



## Influence of phototherapy on adhesive strength and microleakage of bleached enamel bonded to orthodontic brackets: An in-vitro study

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### ABSTRACT

**Aim:** The aim of the present in-vitro study was to explore bleached enamel reversal with phototherapy (Er,Cr:YSGG) when using two dissimilar bonding system to bond brackets on microleakage and shear bond strength.

**Material and Methods:** Amongst one twenty samples, ninety samples were bleached using 35% hydrogen peroxide. After the bleaching procedure, the teeth were randomly divided into three groups according to surface conditioning treatment (n = 30 each). Group 1: treated with Er,Cr:YSGG (ECL) Group 2: 10% sodium ascorbate (SA) and Group 3: Bleached only (BO). Based on the type of adhesive, specimens were further classified into eight subgroups. In subgroup 1,2,3 and no treatment (NT) (n = 15) adhesive Transbond XT was applied on already etched surface and these subgroups were named as NT-TEP, BO-TEP, ECL-TEP and SA-TEP. Similarly, in subgroup 5,6,7 and NT specimens (n = 15) were conditioned with Transbond Plus self-etching primer and these subgroups were named as NT-SEP, BO-SEP, ECL-SEP and SA-SEP. Samples from each subgroup were exposed to increasing load for evaluation of shear bond strength. Microleakage among subgroups were tested by immersing samples in Methylene blue prior one day. Analysis of variance and Tukey multiple comparisons test was used to assess data.

**Results:** The maximum and minimum bond strength was observed in group NT-TEP [17.14(2.54)] and BO-SEP [6.14(0.215)] respectively. Samples conditioned with phototherapy ECL-TEP [16.14(1.231)] exhibited comparable bond strength to specimens conditioned with sodium ascorbate (SA-TEP) [16.72(1.298)]. Similarly, bond strength values of ECL-SEP [13.43(0.921)] and SA-SEP were comparable. The highest microleakage score was demonstrated in BO-SEP [83.21(38.21)] whereas, the lowest microleakage scores were displayed in NT-TEP [23.73(13.45)].

**Conclusion:** Er,Cr:YSGG phototherapy reversal on bleached enamel with etch and rinse adhesives has a potential to be used in clinical settings alternate to conventional sodium ascorbate when bonding orthodontic brackets.

### 1. Introduction

Dental bleaching in orthodontics plays a significant role in improving dental aesthetics and is one of the most conservative treatment procedures [1,2]. For in-office and home, whitening procedure hydrogen and carbamide peroxide are the agents of choice [3]. Bleaching

procedures are safe and in recent times have gained more popularity and acceptance both by the clinician and patients [4]. However, there are some undesirable effects of bleaching which have been already reported in the literature. These effects may range from increase tooth sensitivity, gingival burning, erosion of the enamel, increase enamel porosity and decrease bond strength [5,6].

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The reduce bond strength after bleaching is due to residual peroxide which may interfere with resin attachment and formation of free radicals which may inhibit polymerization [7,8]. Therefore, it is advisable to delay bonding procedure for a period of 3–4 weeks [9]. However not always this waiting time is possible due to busy working hours of the dentists, personal patient commitments and feasibility issues. Conventionally, 10% sodium ascorbate is used to reverse the effect and eliminate free radicals after bleaching procedures and improve bond strength but there use in dental practice is limited [10–13]. Conversely, the type of adhesive also plays a deciding role when bonding to bleached enamel [14].

Adhesive technology has evolved with time and has directed to the progression of multimode adhesives. A clinician can accustom to any of the adhesive for bonding of bracket according to their expertise and case [15]. Conventional etch and rinse adhesives has an advantage of less technique sensitive, unlimited working time and setting on demand which allows accurate bracket placement [16,17]. Similarly, newly formed self-etching adhesives reduce and simplifies bonding steps, decreases saliva contamination but are more technique sensitive [16,17].

Contemporary laser strategies, in the form of Erbium, chromium-doped yttrium, scandium, gallium and garnet (Er,Cr:YSGG) have been recently used in different dental treatments and have shown convincing results [18–20]. It is observed that Er,Cr:YSGG has a better affinity with water and hydroxyapatite crystals hence, it is well absorbed by enamel. The laser causes minimal thermal damage to the pulp, has better gingival contouring and improved cut surface [21]. Er, YAG has found to improve bond strength on bleached enamel and have shown encouraging result [22].

