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Bond strengths of eight contemporary adhesives to enamel and to dentine: an *in vitro* study on bovine primary teeth

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Summary. *Objectives.* The aim of this study was to compare the shear and tensile bond strengths of eight adhesive systems to the enamel and dentine of primary bovine teeth.
Methods. Two hundred and fifty-six noncarious bovine mandibular primary incisors were collected and stored in an aqueous 1% chloramine solution at room temperature for no longer than 3 months after extraction. The tested adhesives were: Clearfil SE bond (SE); Adper Prompt L Pop (LP); Optibond Solo Plus Self-etch (OB); AdheSE (AS); Xeno III (XE); Scotch Bond 1 (SB); Etch & Prime 3·0 (EP); and I Bond (IB). For the shear bonding test and the tensile bonding test, the labial surfaces of primary incisors were used. To obtain a flat surface, the labial surfaces of the teeth were sanded on wet silicon carbide paper, first with number 200 grit for 20 s and then with number 600 grit for 60 s ($n = 128$; 64 for shear bonding and 64 for tensile bonding). The results were compared with an analysis of variance and Bonferroni's multiple comparison test.
Results. Shear bond strength values ranged from 18·1 to 8·9 MPa on enamel (in decreasing order, SE, LP, OB, AS, XE, SB, EP and IB), and from 17·8 to 8·2 MPa on dentine (in decreasing order, SE, SB, OB, AS, XE, LP, IB and EP). Tensile bond strength values ranged from 13·1 to 6·7 MPa on enamel (in decreasing order, SE, OB, AS, LP, XE, IB, SB and EP), and from 12·1 to 5·7 MPa on dentine (in deceasing order, SE, SB, OB, AS, XE, LP, IB and EP). The differences in bond strengths between the eight systems on enamel and dentine were all statistically significant. This was true for both the shear and tensile bond strengths.
Conclusions. The highest shear bond strength was achieved by SE on enamel and dentine, and the lowest by IB on enamel and EP on dentine. The highest tensile bond strength was obtained by SE on enamel and dentine, and the lowest by EP. Shear bond strengths were significantly higher on enamel when compared to dentine for five of the eight adhesives systems, and tensile bond strengths were significantly higher on enamel when compared to dentine for all but two systems.

Introduction

The increasing demand for aesthetic dental restorations in paediatric dentistry has led to the development of many systems designed to provide sufficient bonding ability to both enamel and dentine with fewer bonding steps [1,2]. The bonding mechanism is based on the combined effect of hybridization and the formation of resin tags [3,4].

Adhesive systems should be easy to use, not too technique-sensitive, and perform equally well on dentine and enamel [5]. To reduce the technique sensitivity that affects the bonding ability of

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adhesive systems [6,7], the steps required for bonding procedures have been reduced. Thus, self-etching primers were developed to simplify the bonding procedure. They are based on the use of nonrinse, acidic polymerizable monomers which serve as conditioner, primer and bonding resin [8], and form a continuous layer between the resin composite and the tooth surface, which is simultaneously demineralized with acidic monomers followed by bonding agent penetration into the tooth substrate [9].

Despite the amount of research reporting on the bonding efficacy of resin adhesives to permanent teeth, there is little in the literature on the bond strength of adhesive systems to primary teeth [10,11]. Thus, the aim of this study was to compare the shear and tensile bond strength of different self-etching primers, an all-in-one self-etching adhesive and a multistep system on dentine and enamel. Since it is difficult to obtain large numbers of intact extracted human teeth for conducting bond strength tests, especially for studies on primary dental tissues, bovine teeth can be considered as possible substitutes for human teeth in adhesion tests [12,13]. Primary bovine teeth were used in this study. The null hypothesis tested was that simplified application procedures following either a total- or self-etching approach would not affect the shear and tensile bond strength to enamel and dentine of bovine primary teeth.

