintered ceramic brackets. Ceramic brackets have been introduced in orthodontics for their excellent optical characteristics [Waring et al., 2013]. Ceramics are a class of materials, neither metallic nor polymeric, consisting of metal oxide and non-metal elements that include precious stones, clays and glasses. Alumina [A12O3] is a typical member of modern ceramics, formed when aluminium is added to steel to remove oxygen dissolved in the steel and is used to manufacture orthodontic ceramic brackets [Waring et al., 2013]. In the present investigation sintered ceramic brackets after acid etching showed the highest adhesion values of 16.70 MPa. Previous studies in the literature measured shear bond strength of ceramic brackets bonded after conventional acid etching and adhesive application, showing similar results [Atsu et al., 2011; Reddy et al., 2013; Prabhakar et al., 2014; Zielinski et al., 2014; Mirzakouchaki et al., 2016]. Ceramic brackets shear bond strength values have been reported to be similar than conventional metallic brackets or even if some studies reported higher or lower shear strength values [Bakhadher et al., 2015]. Therefore these braces can be considered a viable and validated aesthetic alternative to standard stainless steel brackets.

Another appliance that reported the highest shear bond strength values, after conventional acid conditioning, in the present study (19.59 MPa) are sapphire brackets. Sapphire brackets are made from pure grown sapphire crystals. The crystal is honed and heat polished into a remarkably clear bracket that is nearly invisible on the teeth. Sapphire brackets have been tested in the literature only for growth and adherence of microorganisms [Saloom et al., 2013], and to our knowledge nowadays there are no studies that recorded shear bond strength values of these devices.

The third appliance that presented in this report the highest bond strengths after orthophosphoric etching are polyoxymethylene brackets (15.41 MPa). Polyoxymethylene is a polymer of formaldehyde, either cyclic or linear, and is an engineering thermoplastic used in precision parts requiring dimensional stability, high stiffness and low friction. Bacterial adhesion [Faltermeier et al., 2008], cytotoxic effects [Kloukos et al., 2013] and ionizing radiation effects [Faltermeier et al., 2014] of plastic polyoxymethylene brackets have been previously investigated. Shear bond strength of these braces have been tested in a single study [Ali et al., 2012], that showed similar shear bond strength values similar to those achieved in the present report.

In our study microfilled copolymer brackets showed significantly lower shear strength values than all the above mentioned appliances (10.01 MPa). These brackets are made with copolymers with microfilled particles that vary between 0.04 and 0.2 micron, and in the literature have been tested for cytotoxicity [Kloukos et al., 2013] and physical properties [Ajith et al., 2013] but not for shear strength.

In the present report the brackets that presented the lowest shear bond strength values after acid etching were glass fiber braces (3.32 MPa). A glass fiber is a strong plastic material containing embedded glass filaments for reinforcement. In the literature glass-fiber brackets have been tested for surface roughness [Choi et al., 2014], cytotoxic effects [Kloukos et al., 2013] and frictional forces [Fernandes et al., 2010] but no report tested their shear bond strength values.

In the present investigation all the above mentioned brackets have been tested also after Er:YAG laser enamel conditioning. Er:YAG conditioning significantly reduced shear bond strength values of sapphire, polyoxymethylene and sintered ceramic brackets. On the other hand no significant difference between acid etching and Er:YAG conditioning was reported for microfilled copolymer and glass fiber brackets. Lasers are increasingly employed in oral medicine. These devices present high brightness, strong directionality, good monochromaticity and excellent coherence. In orthodontics, lasers are used for debonding appliances, reconditioning of debonded braces, accelerating tooth movement, and preventing enamel demineralisation around brackets [Han et al., 2016]. Conditioning enamel prior to bonding with Er:YAG laser has been reported to be an advantageous procedure [Aglarci et al., 2016]. In fact the research on enamel surface roughness showed that laser conditioning yielded a comparable amount of surface roughness as conventional orthophosphoric acid-etch technique, with the advantage that laser etching inhibits caries [Contreras-Bulnes et al., 2013] and minimises enamel loss, even if some authors reported enamel damages also using Er:YAG laser conditioning [Turkoz and Ulusoy, 2012]. Laser irradiation has been described as a suitable technique to etch enamel for orthodontic bonding and some studies evaluated shear bond strength of conventional metallic brackets after Er:YAG enamel pretreatment, showing acceptable bond strength values [Hosseini et al., 2012; Turkoz and Ulusoy 2012; Contreras-Bulnes et al., 2013].

Other authors evaluated the effect of Er:YAG laser conditioning with aesthetic brackets testing only ceramic appliances, showing results similar to the present investigation [Yassaei et al., 2014; Han et al., 2016]. To our knowledge no studies have been conducted testing shear bond strength of microfilled copolymer, glass fiber, sapphire and polyoxymethylene aesthetic brackets after Er:YAG enamel pretreatment.

Finally in the present work ARI scores have been calculated for all groups. Microfilled copolymer and polyoxymethylene brackets reported a significant decrease using Er:YAG laser application if compared with acid etching. Other groups (glass fiber, sapphire and sintered ceramic brackets) reported no significant difference in ARI scores when comparing conventional acid etching versus Er:YAG laser conditioning. Moreover the results of the present investigation demonstrated higher frequency of ARI=1 and ARI=2, showing a mixed adhesion modality for all groups, except for glass fiber brackets that reported a higher frequency of ARI=3.

Previous reports that evaluated Er:YAG lasers with conventional metallic [Hosseini et al., 2012; Turkoz and Ulusoy 2012; Contreras-Bulnes et al., 2013; Akin et al., 2016; Aglarci et al., 2016] and ceramic [Yassaei et al., 2014; Han et al., 2016] brackets showed similar results. An ARI=0 means a higher adhesion of bonding system, more to the bracket base than to the tooth, during the debonding process. In this case it is claimed that less time is needed for adhesive removal from tooth surface. In contrast, an ARI=3 indicates failure between the bracket and adhesive, thus lowering risk of enamel fracture upon removal [Montasser and Drummond, 2009].

The present study is the first report that analysed shear bond strength and ARI scores of microfilled copolymer, glass fiber, sapphire brackets after conventional acid etching. Moreover this is the only research in the literature that recorded bond strength of microfilled copolymer, glass fiber, sapphire, polyoxymethylene brackets after Er:YAG laser pretreatment, further studies are needed in order to confirm the present results.

Conclusions

The present investigation demonstrated that all the groups tested showed clinically acceptable bond strength values. When compared to conventional orthophosphoric acid etching, Er:YAG laser conditioning of enamel prior to adhesive application can significantly reduce bonding efficacy of sapphire, polyoxymethylene and sintered ceramic brackets. Moreover also ARI score frequencies of microfilled copolymer and polyoxymethylene brackets are significantly reduced after Er:YAG laser conditioning.

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Conflict of interests
The authors declare that there is no conflict of interest regarding the publication of this paper.

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