Research shows there is limited evidence on reversal potential of Er,Cr:YSGG on bleached enamel. Additionally, controversial evidence exists on the influence of orthodontic adhesive on shear bond strength and microleakage scores to bleached enamel. It is hypothesized enamel reversed with phototherapy will exhibit comparable outcomes related to conventional sodium ascorbate when using, unlike bonding system. Thus, the purpose of the present in-vitro study was to explore bleached enamel reversal with phototherapy (Er,Cr:YSGG) when using two dissimilar bonding system to bond brackets on microleakage and shear bond strength.

## 2. Material and methods

This research follows the general guidelines as described in the CRIS (checklist for Reporting In-vitro Studies). A total of one-twenty intact maxillary permanent premolars free from any restoration, carious lesion, cracks and endodontic treatment were kept in a thymol solution of 0.01% at 37°C for 1 week and then transferred to distilled water at 4°C until preparation. Periodontal scaler (Sonic flex 2000, Biberach, Germany) was used for removal of tissue debris and organic remnants. Each premolar specimen was then rinsed and mounted in a vertical direction inside the sections of polyvinyl chloride pipe (7 mm diameter) in acrylic resin (Meliodent, Heraeus/Kulzar Hanau, Germany) up to cement-o-enamel junction (CEJ) exposing only the buccal surface of the clinical crown. Additionally, the buccal surface of all premolar teeth was grounded to a depth of 1 mm for enamel standardization. Moreover, a flat surface of (2 x 2 mm) on the buccal surface of exposed enamel was prepared by polishing with 600 grit carbide silicon paper over a 250 rpm rotating polishing machine (Automet 250 Pro, Buehler) underneath the water for 15 seconds.

Amongst one twenty samples, ninety samples were bleached using 35% hydrogen peroxide (HP) (Total Blanc Office H35/Nova DFL Batch No.12050770). A thin coating of bleaching gel (2 mm) was applied in a solo session two times in an uninterrupted and moisture free surface for twenty minutes each on the buccal surface and removed with a cotton pellet, rinsed with water and air dried. After the bleaching procedure the teeth were randomly divided into three groups according to surface conditioning treatment (n = 30 each). Group 1: treated with

Er,Cr:YSGG (ECL) Group 2: 10% sodium ascorbate (SA) and Group 3: Bleached only (BO). The protocol used for these groups were as follows:

Group 1 (ECL): Thirty bleached samples were exposed to Er,Cr:YSGG phototherapy (Biolase-Waterlase I-Plus) with power 4.5 W and frequency 30 Hz for one minute from a distance of 2 mm in a non-contact mode using (tip MZ = 8) [19].

Group 2 (SA): Thirty bleached specimens were exposed to 10% sodium ascorbate (Merck, Germany). Sodium ascorbate in 10 ml solution at pH 7.5 was dispensed on buccal bleached surface of premolars with a speed of 1 ml/min with immediate rinsing of water and drying.

Group 3 (BO): The samples in this group were not conditioned with anything after bleaching procedure with 35% hydrogen peroxide (HP) (Total Blanc Office H35/Nova DFL Batch No.12050770). This group was classified as a negative control.

No treatment (NT) group: The specimens in this group did not undergo bleaching or any other surface conditioning. They were kept in artificial saliva (Oasis, Aquoral) for 1 week before bonding of the brackets. This group was classified as positive control.

According to the type of adhesive, specimens were further classified into eight subgroups. In subgroup 1,2,3 and NT (n = 15) samples were etched with 37% phosphoric acid (3 M ESPE) for 30 s washed and dried until chalky white appearance. An adhesive primer Transbond XT (3 M Unitek, Monrovia, Calif) was applied on the etched surface and these subgroups were named as NT-TEP, BO-TEP, ECL-TEP and SA-TEP. Similarly, in subgroup 1,2,3 and NT specimens (n = 15) were conditioned with Transbond Plus self-etching primer (3 M Unitek, CA, USA). The system consists of two compartments mixed together to form a single paste which was rubbed on the buccal surfaces of the tooth for 15 seconds and dried with compressed air for 1–2 s. These subgroups were named as NT-SEP, BO-SEP, ECL-SEP and SA-SEP.

