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ORIGINAL ARTICLE

Comparison of the different retention appliances produced using CAD/CAM and conventional methods and different surface roughening methods

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Abstract

The purposes of this study are to conduct an in vitro comparison of the shear bond strength, breakage mode, and wire deformation of three different types of retainers and to compare the subsequent enamel surface changes. Two hundred seventy intact lower incisor teeth were embedded in acrylic blocks in pairs. Dead wire and CAD/CAM-fabricated and fiber-reinforced wires were applied to the teeth roughened with acid and Er:YAG or Er,Cr:YSGG laser. The surface roughness was observed by scanning electron and atomic force microscopy. The samples were analyzed for shear bonds. The dead wire and acid group were found to have the highest bonding strength and the strengths for all groups in which acid was used as an agent were found to be higher than others. Deformation of retainers was most noted in the dead wire-acid group. Among all the groups, the CAD/CAM-fabricated wire group showed the least deformation, with no deformation observed. In this study, it was determined that there is a significant correlation between ARI scores and agents. Consequently, acid etching was found to create more enamel surface roughness than laser groups. It was also seen that the combined use of the acid method and dead soft wire had the highest bond strength, even though it was not statistically significant. It was concluded that CAD/CAM-fabricated wire provides the opportunity for reuse in clinical applications due to its lack of deformation, being more conservative for the patient, and being more advantageous for the clinician in terms of session time, considering the residual adhesive amount left on the enamel surface.

Keywords AFM · Bonding strength · Laser · Memotain · SEM · Strengthening

Introduction

One of the main targets of orthodontic treatment is maintaining a long-term stability of the results obtained [1]. The use of retainers after orthodontic treatment, which are classified as fixed or removable, has become mandatory in many orthodontic cases [2].

The overall failure rate of retainers used after orthodontic treatment varies between 10.3 and 47%. The reasons for failure include contamination during application, separation between the teeth and the adhesive wire, and insufficient amount of adhesive [2].

Improvements made in the bonding procedures in orthodontic practice enable reduction in the failure rate, minimal enamel damage, and a decrease in the time spent at the point of care [3]. Methods used in the roughening of enamel surfaces have significant effects on the adhesion of bonding resins, and acid, laser, and sandblasting procedures can be used for this purpose [4].

The attribution of white spot lesions observed around the bracket during orthodontic treatment to acid, the need for technical precision for the surface roughening method with acid, and the laser's ease of application where moisture control is difficult have all led orthodontists to use laser in the roughening of enamel surfaces [5]. With the advent of dental laser devices, the roughening effects of these devices on the enamel were examined and the roughening of the enamel surface using laser rays became an alternative to surface roughening with acid. Investigators have shown that the surface roughening ratio of laser ray is comparable [6] or similar [7] to that of acid.

Retention wires used to stabilize the position of orthodontic teeth and prevent relapse can be made of metal alloys (stainless steel, gold-plated stainless steel) or glass or polyethylene

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fiber-reinforced composite (FRC) materials. Even though retainers are frequently used, there are a limited number of in vitro and clinical studies on the wire type, bonding system, and the effect of the composite used [8]. Contradictory results were found in the literature when the failure rates of stainless steel and FRC retainers were compared. Some studies report that multi-strand wires are more reliable [9], while some point out no difference [9].

The main problem with multi-strand stainless steel retainers is their high rate of failure [10]. Besides this, they have disadvantages such as difficulty in brushing, plaque accumulation, misalignment of teeth or gaps between the teeth associated with deformation in the wire, loss of torque, irritation in the tongue, and emergence of occlusal conflict. Orthodontists are unwilling to apply lingual retainers on their patients due to the frequent breakage of retainers, and the need for fixing. In order to eliminate all these negative aspects, Memotain retainers manufactured using nickel titanium by means of CAD/CAM have been developed as an alternative to multi-strand wires [11].

The aim of this study is to conduct an in vitro comparison of the change observed on the enamel surface after three different enamel roughening methods (surface roughening with acid, Er:YAG laser, and Er,Cr:YSGG laser) and to compare the shear bonding strength, breakage mode (ARI), and deformation amounts of the three different types of retainers (0.016×0.022-in. dead soft eight-strand wire, CAD/CAM-fabricated and fiber-reinforced wire). The null hypothesis is that there will be no difference in the SBS values, ARI scores and wire deformations for brackets bonded to enamel surfaces conditioned with acid and Er:YAG and Er,Cr:YSGG laser systems.

Materials and methods

Ethical approval was received from Gaziantep University Clinical Trials Ethics Committee for our study with decree no. 47 dated 27.02.2017. According to the statistical power analysis (G Power, version 3.0.10, Kiel, Germany), aimed at determining the number of samples to be used in our study, it was determined that there must be 30 mandibular incisors (15 blocks) in each group in order to provide a power value of 80% with 5% error.

Sample collection

Two hundred seventy intact mandibular incisors were collected from the patients under dental treatment by choosing mandibular incisors indicated for extraction due to periodontal problems, excluding decayed, broken, cracked, or abnormal teeth, or those with fillings.