Materials and methods

Two hundred and fifty-six noncarious bovine mandibular primary incisors were collected and stored at 4 °C in an aqueous 1% chloramine solution for no longer than 3 months after extraction [14–16]. The teeth were randomly divided into two groups (shear bond and tensile bond), each containing 128 teeth. For the shear bonding and tensile bonding tests, the labial surfaces of the primary incisors were used. To obtain a flat enamel, the labial surfaces of the teeth were sanded on wet silicon carbide (SiC) paper, first with number 200 grit for 10 s and then with number 600 grit for 60 s ($n = 128$; 64 for shear bonding and 64 for tensile bonding). To obtain flat dentine surfaces, the labial surfaces were sectioned using a low-speed saw (Leica 1600, Bensheim, Germany), then abraded with 400 and 600 grit wet SiC papers, and placed in slow-curing epoxy resin Epofix (EMS, Fort Washington, PA, USA) with the labial surface positioned for surface treatment and composite bonding ($n = 128$; 64 for shear bonding and 64 for tensile bonding). A polytetrafluoroethylene jig was placed over each specimen to limit and standardize the area available for bonding to 2 mm in diameter [17]. For each type of surface, the specimens were randomly divided into eight adhesive treatment groups of 16 specimens each.

Bonding procedures

Eight commercial adhesive systems were used in this study and applied according to the manufacturers' instructions: Clearfil SE Bond (SE; Kuraray Dental, Osaka, Japan); Adper Prompt L Pop (LP; 3M Dental Products, St Paul, MN, USA); Optibond Solo Plus Self-Etch (OB; Kerr, Glendora CA, USA); AdheSE (AS; Ivocalr, Vivadent Schaan, Liechtenstein); Xeno III (XE; Dentsply, Detrey, Konstanz, Germany); Scotch Bond 1 (SB; 3M Dental Products); Etch & Prime 3·0 (EP; Degussa AG Geschâflsbereich Dental, Hanau, Germany); and I Bond (IB; Heraeus-Kulzer Inc, New York, USA). The composition of the materials is listed in Table 1.

After appropriate surface treatment, a polytetrafluoroethylene mould was used to create an inverted, truncated cone of composite (bonding diameter = 2 mm, height = 4 mm) on all pretreated tooth surfaces. Composite resin Z250 (Filtek™ 3M Dental Products) was placed in the mould in two increments and each increment was light-cured for 40 s with a standard light source (Elipar Highlight, ESPE, Seefeld, Germany). All specimens were stored in water at 37 °C for 48 h before testing [18].

Shear bond strength

For each group, the specimens were embedded in slow-curing epoxy resin Epofix and sheared with a knife-edge blade on a universal testing machine at a cross-head speed of 0·5 mm min^{-1} (the apparatus is shown diagramatically in Fig. 1). The force required to break the resin–tooth bond was recorded in Newtons and bond strengths were expressed in MegaPascals (MPa).

Tensile bond strength

After storage, the specimens were mounted on a loading jig and debonded under tension using a universal testing machine at a cross-head speed of 0·5 mm min^{-1} (apparatus shown in Fig. 2). Peak tensile separation was recorded in Newtons and bond strengths expressed in MegaPascals (MPa).

Table 1. Components and the manufacturers of the materials investigated.

Group	Material	Composition	Manufacturer
SE	Clearfil SE Bond	Primer: MDP, HEMA, hydrophilic dimethacrylate, di-camphorquinone, N-N-diethanol-p-toluidine, water Bond: MDP, HEMA, bis-GMA, hydrophobic dimethacrylate, di-camphorquinone, N-N-diethanol-p-toluidine, silanated colloidal silica	Kuraray Dental, Osaka, Japan 3M Dental Products, St Paul, MN, USA
LP	Adper Prompt L Pop	Liquid 1 (red blister): methacrylate phosphoric esters bis-GMA initiators based on camphorquinone stabilizers Liquid 2 (yellow blisters): water 2-hydroxylethylmethacrylate (HEMA) polyalkenoic acid stabilizers	
OB	Optibond Solo Plus Self-etch	Self-etch primer: glycerophosphatedimethacrylate (GPDM) Adhesive: bis-GMA GDM, HEMA, GPDM, ethanol	Kerr, Glendora, CA, USA
AS	AdheSE	Primer: phosphoric acid acrylate bis-acrylamide water initiators and stabilizers Bond: dimethacrylate hydroxyethylmethacrylate highly dispersed silicon dioxide initiators and stabilizers	Ivoclar, Vivadent Schaan, Liechtenstein
XE	Xeno III	Liquid A: 2-hydroxylethylmethacrylate (HEMA) purified water ethanol butylated hydroxyl toluene (BHT) highly dispersed silicon dioxide Liquid B: phosphoric acid modified methacrylate resins monofluorophosphazene modified polymethacrylate resin urethane dimethacrylate butylated hydroxyl toluene (BHT) camphorquinone ethyl-4-dimethylaminobenzoate	Dentsply, Detrey, Konstanz, Germany
SB	Scotch Bond 1	Etchant: 35% phosphoric acid Primer/adhesive: ethanol diglycidyle oxide dimethacrylate 2-hydroxylethylmethacrylate (HEMA) 2-hydroxy-1,3-propanediyle bismethacrylate 2-propenoic acid purified water	3M Dental Products, St Paul, MN, USA
EP	Etch & Prime3·0	Catalyst: tetra-methacryloxyethyl pyrophosphate 2-hydroxyethylmethacrylate Universal: 2-hydroxyethylmethacrylate ethanol distilled water stabilizer	Degussa AG Geschâflsbereich Dental, Hanau, Germany
IB	I Bond	Acetone/water-based Formulation of light-activated methacrylate resins and glutaraldehyde	Heraeus Kulzer Inc., New York, USA