Pre-adjusted edgewise appliance (PEA) metal brackets for maxillary premolars dimensions 0.022 x 0.028 MBT slot mesh size 80 gauge (Gemini 3 M Unitek Monrovia, Calif) were used for bonding. All specimens from subgroups were bonded with Transbond XT composite paste (3 M Unitek, Monrovia, Calif) and light-cured (Bluephase C8, Ivoclar Vivadent, Schaan, Liechtenstein) at an intensity of 750 mW cm<sup>-2</sup> for 20 s with direction of the light beam directed towards mesial and distal faces for 10 s each. The bonding was done by a single operator to avoid intra operator variations. After the procedure, all the specimens were placed in artificial saliva (NeutraSal) at 37°C for 24 h and underwent accelerated ageing thermocycling (TC) between 10 and 60 °C for 5000 cycles for 30 s before testing shear bond strength.

### 2.1. Shear bond strength (sbs) outcomes

To evaluate sbs (n = 10 samples each subgroup) were exposed to increasing load at occluso- gingival direction at the junction of bracket and tooth interface at a transversal velocity of 1 ml/min on a universal testing machine (Instron Model 4400 Universal Testing System, Instron Corporation).

### 2.2. Microleakage outcomes

Prior to microleakage testing (n = 5) samples from each subgroup were engrossed in methylene blue dye for one day in a dark environment away from light. An isomet (Buehler Isomet 2000 Germany) was used to section the samples without dislodgement of the brackets in a buccolingual direction. A polishing machine (Buehler Polishing Machine type: 49-5100-230, Buehler, Germany) was used to smoothen the surfaces. The samples were cleaned with distilled water (Pure Steam Distilled H<sub>2</sub>O - 1100 ml by Innovative Naturopathics) and air dried. A binocular microscope (Olympus® SZH10, Tokyo, Japan) at 40X magnification was used to evaluate microleakage in specimens.

The data were assessed for normality using Kolmogorov Smirnov test and the data was found to be normally distributed. The influence of different conditioning treatment of bleached enamel along with

**Table 1**  
Means and SD for Shear Bond strength values among study groups using ANOVA and Tukey multiple comparisons test.

Surface treatment/ Type of adhesive	Mean (Mpa)	SD (Mpa)	P value <sup>†</sup>
NT-TEP <sup>†</sup> (Positive Control)	<b>17.14</b>	2.54	
NT-SEP <sup>†</sup> (Positive Control)	14.25	1.27	
BO-TEP <sup>†</sup> (Negative Control)	8.21	0.421	< 0.001
BO-SEP <sup>†</sup> (Negative Control)	<b>6.14</b>	0.215	
ECL -TEP <sup>†</sup>	16.14	1.231	
ECL -SEP <sup>†</sup>	13.43	0.921	
SA-SEP <sup>†</sup>	13.21	0.854	
SA-TEP <sup>†</sup>	16.72	1.298	

NT: No treatment, TEP: Total etch primer, SEP: Self etch primer, ECL: Er, Cr: YSGG, BO: Bleached Only, SA: Sodium ascorbate.

The highest and lowest SBS values are in bold.

(Tukey multiple comparison test).

<sup>†</sup> Significantly different from groups- BO-TEP, BO-SEP, ECL-SEP, SA-SEP, SA-TEP, NT-TEP, NT-SEP (p < 0.05).

\* Significantly different from all other groups (p < 0.05).

<sup>†</sup> Significantly different from groups- BO-TEP, BO-SEP, ECL-TEP, SA-TEP, NT-TEP, NT-SEP (p < 0.05).

<sup>†</sup> Showing significant difference among study group (ANOVA).

different adhesives was analyzed using statistical program for social sciences (SPSS). Furthermore, analysis of variance (one-way- ANOVA) and post hoc Tukey multiple comparisons test was used to compare the bond strength and microleakage scores among the experimental groups. p < 0.05 was a statistical significance among the experimental groups

### 3. Result

Means and standard deviations of shear bond strength (sbs) and microleakage scores are exhibited in [Tables 1 and 2](#).

