

## Original Article

# Optimal enamel conditioning strategy for rebonding orthodontic brackets: a laboratory study

Qi-Feng Zhang, Hua Yao, Zhi-Yong Li, Li Jin, Hui-Ming Wang

Department of Stomatology, The First Affiliated Hospital of Medical College, Zhejiang University, Hangzhou, Zhejiang, China

Received July 16, 2014; Accepted August 16, 2014; Epub September 15, 2014; Published September 30, 2014

**Abstract:** Objective: To compare the conventional etching and primer method (CEP) and the self-etching primer method (SEP) in rebonding brackets. Methods: Forty human maxillary second premolars extracted for orthodontic purpose were randomly divided into 4 equal groups. Group 1 and Group 2 were bonded using the CEP method; Group 3 and Group 4 using the SEP method. All the brackets were debonded and 40 new brackets were rebonded with four different protocols after surface cleaning: Group 1: CEP + adhesive; Group 2: CEP without etch step + adhesive; Group 3: SEP + adhesive; Group 4: non-acidic primer + adhesive. Then, the shear bond strength (SBS) of each group was tested and the measurements of adhesive remnant index scores (ARI) and SEM examination were performed. Results: The mean SBSs for Group 1, 2, 3 and 4 were 14.18, 6.57, 11.90, 5.91 MPa, respectively. Statistical differences of the SBS existed between Group 1 and 2 ( $P < 0.05$ ) and between Group 3 and 4 ( $P < 0.05$ ). No difference was found between Group 1 and 3, or Group 2 and 4. Conclusion: Omission of the acid-etching step in rebonding orthodontic brackets may be adequate for the clinical requirement. No differences in SBS and ARI of the rebonded brackets were showed between CEP and SEP methods.

**Keywords:** Orthodontics, dental bonding, acid-etching, bond strength

## Introduction

Bond failure of brackets is common and undesirable during orthodontic treatment. Mostly, new brackets are rebonded using the same protocol as the first bonding. However, etching from the first bonding has induced enamel alteration and etching during second bonding (rebonding) may induce further enamel loss. Montasser et al. found that shallow depressions and pits from etching were still presented on the enamel surface after debonding and removal of all visible adhesive. Until now, most published data were just focused on the effect of acid etching on the first bonding of brackets, with only a few studies on the rebonding of brackets using different adhesive systems [1, 2], or on the optimal procedure for rebonding brackets [3].

Conditioning enamel surface with acid and subsequently applying primer are the traditional method of direct bonding of orthodontic attachments [4]. This method may result in side-effects such as excessive enamel loss by inevi-

table over-range etching [5] and acid-etching-induced enamel surface vulnerable alterations [6-8].