First of all, mechanical debridement was applied to the collected teeth using ultrasonic tools, and they were stored in thymol solution. Storage solutions were replaced once a month, and the storage time for the extracted teeth was determined as a maximum of 6 months.

Sample preparation

In order to reflect the positions of the incisors inside the mouth, they were embedded inside plastic blocks made of chemically curing acrylic resin to enable contact in pairs at contact points. The roots of the teeth were placed so that the long axis of the tooth was perpendicular to the acrylic block, and 135 blocks of teeth were prepared in total.

Roughening of enamel surfaces

Transbond XT etching gel system group

The lingual surfaces of the teeth were cleaned with fluoride-free pumice. They were acidified with 37% orthophosphoric acid (Transbond XT etching gel system; 3M Unitek, Monrovia, CA, USA) for 15 s, washed with water using a three-part injector for 30 s, and dried with oil-free air supply for 20 s.

They were then left without irradiation after being applied as a thin layer in line with the instructions of the primer manufacturer (3M Unitek, Monrovia, CA, USA).

Er:YAG laser (2940-nm wavelength; LightWalker, Fotona, Slovenia) group

The lingual surfaces of the teeth were roughened with a Er:YAG dental laser at middle-short pulse mode (MSP) for 15 s at 120 mJ, 10 Hz, 1.2 W, and a water rate of 50 ml/min. They were scanned using a contact-type tip with horizontal movements so that the laser beam was perpendicular to the enamel surface.

Er,Cr:YSGG laser (Waterlase, Biolase Europe GmBH, Floss, Germany) group

An Er, Cr: YSGG laser (Waterlase MD Turbo, Biolase) with a turbo head was used for the laser surface roughening process. The enamel surface was roughened at a wavelength of 2.78 μm and a speed of 20 Hz, with a pulse time of 150 μs and power of 2 W. Air and water levels were set to 90 and 80%, respectively. The laser beam was reflected from a distance of 1 mm, perpendicular to the enamel of the teeth, by using a sapphire-type tip for 15 s.

Imaging of roughened surfaces

Imaging with scanning electron microscopy

SEM images were taken of two teeth in each group in order to observe the changes on the enamel surfaces.

The enamel surfaces were evaluated according to the enamel damage index (EDI), which is a modification of the surface roughness index defined by Howell and Weekes.

EDI Index:

Degree 0: Smooth surface without scratches and visible perikymata
Degree 1: Acceptable surface, thinly spread scratches
Degree 2: Rough surface, large grooves, and enamel damage that is visible to the naked eye
Degree 3: Roughly scratched surface, large grooves, and enamel damage visible to the eye [12]

Imaging with atomic power microscope

A total of six teeth, including two from each group, were examined under the atomic power microscope to evaluate the surface roughness. Statistical results were taken by recording the mean surface roughness values (Ra).

Preparation and adhesion of lingual retainers

Preparation of Bond-a-Braid and EverStick Ortho lingual retainers

The lingual retainers to be used (Bond-a-Braid and EverStick Ortho) were cut into 10-mm pieces, marked at their midpoints with a pen, and placed on the surface of the teeth. Wires were carefully placed on the lower part of the contact points of the teeth so that they were parallel to the block base.

A Mini-Mold (Mini-Mold; Ortho-Care Ltd., Bradford, UK) adhesive set was used to standardize the composite amount used to adhere the lingual retainers. A single composite Transbond lingual retainer (3M Unitek, Monrovia, CA, USA) type was used in all groups. Composites placed on the teeth and the wire were adhered by applying irradiation for 10 s with an LED device (LED Curing Light | VALO® Ortho Cordless- Ultradent Products, Inc. in Utah, USA). A light device was held as close to the surface of the teeth as possible. Each composite layer has a 4-mm diameter and 1.5-mm depth, which corresponds to a total area of 12.6 mm^2 on the tooth's surface. Following the completion of all processes, blocks were left in the distilled water 24 h before the application of the test process.

Preparation of Memotain lingual retainer

To manufacture the Memotain wire, three D scans of the blocks were performed firstly using a 3Shape laboratory scanner (D-250; 3Shape, Copenhagen, Denmark). In order for these scans to be performed and the Memotain wires to be manufactured, two new blocks made of acrylic reflecting an arch form were prepared for both sides of the blocks we made from two mandibular incisors. Once a premolar to premolar arch form was created and all the blocks were secured to the plate using wax, three-dimensional scans were performed. A total of 45 blocks were scanned and saved in STL format, and this data was sent to the company CA-Digital in Mettman, Germany, by means of a cloud storage system, in order for the Memotain retainers to be manufactured.

Prior to the breaking point following the adhesion of retainers on the 135 samples prepared, they were left in distilled water at 37 °C for 24 h, and subjected to thermokinesis (GM, Gokceler Mechanical, Sivas, Turkey) so that there would be 5000 cycles with a waiting time of 30 s (5–55 °C).