#### 3.1. Shear bond strength

Maximum and minimum shear bond strength was observed in group NT-TEP [17.14(2.54)] and BO-SEP [6.14(0.215)] respectively. Samples conditioned with phototherapy ECL-TEP [16.14(1.231)] exhibited comparable bond strength to specimens conditioned with sodium ascorbate (SA-TEP) [16.72(1.298)]. Similarly, bond strength values of ECL-SEP [13.43(0.921)] and SA-SEP were comparable. For bond strength scores, analysis of variance (ANOVA) showed a significant difference among the study groups (p < 0.001). ECL-TEP and SA-TEP

**Table 2**  
Means and SD for Microleakage values among study groups using ANOVA and Tukey multiple comparisons test.

Surface treatment/ Type of Primer	Mean (nm)	SD (nm)	P value <sup>†</sup>
NT-TEP <sup>†</sup> (Positive Control)	<b>23.73</b>	13.45	
NT-SEP <sup>†</sup> (Positive Control)	29.89	16.27	
BO-TEP <sup>†</sup> (Negative Control)	75.41	31.16	< 0.001
BO-SEP <sup>†</sup> (Negative Control)	<b>83.21</b>	38.21	
ECL -TEP <sup>†</sup>	33.54	17.41	
ECL -SEP <sup>†</sup>	43.68	26.85	
SA-SEP <sup>†</sup>	41.69	23.14	
SA-TEP <sup>†</sup>	31.78	18.82	

NT: No treatment, TEP: Total etch primer, SEP: Self etch primer, ECL: Er, Cr: YSGG, BO: Bleached Only, SA: Sodium Ascorbate.

The highest and lowest SBS values are in bold.

(Tukey multiple comparison test).

<sup>†</sup> Significantly different from groups- BO-TEP, BO-SEP, ECL-SEP, SA-SEP, SA-TEP, NT-TEP, NT-SEP (p < 0.05).

\* Significantly different from all other groups (p < 0.05).

<sup>†</sup> Significantly different from groups- BO-TEP, BO-SEP, ECL-TEP, SA-TEP, NT-TEP, NT-SEP (p < 0.05).

<sup>†</sup> Showing significant difference among study group (ANOVA).

were found to be significantly higher than BO-TEP, BO-SEP, ECL-SEP, SA-SEP, SA-TEP, NT-TEP, NT-SEP (p < 0.001). Similarly, bond strength of NT-TEP, NT-SEP, BO-TEP, BO-SEP was statistically significant compared to all other groups. Bond strength values in bleached samples only (BO) was significantly lower compared to all other groups ([Table1](#)).

#### 3.2. Microleakage outcomes

Significant difference among the study group was established regarding microleakage scores ([Table 2](#)). The highest microleakage score was demonstrated in BO-SEP [83.21(38.21)] whereas, the lowest microleakage scores were displayed in NT-TEP [23.73(13.45)]. For microleakage values, analysis of variance (ANOVA) showed a significant difference among the study groups (p < 0.001). Microleakage scores in samples of group ECL -TEP was comparable to specimens in group ECL-SEP. Moreover, microleakage in BO-SEP and BO-TEP was highest amongst all groups. Furthermore, microleakage in groups ECL-SEP and SA-SEP was statistically different from groups BO-TEP, BO-SEP, ECL-TEP, SA-TEP, NT-TEP and NT-SEP (p < 0.001).

### 4. Discussion

In the present study different surface treatment was used for the reversal of bleached enamel bonded with orthodontic brackets using different adhesives. The bonding efficacy was evaluated using shear bond strength testing whereas, by means of dye penetration test microleakage scores were assessed. The current study was constructed on the hypothesis that enamel reversed with phototherapy Er,Cr:YSGG will exhibit comparable outcomes related to conventional sodium ascorbate when using different bonding system. Captivatingly, this hypothesis was accepted as bleached enamel conditioned with phototherapy using laser unveiled comparable microleakage and shear bond strength scores.