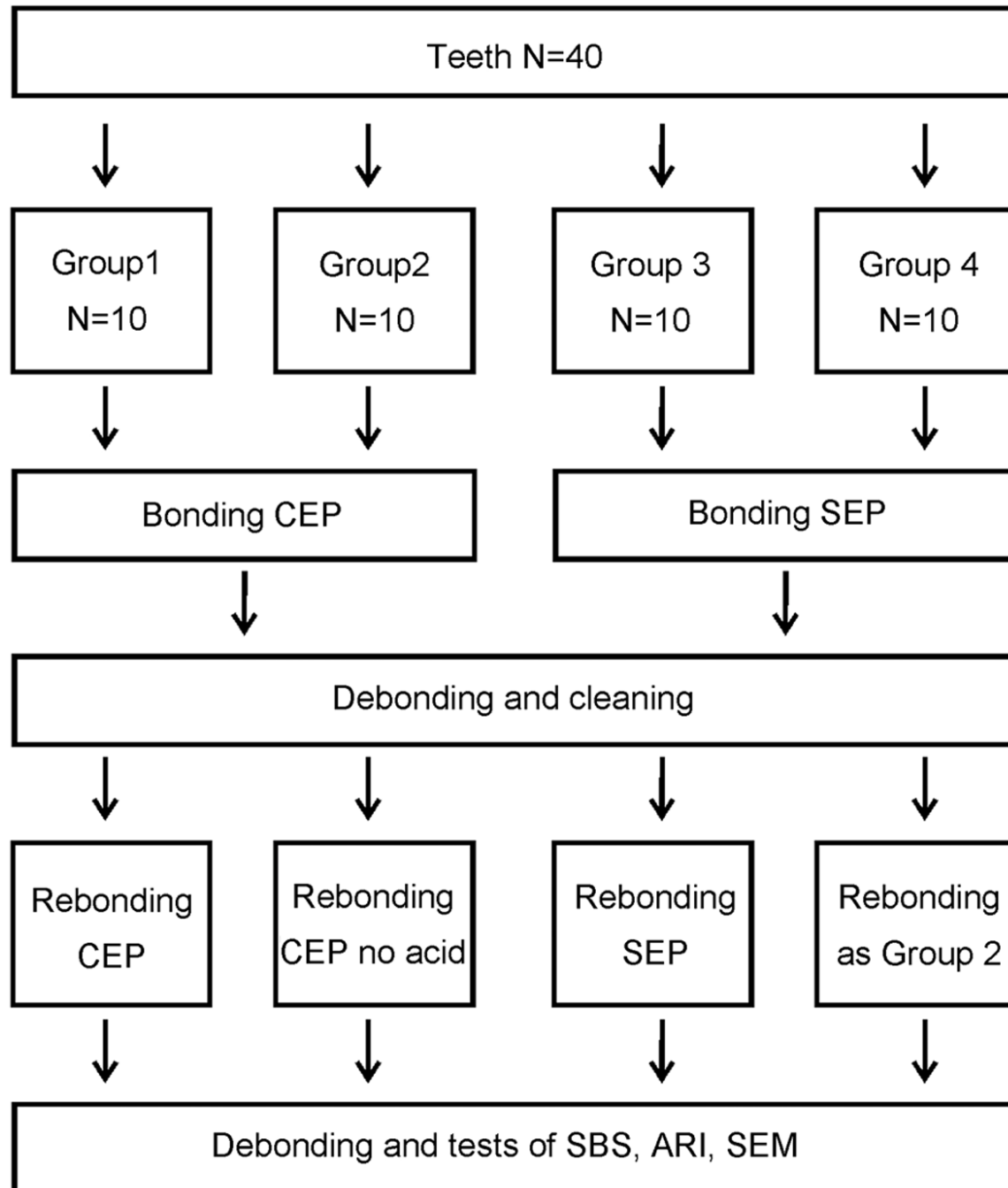
Two main methods are used for direct bonding of brackets: the conventional two-stage etching and primer method (CEP) and the self-etching primer method (SEP) [9, 10]. Differences between these two methods in the first bonding of brackets have been studied comprehensively [11, 12]. However, no study has addressed the application of these methods on rebonding brackets.

The aim of the present study was to study whether an acid etching step is necessary for rebonding orthodontic brackets, and to compare the results of brackets rebonding with the CEP and the SEP methods.

## Materials and methods

### Teeth

40 human maxillary second premolars freshly extracted for orthodontic reasons were used.



**Figure 1.** Protocols of enamel conditioning for first bonding and rebonding.

These teeth were stored in an aqueous solution of thymol (0.1% weight/volume). Informed consent was obtained from each patient. The use of extracted human teeth has been approved by the ethical committee of Sichuan University. The root of each tooth was mounted to a block of self-curing acrylic, with the long axis vertical.

Every tooth was given a unique number, and randomly divided into four equal groups.