Retainer breaking point

The blocks with embedded teeth were placed and secured on the base plate of the Instron Testing Machine (Instron Corp., Norwood, MA, USA). The tip of the machine that performs the breaking process was adjusted so that the tip would align right with the center of the wire, and not contact any other surface except the wire. The piston speed was set to 1 mm/min, and the maximum load required for the wire to break was recorded.

Measurement stage of wire deformation

After the retainers were broken, the composite residues left on the wire were cleaned carefully using a tungsten carbide drill. The wire was then placed on graph paper, and the deflection amount of the wire was recorded in millimeters with a magnification of × 20 under an optical stereomicroscope (SZ 40; × 20 magnification Olympus, Tokyo, Japan).

Breakage analysis

The first area of the wire that broke was assessed using an optical stereomicroscope with × 20 magnification. Residual adhesive on the enamel surface was coded by an investigator who did not know the treatment groups. The broken area was scored according to the Adhesive Remnant Index (ARI) [13]. In this system, the scores were interpreted as follows according to the amount of residual adhesive on the enamel surface after the removal of the retainer:

0: No residue on the enamel surface
1: Less than 50% adhesive on the tooth surface
2: More than 50% adhesive on the tooth surface
3: Adhesive entirely remaining on the surface of the teeth as residue

Statistical analysis

The compliance of the data with normal distribution was tested with the Shaphiro-Wilk test, and one-way ANOVA-LSD Multiple Comparison tests were used in the comparison of variables with normal distribution in more than two independent groups. Numerical variables with no normal distribution were converted to normal distribution using logarithmic transformation. A two-way ANOVA was used with the aim of showing the effect of two factors on the normally distributed variables. The chi-square test was used to test the relationship between categorical variables. Mean ± standard deviation values were given for the numerical variables as the descriptive statistics. SPSS (Chicago, IL, USA) for Windows, Version 24.0 software package was used for statistical analyses, and $p < 0.05$ was considered statistically significant.

Results

In this study, surfaces roughened with an abrasion method and unprocessed smooth surfaces were imaged using SEM with 1000 magnification. It was seen that areas abraded with the Er:YAG and Er,Cr:YSGG laser showed an approximately similar roughening (EDI degree 3), and were more rough and irregular compared to the surfaces on which acid was applied (EDI degree 2) (Fig. 1).

Figure 2 shows the AFM images of an enamel surface that did not undergo any abrasive process, and the enamel surfaces where Er:YAG and Er,Cr:YSGG laser were applied. The results were parallel with the obtained SEM images. In light of this information, it was found that the surfaces on which acid was applied showed a more regular roughness, and that the laser groups created rough, irregular and more rippled surfaces (Table 1). According to the results of the study, the difference between the abrasion methods used to roughen the enamel surface was statistically significant in terms of roughness value ($p = 0.001$) (Table 2).

The descriptive statistics results of the groups' bonding strengths are shown in Table 3. The intra-group difference for retainers (Bond-a-Braid-EverStick Ortho, Bond-a-Braid-Memotain) (Table 4) and abrasion methods (acid-Er:YAG, acid-Er.Cr:YSGG) (Table 5) was statistically significant in terms of bonding strength ($p = 0.001$). Retainer*agent interaction was not found to be statistically significant when examined in terms of bonding strength ($p = 0.181$).