Laser phototherapy in the form of Er,Cr:YSGG had already been used in dentistry to condition different dental materials and tooth structure and their results are overwhelming [18,23,19]. The laser is safe, convenient, efficient and conservative treatment modality for hard and soft dental tissues of the oral cavity [24]. Er,Cr:YSGG exhibits bactericidal action when used to condition tooth structure [25]. In the present study, bleached enamel lasered with Er,Cr:YSGG showed comparable bond strength to specimens conditioned with 10% sodium ascorbate. A credible explanation for these outcomes is that when the enamel is treated with Er,Cr:YSGG it produces scaly rugged appearance free from smear layer [26,27]. This results in easy penetration of the adhesive. Secondly, micro explosion on the enamel due to thermal effect of phototherapy results in the removal of free radicals and oxygen making mechanism of bonding more favourable [28]. However, previous studies using Er,YAG laser on bleached enamel did not show significant difference between bond strength [29,30]. This can be explained by different laser parameters i.e., frequency, power, pulse, duration and distance which may influence the outcome [27,26].

Shear bond strength was measured in the present study using universal testing machine. It is an in-vitro quantitative method which maintains consistency and standardization and delivers swift and precise data on detailed parameters [31]. Two different adhesives were used i.e., Transbond XT (TEP) and Transbond Plus self-etching (SEP) primer for bonding of orthodontic brackets. Transbond XT demonstrated better bond strength score over all, among all experimental subgroups. In authors opinion, a logical explanation of total-etch having better bond strength scores among different groups is additional etching step improving micromechanical retention, complete removal of smear layer and better penetration of the adhesive [15,32]. In addition, multiple factors have been reported previously which influences bond strength i.e., type of bracket, enamel quality, curing time, method of curing, type of adhesive and aging process [33].

Microleakage among specimens were assessed using dye penetration test. It is the most widely used, cost-effective, non-toxic and easiest available technique to detect microleakage [34]. In the current study microleakage score in ECL-TEP was significantly lower than BO-TEP and comparable to AS-TEP. Microleakage is dependent on multiple factors i.e., coefficient of thermal expansion, type of bonding agent, polymerization shrinkage, surface topography and location of margins [35,15]. Comparable microleakage scores between specimens ECL-TEP and SA-TEP can be ascribed to increase surface roughness of the enamel after phototherapy using laser resulting in better adaptation of the adhesive [36]. Moreover, Er,Cr:YSGG at wavelength 2240 nm is better absorbed by enamel and forms smear free layer hence it decreases microleakage. Moreover, highest microleakage scores in BO-TEP can be credited to presence of free radicals which inhibits penetration of adhesive and inhibits polymerization [37].

Interestingly, Transbond Plus self-etching (SEP) displayed the highest microleakages scores among all experimental group. A plausible explanation to this finding is that Transbond Plus is free of organic solvents i.e. water-based, hence results in decrease micromechanical retention [38]. Furthermore, evidence suggests self-etch primer compromises the extent and depth of etching pattern, hence increasing microleakage scores [38].

The present study has restraints based on its invitro design. The outcomes of the current study are applicable only on the type of adhesive, quality of enamel, phototherapy used and type of orthodontic brackets. In authors knowledge this is a maiden study hence more work should be done on surface profilometry along with surface topography using a scanning electron microscope (SEM) on reversal of bleached enamel with phototherapy. The effect of acetone-based adhesive should also be assessed on bleached enamel. Furthermore, more studies are needed to extrapolate the findings of present study.

## 5. Conclusion

Er,Cr:YSGG phototherapy reversal on bleached enamel with etch and rinse adhesives has a potential to be used in clinical settings alternate to conventional sodium ascorbate when bonding orthodontic brackets.

## Conflict of interest

The authors declare no conflict of Interest.