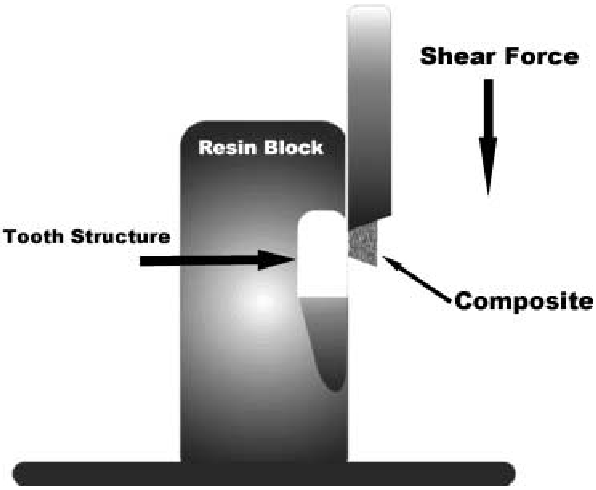

Fig. 1. Diagram of shear test apparatus.

Statistical analysis

For the dentine and enamel groups, all shear and tensile bond strength values were compared with an analysis of variance and Bonferroni's multiple comparison test.

Results

Results for testing of bond strengths are summarised in Figs 3 and 4, and Tables 2–5.

An overall comparison of the distribution of the measures was statistically significant ($P < 0{\cdot}05$). The absolute adhesive strengths decreased in the following order:

1 Shear bond strength on enamel: SE, LP, OB, AS, XE, SB, EP and IB.
2 Tensile bond strength on enamel: SE, OB, AS, LP, XE, IB, SB and EP.
3 Shear bond strength on dentine: SE, SB, OB, AS, XE, LP, IB and EP.
4 Tensile bond strength on dentine: SE, SB, OB, AS, XE, LP, IB and EP.

Bonferroni's multiple comparison test showed significant differences ($P < 0{\cdot}001$) for all pairs except: (for shear bond strengths test on enamel) LP versus AS, LP versus SE, XE versus EP, XE versus SB, IB versus EP, AS versus SB and EP versus SB; (for shear bond strengths test on dentine) XE versus SE, LP versus XE, LP versus IB, IB versus EP, OB versus AS and SE versus SB; (for tensile bond strengths test on enamel) LP versus XE, LP versus IB, LP versus OB, LP versus AS, XE versus IB, XE versus AS, XE versus SB, IB versus SB, OB versus AS and OB versus SE; and (for tensile bond strengths test on dentine) LP versus XE, LP versus IB, LP versus EP, XE versus IB, IB versus EP, OB versus AS and SE versus SB.

Table 2. Shear bond strength of the adhesives on enamel.