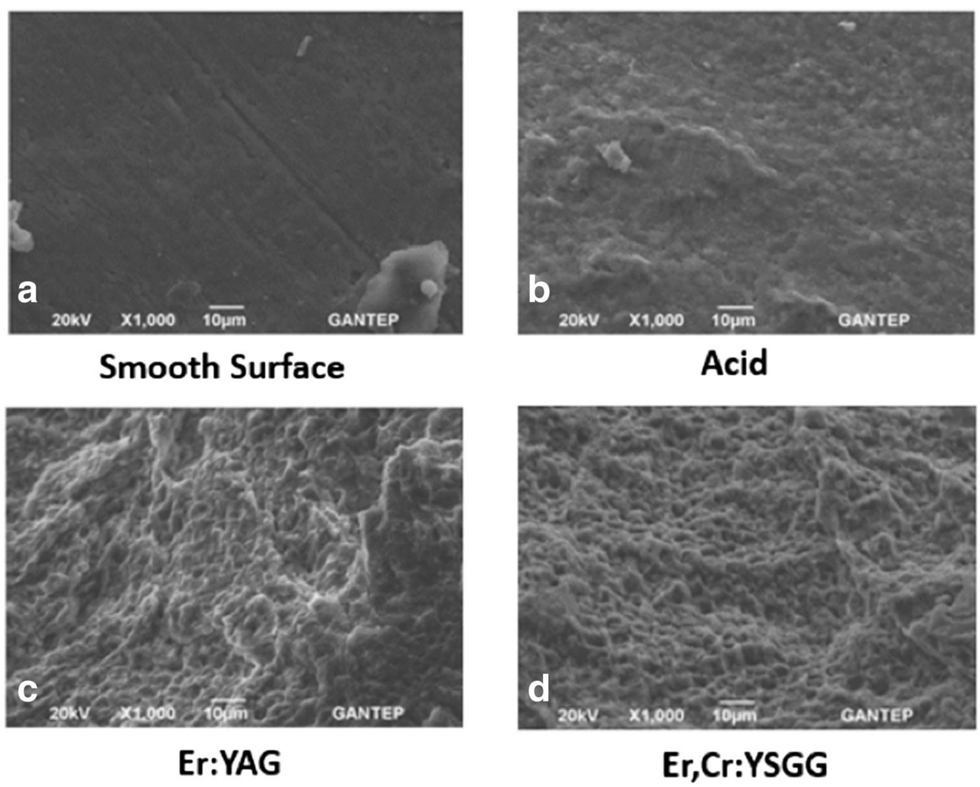

Fig. 1 The samples obtained with SEM after roughening. **a** Smooth surface with no roughening. **b** Surface roughened with acid. **c** Surface roughened with Er:YAG laser. **d** Surface roughened with Er,Cr:YSGG laser

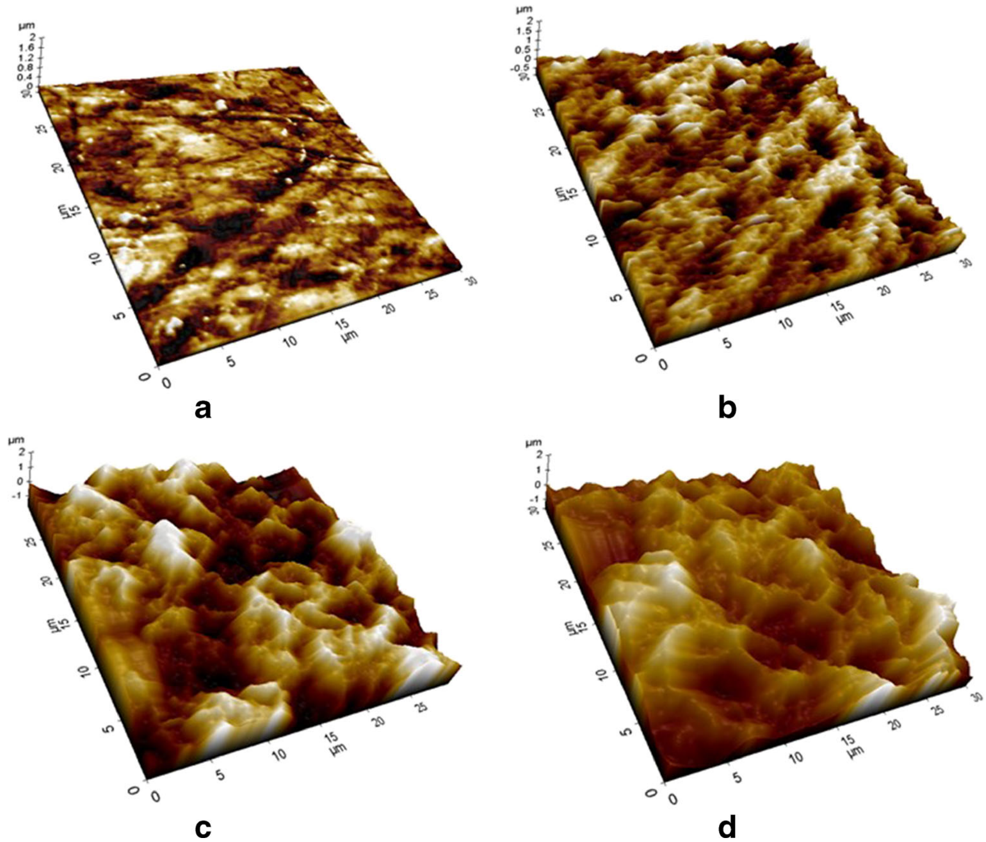

Fig. 2 The samples obtained with AFM after roughening. **a** Smooth surface with no roughening. **b** Surface roughened with acid. **c** Surface roughened with Er:YAG laser. **d** Surface roughened with Er,Cr:YSGG laser

The descriptive statistics results of the groups' deformation amounts are shown in Table 3. In our study, retainer*agent interaction was found to be statistically significant in terms of deformation values ($p = 0.001$). While the effect of the change in abrasion method on deformation value was not statistically significant ($p = 0.332$), the effect of the retainer was significant ($p = 0.001$).