## References

- [1] M. Khoroushi, T. Saneie, Post-bleaching application of an antioxidant on dentin bond strength of three dental adhesives, *Dent. Res. J. (Isfahan)* 9 (2012) 46–53, <https://doi.org/10.4103/1735-3327.92943>.
- [2] F.A.R. Britto, A.S. Lucato, H.C. Valdrighi, S.A.S. Vedovello, Influence of bleaching and desensitizing gel on bond strength of orthodontic brackets, *Dental Press J. Orthod.* 20 (2015) 49–54, <https://doi.org/10.1590/2176-9451.20.2.049-054.oar>.
- [3] L. Giachetti, F. Bertini, C. Bambi, M. Neri, D. Scaminaci Russo, A randomized clinical trial comparing at-home and in-office tooth whitening techniques: a nine-month follow-up, *J. Am. Dent. Assoc.* 141 (2010) 1357–1364 (Accessed 12 December 2018), <http://www.ncbi.nlm.nih.gov/pubmed/21037194>.
- [4] T. Wille, I.J. Pesun, E.C. Combe, G.C. Lindquist, J.S. Hodges, A clinical pilot study of the time-dependent composition of tooth bleaching systems, *J. Oral Rehabil.* 30 (2003) 510–514 (Accessed 12 December 2018), <http://www.ncbi.nlm.nih.gov/pubmed/12752932>.
- [5] M. Goldberg, M. Grootveld, E. Lynch, Undesirable and adverse effects of tooth-whitening products: a review, *Clin. Oral Investig.* 14 (2010) 1–10, <https://doi.org/10.1007/s00784-009-0302-4>.
- [6] T.M. Ausschill, E. Hellwig, S. Schmidale, A. Sculean, N.B. Arweiler, Efficacy, side-effects and patients' acceptance of different bleaching techniques (OTC, in-office, at-home), *Oper. Dent.* 30 (n.d.) 156–163. <http://www.ncbi.nlm.nih.gov/pubmed/15853099> (Accessed 12 December 2018).
- [7] M.E. Bittencourt, M.S. Trentin, M.S.S. Linden, Y.B. de Oliveira Lima Arsat, F.M.G. França, F.M. Flório, R.T. Basting, Influence of in situ postbleaching times on shear bond strength of resin-based composite restorations, *J. Am. Dent. Assoc.* 141 (2010) 300–306 (Accessed 12 December 2018), <http://www.ncbi.nlm.nih.gov/pubmed/20194386>.
- [8] T. Attin, C. Hannig, A. Wiegand, R. Attin, Effect of bleaching on restorative materials and restorations—a systematic review, *Dent. Mater.* 20 (2004) 852–861, <https://doi.org/10.1016/j.dental.2004.04.002>.
- [9] S. Gurgan, T. Alpaslan, A. Kiremitci, F.Y. Cakir, E. Yazıcı, J. Gorucu, Effect of different adhesive systems and laser treatment on the shear bond strength of bleached enamel, *J. Dent.* 37 (2009) 527–534, <https://doi.org/10.1016/j.jdent.2009.03.012>.
- [10] A.Y. Gungor, E. Ozcan, H. Alkis, H. Turkkahraman, Effects of sodium ascorbate and delayed bonding after bleaching on shear bond strengths of orthodontic brackets, *J. Adhes. Sci. Technol.* 31 (2017) 958–964, <https://doi.org/10.1080/01694243.2016.1238121>.
- [11] B. Khosravanifard, V. Rakhshan, S. Araghi, H. Parhiz, Effect of Ascorbic Acid on Shear Bond Strength of Orthodontic Brackets Bonded with Resin-modified Glass-ionomer Cement to Bleached Teeth, *J. Dent. Res. Dent. Clin. Dent. Prospects* 6 (2012) 59–64, <https://doi.org/10.5681/joddd.2012.013>.
- [12] S. Kimyal, H. Valizadeh, Comparison of the effect of hydrogel and a solution of sodium ascorbate on dentin-composite bond strength after bleaching, *J. Contemp. Dent. Pract.* 9 (2008) 105–112, <https://doi.org/10.2341/05-85>.
- [13] C. Türkmen, N. Gülleryüz, P. Atalı, Effect of sodium ascorbate and delayed treatment on the shear bond strength of composite resin to enamel following bleaching, *Niger. J. Clin. Pract.* 19 (2016) 91, <https://doi.org/10.4103/1119-3077.164328>.
- [14] J.H. Montalvan, Vaidyanathan E, T.K. Shey, Janal Z, M.N. Caceda, The shear bond strength of acetone and ethanol-based bonding agents to bleached teeth, *Pediatr. Dent.* 28 (2006) 531–536 (Accessed 12 December 2018), <https://www.ingentaconnect.com/content/aapd/pd/2006/0000028/0000006/art00009>.
- [15] F.D. Oz, Z.B. Kutuk, Effect of various bleaching treatments on shear bond strength of different universal adhesives and application modes, *Restor. Dent. Endod.* 43 (2018), <https://doi.org/10.5395/rde.2018.43.e20>.
- [16] S. Sharma, P. Tandon, A. Nagar, G.P. Singh, A. Singh, V.K. Chugh, A comparison of shear bond strength of orthodontic brackets bonded with four different orthodontic adhesives, *J. Orthod. Sci.* 3 (2014) 29–33, <https://doi.org/10.4103/2278-0203.132892>.