Material	Mean ± SD (MPa)
Clearfil SE Bond	18·1 ± 1·1
Adper Prompt L Pop	16·9 ± 0·9
Optibond Plus Self-etch	16·9 ± 1·9
AdheSE	16·2 ± 2·3
Xeno III	12·8 ± 1·3
Scotch Bond 1	11·4 ± 1·5
Etch & Prime 3·0	11·3 ± 1·4
I Bond	8·9 ± 0·7

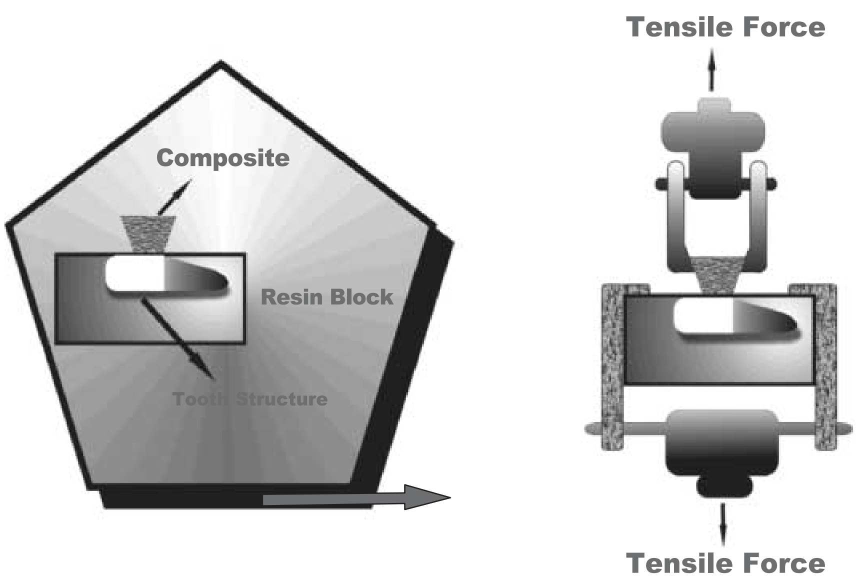

Fig. 2. Diagram of tensile test apparatus.

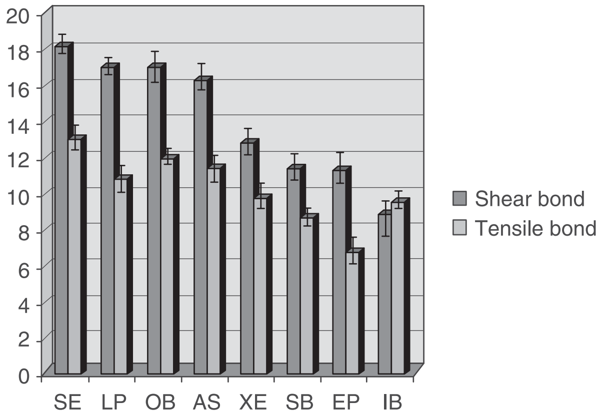

Fig. 3. Shear and tensile bond strengths on bovine enamel: (SE) Clearfil SE bond; (LP) Adper Prompt L Pop; (OB) Optibond Solo Plus Self-etch; (AS) AdheSE; (XE) Xeno III; (SB) Scotch Bond 1; (EP) Etch & Prime 3·0; and (IB) I Bond.

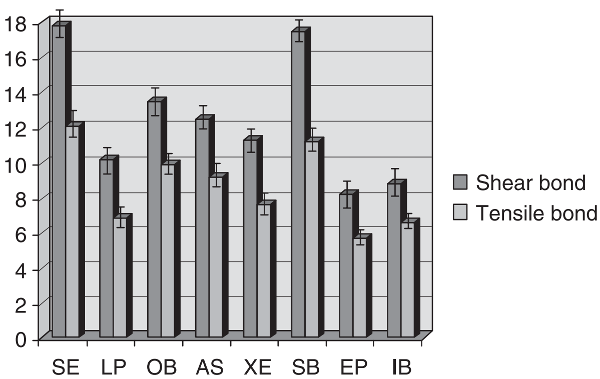

Fig. 4. Shear and tensile bond strengths on bovine dentine. For the key to the abbreviations, see the legend to Fig. 3.

Table 3. Shear bond strength of the adhesives on dentine.