Table 6 shows a comparison of the retainer*agent interaction in terms of deformation amount. The difference in deformation amounts between the Bond-a-Braid-Acid group and Bond-a-Braid-Er:YAG, EverStick-Acid, EverStick-Er,Cr:YSGG, Memotain-Acid, Memotain-Er,Cr:YSGG and Memotain-Er:YAG groups was found to be statistically significant. The difference between the Bond-a-Braid-Er,Cr:YSGG group and Bond-a-Braid-Er:YAG, EverStick-Acid, EverStick-Er,Cr:YSGG, Memotain-Acid, Memotain-Er:YAG and Memotain-Er,Cr:YSGG group was found to be statistically significant in terms of deformation amounts. The difference in deformation amounts between the Bond-a-Braid-Er:YAG group and EverStick-Er:YAG, Memotain-Acid, Memotain-Er:YAG and Memotain-Er,Cr:YSGG groups was found to be statistically significant. The difference between the EverStick-Acid group and EverStick-Er:YAG, Memotain-Acid, Memotain-Er,Cr:YSGG, and Memotain-Er:YAG groups, and lastly EverStick-Er,Cr:YSGG and EverStick-Er:YAG group, and all Memotain groups was found to be statistically significant in terms of deformation amounts.

A comparison of different retainers and agents in terms of ARI index is shown in Table 7. The residual amount on the

Table 1 Descriptive statistics results of roughness levels imaged with AFM in nanometers

	N	Mean	Std. deviation	Minimum	Maximum
Smooth surface	6	31.66	4.22	26.00	38.00
Acid	6	172.33	18.87	147.00	192.00
Er:YAG	6	369.83	31.71	329.00	403.00
Er,Cr:YSGG	6	491.16	45.58	416.00	548.00
Total	24	266.25	182.76	26.00	548.00

Table 2 Intra-group comparison of the roughness levels imaged with AFM

*$p < 0.001$	Acid	Er:YAG	Er,Cr:YSGG
Smooth surface	0.001*	0.001*	0.001*
Asit		0.001*	0.001*
Er:YAG			0.001*

Table 3 Descriptive statistics results of the bonding strengths between retainers and agents and deformation amounts

		Shear bond strength (mean ± Std. deviation) (MPa)	Deformation Amounts (mean ± Std. deviation) (mm)	*N*
Bond a Braid	Acid	11.02 ± 3.94	0.94 ± 0.44	15
	Er,Cr:YSGG	5.49 ± 5.41	0.92 ± 0.55	15
	Er:YAG	7.22 ± 3.19	0.51 ± 0.31	15
	Total	7.91 ± 4.79	0.79 ± 0.48	45
Everstick	Acid	8.02 ± 4.42	0.55 ± 0.23	15
	Er,Cr:YSGG	3.30 ± 2.47	0.65 ± 0.27	15
	Er:YAG	5.91 ± 1.83	0.78 ± 0.31	15
	Total	5.50 ± 3.62	0.66 ± 0.28	45
Memotain	Acid	6.94 ± 2.97	0.00 ± 0.00	15
	Er,Cr:YSGG	5.07 ± 2.12	0.00 ± 0.00	15
	Er:YAG	3.83 ± 1.52	0.00 ± 0.00	15
	Total	5.28 ± 2.58	0.00 ± 0.00	45
Total	Acid	8.66 ± 4.13	0.50 ± 0.48	45
	Er,Cr:YSGG	4.62 ± 3.69	0.52 ± 0.52	45
	Er:YAG	5.41 ± 2.65	0.43 ± 0.41	45
	Total	6.73 ± 3.93	0.48 ± 0.47	135

enamel surface was observed to be minimal in the Memotain group, and higher in the EverStick Ortho group. As a result of the statistical assessment, a significant correlation was seen between retainers in terms of ARI index ($p = 0.001$). A significant correlation was found as a result of the statistical assessment performed between agents ($p = 0.001$).

Discussion

The results obtained from this study clearly show that acid, Er:YAG laser, and Er,Cr:YSGG laser and different retainers have clinically acceptable SBS values. Even though the highest bonding strength value was in the Bond-a-Braid retainer and acid group, there was no statistically significant difference between the interaction of different retainers and different abrasion methods in terms of bonding strength. However, due to the significance of the intra-group comparisons of the retainer and abrasion methods, the null hypothesis stating that there was no difference between SBS values for acid and Er:YAG and Er,Cr:YSGG laser systems and Bond-a-Braid, EverStick and Memotain retainers was rejected. Furthermore, despite the effect of interaction between the retainer and abrasion method used in the study on the deformation amount, it was determined that the retainer was the main factor in terms of the deformation amount, and the null hypothesis was rejected for deformation amounts. Lastly, as is the case with the deformation values, the null hypothesis was rejected due to the different results obtained for different retainers and agents in terms of the ARI index.

In orthodontics, clinically acceptable bonding strengths vary between 6 and 8 MPa [14, 15]. Contradictory results are observed in previous studies that examined the effects of Er:YAG laser on bracket bonding strengths [16–18]. In a study conducted by Ağlarcı et al., no statistically significant difference was reported between the Er:YAG laser and acid in terms of bonding strength [19]. Similarly, Sagir et al. also stated that there was no significant difference in their study that compared roughening by Er:YAG and acid [18]. In this study, on the other hand, a significant difference was seen between acid and Er:YAG laser in terms of bonding strength. The fact that the buccal surfaces of the teeth were used in the studies conducted by Ağlarcı and Sagir et al., the existence of possible differences in the enamel structures, and failure to standardize the tooth ages, as is the case with our study, might have led to these different results.