- [17] A. Gupta, P. Tavane, P.K. Gupta, B. Tejolatha, A.A. Lakhani, R. Tiwari, S. Kashyap, G. Garg, Evaluation of Microleakage with total etch, self etch and universal adhesive systems in class V restorations: an in vitro study, *J. Clin. Diagn. Res.* 11 (2017), <https://doi.org/10.7860/JCDR/2017/24907.9680> ZC53-ZC56.
- [18] F. Vohra, A. Alghamdi, M. Aldakkan, S. Alharthi, O. Alturaigi, M. Alrabiah, K.A. Al-Aali, A. Alrahlah, M. Naseem, T. Abduljabbar, Influence of Er: Cr: YSGG laser on adhesive strength and microleakage of dentin bonded to resin composite. In-vitro study, *Photodiagn. Photodyn. Ther.* 23 (2018), <https://doi.org/10.1016/j.pdpdt.2018.08.002>.
- [19] F. Alkudhairy, M. Naseem, M. Bin-Shuwaish, F. Vohra, Efficacy of Er Cr: YSGG laser therapy at different frequency and power levels on bond integrity of composite to bleached enamel, *Photodiagn. Photodyn. Ther.* 22 (2018), <https://doi.org/10.1016/j.pdpdt.2018.02.019>.
- [20] G.A. Gholami, R. Fekrazad, A. Esmail-Nejad, K.A. Kalhori, An evaluation of the occluding effects of Er,Cr:YSGG, Nd:YAG, CO<sub>2</sub> and diode lasers on dentinal tubules: a scanning Electron microscope *in vitro* study, *Photomed. Laser Surg.* 29 (2011) 115–121, <https://doi.org/10.1089/pho.2009.2628>.
- [21] A. Husein, Applications of Lasers in Dentistry: A Review, (2006) <http://cite-seerx.ist.psu.edu/viewdoc/download?doi=10.1.1.598.3857&rep=rep1&type=pdf> (Accessed 13 December 2018).
- [22] Edos S. Leonetti, J.A. Rodrigues, A.F. Reis, R.S. Navarro, A.C.C. Aranha, A. Cassoni, Microtensile bond strength of resin composite to dentin treated with Er:YAG laser of bleached teeth, *Lasers Med. Sci.* 27 (2012) 31–38, <https://doi.org/10.1007/s10103-010-0838-1>.
- [23] A.S. Al-Qahtani, S.A. AlZain, E.M. AlHamdan, H.I. Tulbah, H.M. Al Alsheikh, M. Naseem, F. Vohra, A comparative evaluation of the effect of phototherapy of fiber post on its bond strength to dental composite, *Photodiagn. Photodyn. Ther.* 24 (2018), <https://doi.org/10.1016/j.pdpdt.2018.08.016>.
- [24] H.G. Yilmaz, S. Kurtulmus-Yilmaz, E. Cengiz, H. Bayindir, Y. Aykac, Clinical evaluation of Er,Cr:YSGG and GaAlAs laser therapy for treating dentine hypersensitivity: a randomized controlled clinical trial, *J. Dent.* 39 (2011) 249–254, <https://doi.org/10.1016/j.jdent.2011.01.003>.
- [25] M. Türkün, L.S. Türkün, E.U. Celik, M. Ateş, Bactericidal effect of Er,Cr:YSGG laser on *Streptococcus mutans*, *Dent. Mater.* J. 25 (2006) 81–86, <https://doi.org/10.4012/dmj.25.81>.
- [26] E.M. Rhim, S. Huh, D.S. Kim, S. Kim, Effect of the Er, Cr : YSGG laser parameters on shear bond strength and microstructure on human dentin surface, *Intechopen. Com.* (2008) (Accessed 1 December 2018), <https://www.intechopen.com/download/pdf/22930>.
- [27] J.-C. Chou, C.-C. Chen, S.-J. Ding, Effect of Er,Cr:YSGG laser parameters on shear bond strength and microstructure of dentine, *Photomed. Laser Surg.* 27 (2009) 481–486, <https://doi.org/10.1089/pho.2008.2282>.
- [28] M. Kerim Ayar, The durability of adhesion to Er,Cr:YSGG laser-irradiated enamel, *Laser Ther.* 27 (2018) 124–130, <https://doi.org/10.5978/islsm.18-OR-12>.
- [29] C.R.G. Torres, T.M.F. Caneppele, R. Del Moral de Lazari, C.F. Ribeiro, A.B. Borges, Effect of dental surface treatment with Nd:YAG and Er:YAG lasers on bond strength of resin composite to recently bleached enamel, *Lasers Med. Sci.* 27 (2012) 755–760, <https://doi.org/10.1007/s10103-011-0946-6>.
- [30] Edos S. Leonetti, J.A. Rodrigues, A.F. Reis, R.S. Navarro, A.C.C. Aranha, A. Cassoni, Microtensile bond strength of resin composite to dentin treated with Er:YAG laser of bleached teeth, *Lasers Med. Sci.* 27 (2012) 31–38, <https://doi.org/10.1007/s10103-010-0838-1>.
- [31] K. Sirisha, T. Rambabu, Y. Ravishankar, P. Ravikumar, Validity of bond strength tests: a critical review-Part II, *J. Conserv. Dent.* 17 (2014) 420–426, <https://doi.org/10.4103/0972-0707.139823>.
- [32] M.F. Ayad, S.F. Rosenstiel, M.M. Hassan, Surface roughness of dentin after tooth