#### *Brackets*

80 stainless steel Gemini MBT brackets (0.022 × 0.028 slot) for maxillary second premolar

## Enamel conditioning strategy in rebonding brackets

**Table 1.** Mean shear bond strengths, standard deviations (SD), and maximum (Max) and minimum (Min) values for each group (n = 10)

Group	Mean	SD	Max	Min
1	14.18	2.59	23.34	9.05
2	6.57	2.58	11.65	2.98
3	11.90	2.70	18.02	8.89
4	5.91	2.73	13.04	3.71

**Table 2.** Frequency distribution of the Adhesive Remnant Index (ARI)

Group	ARI Score				Total Ari Score
	0	1	2	3	
1	3	3	1	3	10
2	10	0	0	0	10
3	2	7	1	0	10
4	10	0	0	0	10

Notes: ARI scores: 0 = no composite left on enamel surface; 1 = less than 50% of composite left; 2 = more than 50% composite left; and 3 = more than 90% composite left. Significant difference existed only between group 1 and 2 ( $P < 0.01$ ).

were used (3M Unitek, Monrovia, Calif.). The bracket base area was 9.08 mm<sup>2</sup>.

### Bonding systems

CEP system: acid (3M™ ESPE™ Etchants); non-acidic primer (Transbond XT Primer); adhesive resin (Transbond XT Light Cure Adhesive Paste). SEP system: acidic primer (Transbond Plus Self Etching Primer); adhesive resin (Transbond XT Light Cure Adhesive Paste). All the materials mentioned above were from 3M Unitek (Monrovia, Calif.).

### Methods

All bonding, rebonding and the following procedures were performed by the same operator.

#### First bonding

Group 1 and Group 2: 20 teeth were bonded with CEP method according to the manufacture's instruction. Briefly, the enamel surface was etched with 37% phosphoric acid for 30 seconds, rinsed and primed with non-acidic primer, then adhesive resin was applied and polymerized for a total of 20 seconds, using a visible light-curing unit (3M Unitek Ortholux™ LED Curing Light) with an output power of 600 mW/cm<sup>2</sup>.

Group 3 and Group 4: 20 teeth were bonded with the SEP method. The enamel was etched and primed with acidic primer, and then the adhesive resin was performed. Two minutes after bonding, the specimens were stored in deionized water (37°C) for 24 hours, with each group in a separate container prior to the following step.

#### Debonding and cleaning

The 40 brackets were debonded by a universal testing machine with a standard protocol. All visible residual adhesive was carefully removed using low speed hand-piece with a tungsten bur under light pressure and adequate air cooling without water spray [13]. Composite removal was considered complete when the tooth surface appeared smooth and free of composite to the naked eye under an operatory lamp.

#### Rebonding

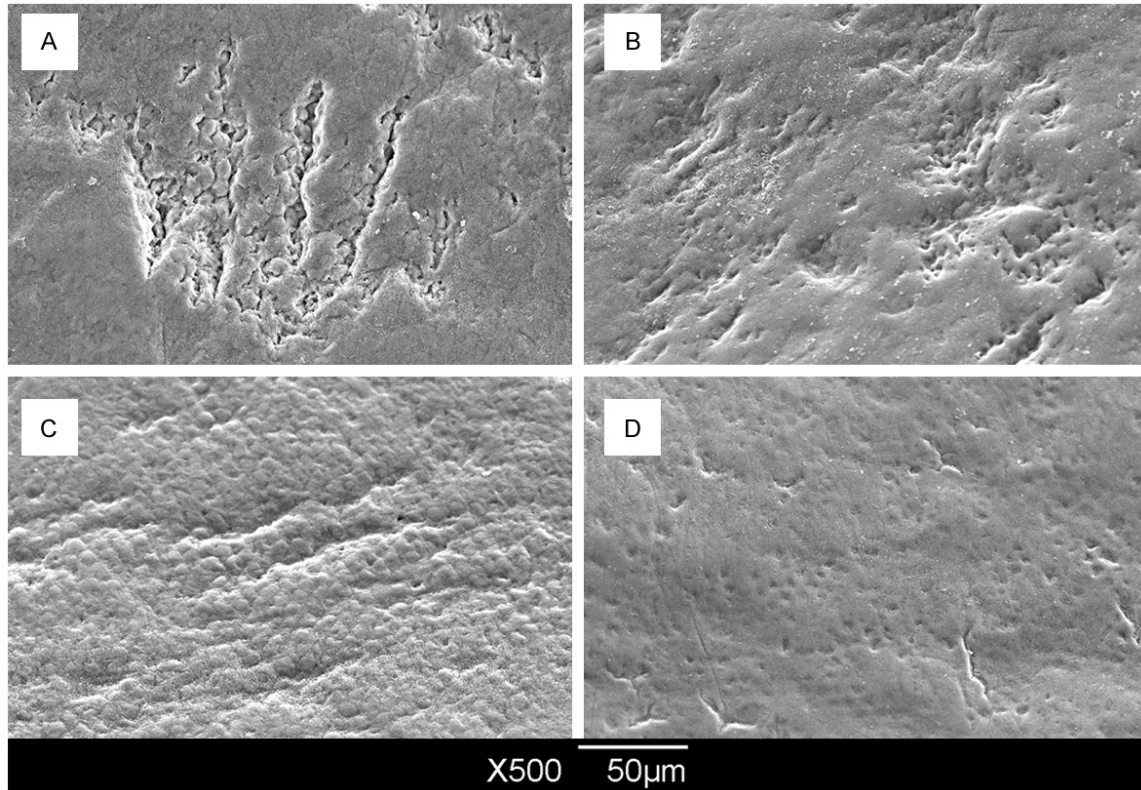
40 brand new brackets were used, and the teeth were subjected to one of four rebonding methods shown in **Figure 1**. Group 1: 37% o-phosphoric acid + non-acidic primer + adhesive;