Table 4 Intra-group comparison of retainers in terms of bonding strength

*$p < 0.001$	Everstick Ortho	Memotain
Bond a Braid	0.001*	0.001*
Everstick Ortho		0.754

Table 5 Intra-group comparison of retainers in terms of abrasion methods

*$p < 0.001$	Er:YAG	Er,Cr:YSGG
Acid	0.001*	0.001*
Er:YAG		0.259

Table 6 Comparison of retainers and abrasion method interaction in terms of deformation amounts

		Bond a Braid		Everstick			Memotain		
Retainer	Abrasion methods	Er,Cr:YSGG	Er:YAG	Asit	Er,Cr:YSGG	Er:YAG	Asit	Er,Cr:YSGG	Er:YAG
Bond a Braid	Acid	0.846	0.001*	0.001*	0.001*	0.147	0.001*	0.001*	0.001*
	Er,Cr:YSGG		0.001*	0.001*	0.001*	0.208	0.001*	0.001*	0.001*
	Er:YAG			0.739	0.215	0.001*	0.001*	0.001*	0.001*
Everstick	Acid				0.362	0.001*	0.001*	0.001*	0.001*
	Er,Cr:YSGG					0.257	0.001*	0.001*	0.001*
	Er:YAG						0.001*	0.001*	0.001*
Memotain	Acid							1000	1000
	Er.Cr:YSGG								1000

*p<0.05

In studies conducted using the Er,Cr:YSGG laser system, contradictory reports have been made about its use for the roughening of the enamel surface. Some investigators state that roughening with a laser has a lower bonding strength compared to roughening with acid [20–23], while some argue that the laser beam is more advantageous [24, 25]. In this study, on the other hand, a significant difference was seen between acid and Er,Cr:YSGG laser in terms of bonding strength. It is thought that results contradictory to the above papers might have been caused by the variability between surface morphology, enamel structure, and ages of the teeth used in the studies. Besides, no statistically significant difference was observed between the agents in terms of their roughness levels. While the highest roughness value was seen in the Er,Cr:YSGG laser group, the lowest value of roughness belonged to the acid group. It might be stated that the fact that the Er,Cr:YSGG laser has a higher pulse rate and power compared to the Er:YAG laser causes a directly proportional increase in the roughness rate.

Many composite and wire combinations can be used for lingual retainer manufacture. In this study, the bonding strengths were tested using three different retainers made of different materials, and a single composite type. One of the wires used was a 0.016 × 0.022 in. eight-strand dead wire called Bond-A-Braid. The manufacturers argue that their product is superior due to the following advantages: the dead soft wire can be more easily adapted compared to five-strand stainless steel wires, and no undesired tooth movement occurs due to the active force applied by the wire. The manufacturer of the eight-strand wire states that splints made out of this wire prevent torque losses that occur with round wires [13]. As a result of this study, it was concluded that there is a statistically significant difference in between Bond-a-Braid, EverStick, and Memotain retainers in terms of their bonding strengths, and that Bond-a-Braid retainer has the highest value. In light of the information provided above, higher bonding force values might have been obtained thanks to the prevention of accumulation of stress on a single area caused by easy adaptation of the dead soft wire on the tooth surface and its lack of any force exertion, as well as its easily bending structure.

Table 7 Comparison of different retainers and abrasion methods in terms of ARI index

Groups	Score 0	Score 1	Score 2	Score 3	Total
Bond a Braid	0	40	4	1	45
Everstick	3	25	17	0	45
Memotain	1	42	2	0	45
Acid	0	29	16	0	45
Er,Cr:YSGG	2	39	4	0	45
Er:YAG	2	39	3	1	45

Another retainer used in the study was EverStick Ortho (E-glass) lingual retainer, which is a glass fiber-reinforced material. Glass fiber-reinforced material is used in various technical fields, such as yachts, racing equipment and boats with light displacement requiring high resistance and lightness. Its use in dentistry involves fields such as composite crowns and bridge construction, and only fiber-reinforced composite retainers have managed to become a recent alternative to twist-flex retainers. Among these, only EverStick Ortho retainer has been designed for orthodontic retention purposes [26]. As a result of this study, a statistically significant difference was observed in the EverStick Ortho retainer in terms of bonding strength compared to the Bond-a-Braid retainer, whereas no significance was seen compared to the Memotain retainer. The fact that the EverStick retainer has a more fibrous structure, and thus its fibers are broken more easily, might have led to its insufficient bonding strength compared to the Bond-a-Braid retainer.