- preparation with different rotary instrumentation, *J. Prosthet. Dent.* 75 (1996) 122–128.
- [33] G. Jain, A. Narad, L.C. Boruah, B. Rajkumar, Comparative evaluation of shear bond strength of three resin based dual-cure core build-up materials: an in-vitro study, *J. Conserv. Dent.* 18 (2015) 337–341, <https://doi.org/10.4103/0972-0707.159754>.
- [34] A. Yagci, T. Uysal, M. Ulker, S.I. Ramoglu, Microleakage under orthodontic brackets bonded with the custom base indirect bonding technique, *Eur. J. Orthod.* 32 (2010) 259–263, <https://doi.org/10.1093/ejo/cjp090>.
- [35] R. Atash, A. Fneiche, S. Cetik, B. Bahrani, A. Balon-Perin, M. Orellana, R. Glineur, In vitro evaluation of microleakage under orthodontic brackets bonded with different adhesive systems, *Eur. J. Dent.* 11 (2017) 180–185, [https://doi.org/10.4103/ejd.ejd\\_312\\_16](https://doi.org/10.4103/ejd.ejd_312_16).
- [36] F. Alkudhairy, A. AlKheraif, M. Bin-Shuwaish, S. Al-Johany, M. Naseem, Fahim Vohra, Effect of Er,Cr:YSGG laser and ascorbic acid on the bond strength and microleakage of bleached enamel surface, *Photomed. Laser Surg.* XX (2018) 1–8, <https://doi.org/10.1089/pho.2018.4437>.
- [37] M. Hossain, Y. Yamada, Y. Murakami, Y. Tamaki, K. Matsumoto, Y. Nakamura, A study on surface roughness and microleakage test in cavities prepared by Er:YAG laser irradiation and etched bur cavities, *Lasers Med. Sci.* 18 (2003) 25–31, <https://doi.org/10.1007/s10103-002-0235-5>.
- [38] K.L. Van Landuyt, P. Kanumilli, J. De Munck, M. Peumans, P. Lambrechts, B. Van Meerbeek, Bond strength of a mild self-etch adhesive with and without prior acid-etching, *J. Dent.* 34 (2006) 77–85, <https://doi.org/10.1016/j.jdent.2005.04.001>.