Material	Mean ± SD (MPa)
Clearfil SE Bond	17·8 ± 1·4
Scotch Bond 1	17·5 ± 1·0
Optibond Plus Self-etch	13·5 ± 1·1
AdheSE	12·5 ± 0·9
Xeno III	11·3 ± 0·9
Adper Prompt L Pop	10·2 ± 1·5
I Bond	8·8 ± 1·1
Etch & Prime 3·0	8·2 ± 1·2

Table 4. Tensile bond strength of the adhesives on enamel.

Material	Mean ± SD (MPa)
Clearfil SE Bond	13·1 ± 1·6
Optibond Plus Self-etch	11·9 ± 0·7
AdheSE	11·3 ± 0·9
Adper Prompt L Pop	10·8 ± 0·7
Xeno III	9·7 ± 1·1
I Bond	9·5 ± 0·9
Scotch Bond 1	8·6 ± 0·7
Etch & Prime 3·0	6·7 ± 0·8

Table 5. Tensile bond strength of the adhesives on dentine.

Material	Mean ± SD (MPa)
Clearfil SE Bond	12·1 ± 1·3
Scotch Bond 1	11·2 ± 0·9
Optibond Plus Self-etch	9·9 ± 0·6
AdheSE	9·2 ± 0·8
Xeno III	7·6 ± 0·9
Adper Prompt L Pop	6·9 ± 0·7
I Bond	6·6 ± 0·7
Etch & Prime 3·0	5·7 ± 0·6

Discussion

Bond strength is the force per unit area that is required to break a bonded assembly with failure occurring in or near the adhesive/adherend interface [16,19]. The *in vitro* methods used so far for evaluating adhesives vary from laboratory to laboratory. Therefore, it is often impossible to compare results presented by different researchers or manufacturers directly [19]. The International Organization for Standardization has produced a document, with the intention of standardizing the different procedures in vogue as far as possible [16].

Tensile test

In a tensile test, the bond is broken by a force working at a 90° angle (perpendicular) to the tooth surface [20,21].

Shear test

In a shear test, the bond is broken by a force working parallel to the tooth surface [22]. In some studies, the shear test may give somewhat higher values than the tensile test, but with the same ranking of products. However, shear stress is considered to be more representative of the clinical situation [22].

The literature reports large variations in bond strength data which are thought to be caused by differences in protocol [23]. In order to exclude possible influences of different restorative resins on the bond strength, all the bonding agents in this study were used in combination with the Z250 composite resin.

Previous studies have shown that bond strength depends on several factors, including: the influence of the pH value, the influence of the solvent and the influence of filled/unfilled adhesives.

Influence of pH

Total etch systems. The SB bond combines the primer and adhesive in one solution to be applied after etching enamel and dentine simultaneously (the total-etch wet-bonding technique) with 37% phosphoric acid for 20 s [24]. These bonding systems create a mechanical interlocking with etched dentine by means of resin tags, adhesive lateral branches and hybrid layer formation, and show high bond-strength values to both the etched enamel and dentine [25,26].

The classification proposed by Van Meerbeek subdivided self-etching primers into ‘strong’, ‘mild’ and ‘intermediary strong’ self-etching adhesives according to their etching aggressiveness [27].

Strong self-etching adhesives. Both LP (pH = 0·4) and EP (pH = 0·6) [27] are considered to be ‘strong self-etching adhesives’.

For enamel, the resulting acid-etch pattern resembles a phosphoric-acid treatment following a three-step adhesive systems approach [27,28].

For dentine, the collagen is exposed and nearly all the hydroxyapatite corresponding to the hybrid layer is dissolved. Such low-pH self-etching adhesives have often been documented with rather low bond-strength values, especially to dentine [28].

The EP bond showed the lowest bonding strength on dentine. This result is in agreement with other studies [29,30]. It is possible that the acidic primer causes excessive demineralization of the dentine. The resulting increased thickness of the hybrid layer and subsequent failure of the adhesive resin to penetrate the previously demineralized dentine completely may then contribute to the lower bond strength to dentine of primary teeth observed in this study. Furthermore, the low bond strengths may be caused by the high acidity of unpolymerized monomers remaining after light curing at a relatively high concentration at the oxygen-inhibited layer [31,32]. According to other studies, the unreacted acid groups have been hypothesized to attack the polymerization initiation system of the composite resin, especially in the case of prolonged contact of the acidic adhesive monomers with the uncured composite [28].