The last retainer used in our study was Memotain. The Memotain retainer was manufactured from 0.014 × 0.014-in. angular steel wire using CAD/CAM. The wire was cut very flexibly and specially in order for it to completely fit the tongue and tooth anatomy of the patient. The name

Memotain comes from a combination of "memory" and "retainer," reflecting its nickel-titanium characteristics [11]. Memotain provides many advantages compared to conventional multi-stranded lingual retainers. These advantages can be listed as the lack of a need for wire measurement or bending. the opportunity it provides for the most suitable placement due to its design that can be tailored to any individual, higher compliance, tighter inter-proximal adaptation, less tongue irritation, better durability, and less microbial colonization [11]. However, there are currently no in vitro or in vivo Memotain studies in the literature. A statistically significant difference was seen in the comparison of the Memotain retainer with the Bond-a-Braid retainer in terms of bonding strength, whereas there was no significant difference with the EverStick retainer. The flexibility of the Memotain retainer provided by its nickel-titanium content is thought to lead to its separation from the tooth against shear forces.

In a study carried out by Baysal et al., bonding strengths were evaluated using three different retainer materials. The bonding strength of the Bond-a-Braid-acid group was found to be around 40 N [13]. In a study performed by Cooke et al. using Transbond LR in the Bond-a-Braid and acid group, the mean bonding strength was shown to be 37.70 N [27]. Brauchli et al. tested the bonding strength of EverStick Ortho lingual retainer using five different fluent composites. The mean bonding strength of the Transbond LR and EverStick Ortho group was shown to be 8.40 Mpa [26]. In a study by Foek et al., the bonding strength of the EverStick Ortho and acid group was found to be 7.6–2.6 Mpa [28]. In this study, the mean bonding strength of the EverStick Ortho and acid group, EverStick Ortho-Er:YAG laser group, and EverStick Ortho-Er,Cr:YSGG laser group were determined as 8.02, 5.91, and 3.30 MPa, respectively. Considering the other studies in the literature, the results obtained were found to be similar to the bonding strength measurements given by the EverStick Ortho lingual retainer.

Reynolds states that the force required for a bracket to become separated from the enamel surface is between 6 and 8 Mpa, but that this does not apply to lingual retainers [15]. In the literature, there is very little information about the clinically accepted minimum bonding strength of lingual retainers [27]. Therefore, it is very difficult to compare and evaluate the results found in this study. While it is known that the Bond-a-Braid retainer has been used and found to be successful by clinicians so far in orthodontics, no significant difference was found between the Bond-a-Braid, EverStick and Memotain retainers in this study. Considering all these facts, it is thought that the Bond-a-Braid, EverStick, and Memotain retainers used in this study are suitable for clinical use in terms of their bonding strength.

Kucukyılmaz et al. [29] studied the effect of different surface roughness methods on SBS. They reported that there is no difference between different modes of Er:YAG lasers (MSP and QSP). Altunsoy et al. [30] described increasing the µSBS in two pulse modes tested (MSP or QSP) with Er:YAG laser. The best bond strength value was seen in the Er:YAG MSP mode group. In their study, Sagir et al. [18] reported that laser etching with 120 mJ, 10 Hz, and 1.2 W parameters is a successful alternative to the acid method due to the fact that the MSP and QSP mode yielded statistically similar bond strength values. Akin et al. [31] reported similar results to Sagir et al. in their study conducted with the parameters 120 mJ, 10 Hz, and 1.2 W. Therefore, Er:YAG laser with 120 mJ, 10 Hz, and 1.2 W parameters and MSP mode was used in our study for the evaluation of fixed retention appliances.

According to the obtained results, a reverse correlation was seen between the surface roughness values of abrasion methods. The surface roughness values were highest with the Er,Cr:YSGG laser, followed by the Er:YAG laser and lastly acid. As a result, it is seen that the more the roughness values increased, the more the bonding strength values decreased. However, this result contradicts with Sagir et al.'s study. In Sagir et al.'s study where the effects of laser application with different pulse settings on the bracket bonding strength were investigated, the mean bonding strength value of the acid group, MSP mode Er:YAG laser, and QSP mode Er:YAG laser was 6.6, 10.1, and 11.8 MPa, respectively, whereas the mean Ra value of the acid group, MSP mode Er:YAG laser, and lastly QSP mode Er:YAG laser was found to be 32.6, 110.6, and 130.2 nm, respectively [18]. The inconsistency between these two studies might be attributed to the measurement of the bonding strengths of different materials and different teeth surfaces.

In a study conducted by Baysal et al., the mean deformation amount observed in retainers adhered using Bond-a-Braid and acid was 3.5 mm, and 0.5 nm in PentaOne retainer wire, which is a 0.0215-in. five-strand wire. It was stated that less deformation might help the transfer of the obtained force to the teeth, thus improving periodontal health. Additionally, chewing forces and cleaning forces in the area below the wire applied with dental floss might lead to deformation resulting in the breakage of the retainer wire. It has been claimed that retainers that deform more easily are more prone to breakage [13].