Group 2: non-acidic primer + adhesive; Group 3: self-etch acidic primer + adhesive; Group 4: non-acidic primer + adhesive. All the rebonded specimens were then immersed in deionized water, with each group in a separate container, and were placed in a humidior at 37°C for 24 hours prior to SBS test.

#### Data collection

**Shear bond strength:** The shear test was performed with the universal mechanical testing machine (Shimadzu Autograph AGS-J-Serie, 10 kND; Japan) at a feed rate of 1.0 mm/minute with an occlusal-lingival load applied to the bracket, producing a shear force at the bracket tooth interface. Deformation of the bracket wings when shearing off was avoided by placing square steel wire in the bracket slot. Shear power was registered in Newtons (N) and recorded as force/surface in Megapascals (MPa) [14, 15].

**Residual adhesive:** The enamel surfaces were examined with a stereomicroscope at a magnification of 10X to determine the amount of composite resin remaining according to the



**Figure 2.** SEM photomicrographs of the enamel surfaces (Original magnification  $\times 500$ ). (A) Group 1, (B) Group 3, (C) Group 2, (D) Group 4.

adhesive remnant index (ARI), immediately after shear bond strength of debonding was tested.

*Scanning electron microscope examination:* One sample with no remnant was randomly picked up from each group. The crowns of the four subjects were sectioned mesio-distally with a diamond separating disc, leaving only a thin layer of the underlying dentin, polished with pumice and rubber prophylactic cups for 10 seconds and cleaned in distilled water with ultrasonic agitation for 30 minutes and gently air dried. They were affixed to SEM stubs, coated with gold, and examined on Jeol JSM-5900 LV SEM (Tokyo, Japan) operating at 20 kV.

## Statistical analysis

Descriptive statistics, including the mean, standard deviation, maximum and minimum SBS values were calculated for each group. The two-sample t-test was used to determine the differences in SBS between the groups. Monte Carlo exact test was used to determine the differences in ARI scores between the groups.

Difference was considered significant when  $P \leq 0.05$ .