Thus, the low bond strength of EP may be a function of its composition, which primarily includes the monomethacrylate HEMA as the polymerizing part of the primer. This shows a pronounced polymerisa-polymer with a low degree of polymerization, particularly on dentine, where oxygen has access to the activated system both from the free surface, and to some extent, through the permeable dentine structure from the reverse side [33].

Medium-strong self-etching adhesives. Both OB and AS are classified as ‘medium-strong’ self-etching adhesives (pH = 1·5) [27]. Most typical is the twofold build-up of the dentinal hybrid layer with a completely demineralized base [27].

These adhesives are more acidic than SE, as a result of which better micromechanical interlocking is achieved at both the enamel and dentine layers. The residual hydroxyapatite at the hybrid layer base may still allow for chemical intermolecular interactions.

The results obtained with XE were less favourable than those obtained with OB and AS, but IB had weaker bond strength than OB and AS.

Mild self-etching adhesives. The SE bond (pH = 2) is considered to be a ‘mild self-etching adhesive’. This study found SE to have the highest bond strength. These results are in agreement with the findings of several other studies [23]. The SE bond demineralizes dentine only to a depth of 1 μm. Moreover, this superficial demineralization occurs only partially, keeping residual hydroxyapatite still attached to the collagen. Nevertheless, sufficient surface porosity is created to obtain micromechanical interlocking through hybridization. The preservation of hydroxyapatite within the submicron hybrid layer may serve as a receptor for additional chemical bonding [27]. Furthermore, SE contains MDP (methacryloxydecyl dihydrogen phosphate), which has a chemical bonding potential to the calcium in the residual hydroxyapatite [27].

The nature of the solvent

Both LP and EP contain water as their solvents. The bonding performance may be affected by the residual solvent (water) that remains within the adhesive interface and which is difficult to remove completely [34]. The high water content (80%) of LP and EP may result in competition between the monomer and the remaining water inside the demineralized dentine [34,35]. Phase separation of the hydrophobic and hydrophilic monomer components causing blister-like spaces and globule formation of the resin within the hybrid layer has been observed in overly wet conditions [23,36]. In addition, excess water may also dilute the primer and reduce its effectiveness [23,37].

The results obtained with IB can be explained by the nature of its solvent since IB contains acetone, whereas XE contains ethanol. Acetone is much more volatile than ethanol and evaporates rapidly from the dentine surface. Consequently, the application of several layers of IB is required, which may make this procedure more technique sensitive. In addition, the resin components are water miscible and could result in the formation of resin globules during the early evaporation of the acetone solvent in acetone-based systems [38].

Influence of filled/unfilled adhesives

The OB, AS, XE, and SE systems are effectively considered to be filled adhesives [1]. Filled low-viscosity resins are thought to have sufficient strain capacity to relieve stresses between the shrinking composite restoration and rigid dentine substrate [23]. Compared with unfilled systems (i.e. LP, IB and EP), most of the filled bonding tested in this study resulted in higher bond strength to dentine (except for LP versus XE).

These results are in agreement with other findings [23], whereas still other studies failed to find any difference when comparing filled and unfilled adhesive systems [39,40].

Still, the choice of an adhesive in paediatric dentistry does not depend solely on tensile or shear force values. The choice also depends on the child's temperament and age. For children who find it difficult to accept treatment and for toddlers, for whom speed is of the essence, adhesives which require only one application, like LP or XE, can be recommended. For children who accept treatment more readily, adhesives which require two applications in the mouth (first the primer and then the bonding component), such as SE, OB and AS, can be recommended. Finally, in the case of trauma to anterior teeth, or with amelo-dentine fractures of posterior teeth, where the masticatory forces are high, SE or OB adhesives can be recommended.

What this paper adds

- This paper provides bond strengths to primary enamel and dentine for eight adhesive materials.
- Shear bond strengths for bonds to primary enamel ranged from 9 to 18 MPa and from 8 to 18 MPa for primary dentine.
- Tensile bond strengths ranged from 7 to 13 MPa for primary enamel and from 6 to 12 MPa for primary dentine.