In this study, no deformation was seen in the Memotain retainer. This was attributed to the fact that it stretches against the vertical force and regains its former shape thanks to the shape memory characteristic resulting from its nickel-titanium content. Nickel-titanium alloys are materials with limited formation capabilities and thermal memory characteristics. These shape memory alloys are metallic materials which revert to their former shapes and dimensions in relation to the heat and stress applied when they are exposed to deformation [32]. While deformation leading to reversion to the former shape is known as elastic deformation, deformation that does not lead to reversion to the former shape is called plastic deformation. A force of mild severity causes elastic deformation in the orthodontic wire, whereas plastic deformation occurs with an increase in severity. A very high severity force leads the wire to break [33]. In light of this information, fracturing was seen at the force exertion area due to application of a higher force than the plastic deformation limit on only two of the total 45 Memotain wires. However, no deformation was observed on the wire when the broken pieces were combined.

In the comparison of EverStick and Bond-a-Braid retainers in terms of deformation in this study, the fact that the stainless steel Bond-a-Braid retainer has a more rigid and fragile structure due to its material content might be the reason behind its higher rate of deformation compared to the fiber retainer.In this study, a significant difference was seen between different retainers in terms of ARI index. The highest number of samples with an ARI score of 1 that underwent different abrasion methods was seen in the Er:YAG and Er,Cr:YSGG group, as determined in 39 of the 45 samples. Between the two, it was seen that the Er:YAG laser left more residue on the surface of the teeth compared to the Er,Cr:YSGG laser. In the acid group, there were 29 samples with an ARI score of 1. According to these results, it was seen that the more the flexibility of the retainer wire increased, the more fracturing was observed in the bond between the enamel and adhesive. Therefore, a lower residual amount on the surface of the teeth will lead to less time spent at the point of care. Furthermore, it might be interpreted that the more fibrous structure of the EverStick retainer is the cause behind the greater amount of residue on the surface of the teeth.

In a study conducted by Cooke et al., the ARI index of 13 groups using Bond-a-Braid and acid was evaluated. The ARI index of all samples was found to be 2 [27]. They believed that the occurrence of the breakage mode between the wire and composite might be caused by the small size of samples, and that therefore a lower number of adhesive breakages might be observed in other cases.

Baysal et al. evaluated the ARI index of three different stainless steel lingual retainers, one of which was the Bond-a-Braid lingual retainer. They stated that there was no statistically significant difference between the retainers [13]. They also observed that the shorter the diameter of the wire, the higher the inclination in the force of separation from the teeth. This finding is consistent with that of Cooke et al. and might be attributed to the flexibility of thinner wires [27]. Even though such flexibility appears to be advantageous, Zachrisson reported that the more the wire diameter increases, the more wire breakage incidences decreases [34]. Similar to the results of Cooke et al., it was found in this study that residues on the enamel surface were lower in amount due to the more flexible structure of Memotain retainers compared to others. Increase in the flexibility of the wire might be interpreted as enabling easier removal from the teeth. Baysal et al. reported no significant difference between breakage modes in their study. Contradictory results were found when the common breakage modes in the literature were examined. Breakage was observed both between the composite and wire [27], and the composite and teeth [35]. Furthermore, abrasion arising from the breakage of the wire, loosening of the wire, fractures in the wire, and composites has been reported [36].

In this study, a significant correlation was observed between the ARI index and agents. In the acid group, the residual composite amount on the enamel surface was found to be higher compared to the laser groups. The acid group was followed by the Er:YAG laser, and the least residual composite amount was observed in the Er,Cr:YSGG laser group. Martinez-Insua et al. attributed this result to the fact that the enamel was weakened and a more heterogeneous surface was obtained as a result of less or no residue left on the surfaces roughened with a laser, and micro-explosions that occur after laser application [21].

Conclusions

It was seen that 37% orthophosphoric acid and Er:YAG and Er,Cr:YSGG laser systems could be used effectively in surface roughening prior to retainer applications after orthodontic treatment.

An inverse proportion was observed between the mean roughness values and bonding strength values created by acid and Er:YAG and Er,Cr:YSGG lasers used for roughening purposes on the enamel surfaces. The fact that a lower bonding strength was obtained with the creation of a larger bonding area by rougher surfaces, when it was expected to increase the bonding strength, was attributed to the heterogeneous structure of the enamel surface caused by micro-explosions. It was found that the combined use of the conventional acid method and dead soft wire had the highest bond strength, even though it was not statistically significant.

According to the evaluation of the breaking points of the retainers used in our study and ARI scores, the increase in the flexibility of the retaining wire was observed to decrease the residual amount on the enamel surface as a result of the breakage between enamel and adhesive. In contrast, the fibrous structure of the EverStick retainer was found to further increase the residual amount left on the tooth surface after breakage.

Lastly, it was concluded that CAD/CAM-fabricated wire provides an opportunity for reuse in clinical applications due to its lack of deformation, being more conservative for the patient, and more advantageous for the surgeon in terms of session time, considering the residual adhesive amount left on the enamel surface.

Compliance with ethical standards

Ethical approval was received from Gaziantep University Clinical Trials Ethics Committee for our study with decree no. 47 dated 27.02.2017.

Conflict of interest The authors declare that they have no conflict of interest.

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