## **Results**

### *Shear bond strength*

Descriptive statistics for the four groups are presented in **Table 1**. The mean SBS values of Group 1, Group 2, Group 3 and Group 4 are  $14.18 \pm 2.59$ ,  $6.57 \pm 2.58$ ,  $11.90 \pm 2.70$ ,  $5.91 \pm 2.73$  Mpa, respectively. The mean SBS values were significantly different between Group 1 and 2 ( $P < 0.01$ ), and Group 3 and 4 ( $P < 0.01$ ). No difference existed between Group 1 and 3, Group 2 and 4 ( $P > 0.05$ ). Significant difference existed in ARI score between Group 1 and 2 ( $P < 0.05$ ), and no difference existed between Group 1 and 3, Group 2 and 4 or Group 3 and 4 ( $P > 0.05$ ) (**Table 2**).

### *SEM examination*

The obvious differences in size and depth of the anomalies on enamel surface were showed in **Figure 2**. Group 1 (**Figure 2A**) and 3 (**Figure**



**2B)** showed deep and numerous gouges and pits. However, the grooves in the Group 1 (CEP method) were deeper than that in the Group 3 (SEP method). Group 2 (**Figure 2C**) and 4 (**Figure 2D**) showed typical shallow and less arcades and pits representing the still present etching-effect.

### Discussion

The optimal orthodontic bond strength should be sufficient to retain the brackets for the desirable treatment duration, but low enough to allow easy cleanup of adhesives when the brackets are removed. Greater shear bond strengths may help to alleviate unwanted bond failure of brackets during orthodontic treatment, but the risk of enamel fracture and patient discomfort may arise when the brackets are removed. Clinically adequate bond strengths for metal brackets to enamel were suggested between 5.9 to 8 MPa [16, 17]. 9.7 MPa was proposed as the lowest bond strength which led to enamel fracture upon debonding [18]. At loads of 9-11 MPa, enamel fracture was observed [7, 19].

Based on the presented data, the first null hypothesis was rejected. Omission of enamel etching procedure when rebonding a bracket significantly reduced the bonding strength. Yet the mean SBS values of the two groups without acid etching fell within the optimal range of clinical need. More importantly, they were lower than the value of enamel fracture. Therefore such reduction may be beneficial for clinical practice. On the contrast, acid etching in rebonding produced excessive bond strength, which may lead to enamel fracture.

There were two possible mechanisms for the adequate bond strength of the two non-acid etched groups during brackets rebonding. Firstly, the enamel "hybrid" zone (resin penetrated enamel) may have been completely removed after the cleanup procedure. Thus, the mechanically retentive force is mainly from the scarring of enamel surface. This is in agreement with the previous works, which reported that the depth of penetration of the resin tags reached up to 50  $\mu\text{m}$  [20, 21]. The cleanup procedure of the adhesive after debonding may remove 55.6  $\mu\text{m}$  of surface enamel. Therefore, no resin tags would be left after debonding and cleanup [5]. Secondly, after debonding and

cleanup, the residual enamel was still infiltrated with resin, which is consistent with Diedrich's study [7] that the resin tags generally reached a depth of 80  $\mu\text{m}$ , and sometimes extended to 100 to 170  $\mu\text{m}$  in length. Sandison also stated that it was highly possible that tags of composite still remained in most cases following debonding, although, the tooth surface might look very clean clinically [22]. Thus, the substrate is susceptible for copolymerization. Besides this, the cleanup procedure removed a shallow layer of outer enamel, therefore, in the elimination of plaque, pellicle and other surface debris, a more active surface area is available for chemical bonding [6]. As a result, for Groups 2 and 4, the adequate retentive force may come from both chemical and mechanical interaction with the enamel surface. These hypotheses need to be tested further, which is beyond the scope of the present study.

Of primary concern to the clinician is the maintenance of a sound, unblemished enamel surface after bracket removal. In the present study, the ARI scores for Groups 2 and 4 were both 0. This indicated less damage to the enamel surface after rebonding without acid etching. Moreover the neglectable adhesive remnant after debonding would save the time for tooth surface cleaning. Furthermore, the results of ARI scores indicated that brackets rebonded with conventional two-stage etch and prime system (Group 1) and the self-etching primer system (Group 3) showed a similar mode of bond failure. To summarize, our results supported the second hypothesis that no difference in SBS and ARI existed between the CEP and SEP methods in rebonding brackets. Interestingly, it seems that the enamel conditioning methods used for the first bonding had no effect on the rebonding.

The result of SEM examination was in accordance with the phenomenon mentioned above. Omission of the acid-etch step in rebonding protected the enamel from excessive decalcification. The enamel treated with CEP method caused more enamel damage than the one treated with the SEP method, which was in line with the previous studies that the self-etching adhesive system minimized the amount of the enamel loss [23, 24].

Subjects with the ARI values of 0 were selected for SEM tests, because this excluded the enam-

el alteration caused by adhesive-removing procedure. Furthermore, pumicing procedure only removed surface stains but did not produce damage or extensive roughening of the underlying tooth structure. So the different appearance of the enamel reflected the change resulting from etching.

Still, further work is required to assess if the performance of the bracket rebonded without acid-etching system evaluated in this laboratory study is mirrored in the clinical environment. In the present study, the SBS was tested 24 hours after rebonding, which period does not completely reflect clinical orthodontic practice [25, 26]. To simulate clinical situations, the bond strengths of rebonded brackets needs to be measured at more time points in future studies [26-28].

## Conclusion

This study showed that: 1) Irrespective of the enamel etching or priming method for the first bonding of brackets, omitting the acid-etch step in rebonding can achieve adequate and reasonable SBS levels for clinical use; 2) No differences existed in SBS, ARI of rebonded brackets between enamel treated with the CEP or SEP method. However, more enamel damage occurred with CEP method.

## Acknowledgements

This research was funded by Specialized Research Fund for the Doctoral Program of Higher Education (No. 20100101120114), National Natural Science Foundation of China (No. 81101660) and Zhejiang Provincial Natural Science Foundation of China (L14H14001).

## Disclosure of conflict of interest

None.

**Address correspondence to:** Qi-Feng Zhang, Department of Stomatology, The First Affiliated Hospital of The Medical College, Zhejiang University, No. 78 Qingchun Road, Hangzhou 310003, Zhejiang, China. E-mail: zhangqifeng\_doc@163.com

## References

- [1] Montasser MA, Drummond JL, Roth JR, Al-Turki L and Evans CA. Rebonding of orthodontic brackets. Part II, an XPS and SEM study. *Angle Orthod* 2008; 78: 537-544.

- [2] Montasser MA, Drummond JL and Evans CA. Rebonding of orthodontic brackets. Part I, a laboratory and clinical study. *Angle Orthod* 2008; 78: 531-536.
- [3] Mui B, Rossouw PE and Kulkarni GV. Optimization of a procedure for rebonding dislodged orthodontic brackets. *Angle Orthod* 1999; 69: 276-281.
- [4] Newman GV. Adhesion and orthodontic plastic attachments. *Am J Orthod* 1969; 56: 573-588.
- [5] Fitzpatrick DA and Way DC. The effects of wear, acid etching, and bond removal on human enamel. *Am J Orthod* 1977; 72: 671-681.
- [6] Silverstone LM. Fissure sealants. Laboratory studies. *Caries Res* 1974; 8: 2-26.
- [7] Diedrich P. Enamel alterations from bracket bonding and debonding: a study with the scanning electron microscope. *Am J Orthod* 1981; 79: 500-522.
- [8] Ogaard B. Oral microbiological changes, long-term enamel alterations due to decalcification, and caries prophylactic aspects. In: Brantley WA, Eliades T, editors. *Orthodontic Materials: Scientific and Clinical Aspects*. Stuttgart, Thieme. Stuttgart: Thieme; 2001. pp. 124-139.
- [9] Nishida K, Yamauchi J, Wada T and Hosoda H. Development of a new bonding system. *J Dent Res* 1993; 72: 137.
- [10] Dominguez GC, Tortamano A, Lopes LV, Catharino PC and Morea C. A comparative clinical study of the failure rate of orthodontic brackets bonded with two adhesive systems: conventional and self-etching primer (SEP). *Dental Press J Orthod* 2013; 18: 55-60.
- [11] Aljubouri YD, Millett DT and Gilmour WH. Laboratory evaluation of a self-etching primer for orthodontic bonding. *Eur J Orthod* 2003; 25: 411-415.
- [12] Aljubouri YD, Millett DT and Gilmour WH. Six and 12 months' evaluation of a self-etching primer versus two-stage etch and prime for orthodontic bonding: a randomized clinical trial. *Eur J Orthod* 2004; 26: 565-571.
- [13] Hong YH and Lew KK. Quantitative and qualitative assessment of enamel surface following five composite removal methods after bracket debonding. *Eur J Orthod* 1995; 17: 121-128.
- [14] Wendl B and Droschl H. A comparative in vitro study of the strength of directly bonded brackets using different curing techniques. *Eur J Orthod* 2004; 26: 535-544.
- [15] Yassaei S, Fekrazad R, Shahraki N and Goldani Moghadam M. A Comparison of Shear Bond Strengths of Metal and Ceramic Brackets using Conventional Acid Etching Technique and Er:YAG Laser Etching. *J Dent Res Dent Clin Dent Prospects* 2014; 8: 27-34.
- [16] Powers JM, Messersmith ML, among Teeth D, Primers A, Abrasion A and Primers MR. Enamel

## Enamel conditioning strategy in rebonding brackets

- Etching and Bond Strength. In: Brantley WA, Eliades T, editors. *Orthodontic materials: scientific and clinical aspects*. Stuttgart: Thieme; 2001. pp. 107-121.
- [17] Reynolds IR. A review of direct orthodontic bonding. *Br J Orthodont* 1975; 2: 171-178.
  - [18] Retief DH. Failure at the dental adhesive-etched enamel interface. *J Oral Rehabil* 1974; 1: 265-284.
  - [19] Chun K, Choi H and Lee J. Comparison of mechanical property and role between enamel and dentin in the human teeth. *J Dent Biomech* 2014; 5: 1758736014520809.
  - [20] Asmussen E. Penetration of restorative resins into acid etched enamel. I. Viscosity, surface tension and contact angle of restorative resin monomers. *Acta Odontol Scand* 1977; 35: 175-182.
  - [21] Buonocore MG, Matsui A and Gwinnett AJ. Penetration of resin dental materials into enamel surfaces with reference to bonding. *Arch Oral Biol* 1968; 13: 61-70.
  - [22] Sandison RM. Tooth surface appearance after debonding. *Br J Orthod* 1981; 8: 199-201.
  - [23] Øgaard B, Bishara SE and Duschner H. Enamel effects during bonding-debonding and treatment with fixed appliances. In: Graber TM, Eliades T, Athanasiou AE, editors. *Risk Management in Orthodontics: Experts Guide to Malpractice*. Hanover Park, IL, Quintessence Publishing. Chicago: Quintessence; 2004. pp. 19-46.
  - [24] Hosein I, Sherriff M and Ireland AJ. Enamel loss during bonding, debonding, and cleanup with use of a self-etching primer. *Am J Orthod Dentofacial Orthop* 2004; 126: 717-724.
  - [25] Bishara SE, VonWald L, Laffoon JF and Warren JJ. Effect of a self-etch primer/adhesive on the shear bond strength of orthodontic brackets. *Am J Orthod Dentofacial Orthop* 2001; 119: 621-624.
  - [26] Mitchell CA, O'Hagan E and Walker JM. Probability of failure of orthodontic brackets bonded with different cementing agents. *Dent Mater* 1995; 11: 317-322.
  - [27] Rock WP and Abdullah MS. Shear bond strengths produced by composite and compomer light cured orthodontic adhesives. *J Dent* 1997; 25: 243-249.
  - [28] Klocke A, Shi J, Vaziri F, Kahl-Nieke B and Bismayer U. Effect of time on bond strength in indirect bonding. *Angle Orthod* 2004; 74: 245-250.