Why this paper is relevant to paediatric dentists

- There are clear differences in bond strength properties of adhesive systems when used on primary bovine teeth that may affect clinical performance.
- Adhesive systems are technique sensitive and in paediatric dentistry, choice of adhesive system may be affected not only by physical properties of the materials but also by factors related to method required for their application.

Conclusions

Within the limitations of this *in vitro* study, the highest shear bond strength was achieved by SE on enamel and dentine, and the lowest by IB on enamel and EP on dentine.

The highest tensile bond strength was achieved by SE on both enamel and dentine, and the lowest by EP.

As a result of these findings, the hypothesis advanced in this study was rejected.

Résumé. *Objectif.* Comparer la résistance à l'arrachement et à la traction de huit systèmes adhésifs sur la dentine et sur l'émail bovins.

Maétriels et méthodes. 256 incisives temporaires mandibulaires bovines non cariées ont été recueillies et conservées dans une solution aqueuse de chloramine à 1%, à la température de la pièce, sans dépasser trois mois après l'extraction.

Les adhésifs testés ont été Clearfil SE bond (SE), Adper Prompt L Pop (LP), Optibond Solo Plus Self-etch (OB), AdheSE (AS), Xeno III (XE), Scotch Bond 1 (SB), Etch & Prime 3,0 (EP) and I Bond (IB). Pour les résistances à l'arrachement et à la traction, les faces vestibulaires d'incisives temporaires ont été utilisées. Pour obtenir une surface plane, les faces vestibulaires ont été sablées sur papier humide SiC, d'abord avec un grain n° 200 pendant 20 secondes puis avec un grain n° 600 pendant 60 secondes ($n = 128$, 64 pour la résistance à l'arrachement et 64 pour la résistance à la traction). Les résultats ont été analysés par test ANOVA et par comparaison multiple de Bonferroni.

Résultats. Les valeurs de résistance à l'arrachement (MPa, moyenne ± écart-type) allaient:

Sur l'émail. de 18,1 à 8,9, en ordre décroissant à partir de: SE, LP, OB, AS, XE, SB, EP et IB.

Sur la dentine. de 17,8 à 8,2, en ordre décroissant à partir de: SE, SB, OB, AS, XE, LP, IB et EP.

Les valeurs de résistance à la traction (MPa, moyenne ± écart-type) allaient:

Sur l'émail. de 13,1 à 6,7, en ordre décroissant à partir de: SE, OB, AS, LP, XE, IB, SB et EP.

Sur la dentine. de 12,1 à 5,7, en ordre décroissant

à partir de: SE, SB, OB, AS, XE, LP, IB et EP.
Les différences de valeurs de collage antre les 8 systèmes sur l'émail et la dentine étaient toutes statistiquement significatives, aussi bien pour les forces d'arrachement et de traction.
Conclusions. La plus grande résistance à l'arrachement a été obtenue avec le Clearfil SE sur l'émail et la dentine, la plus faible sur l'émail avec le I Bond et sur la dentine avec le Etch&Prime 3,0. La plus forte résistance à la traction sur l'émail et la dentine a été obtenue avec Clearfil SE et la plus basse avec Etch&Prime 3,0.
Les résistances à l'arrachement étaient significativement plus fortes sur l'émail que sur la dentine chez cinq des huit systèmes adhésifs et les résistances à la traction étaient significativement plus fortes sur l'émail que sur la dentine chez tous les systèmes sauf deux.

Zusammenfassung. *Ziel*. Vergleich von Scher- und Abzugshaftwerten von acht Adhäsivsystemen an Schmelz und Dentin von bovinen Milchzähnen. *Material und Methoden*. 256 nichtkariöse bovine mandibulare Milchschneidezähne wurden gesammelt und in einer wässerigen 1%igen Chloraminlösung bei Raumtemperatur gelagert für einen Zeitraum von höchstens 3 Monaten nach Extraktion. *Die getesteten Adhäsive waren*. Clearfil SE bond (SE), Adper Prompt L Pop (LP), Optibond Solo Plus Self-etch (OB), AdheSE (AS), Xeno III (XE), Scotch Bond 1 (SB), Etch & Prime 3.0 (EP) und I Bond (IB).
Für die Scherkraft- und Abzugskraftmessung wurden die labialen Oberflächen der Milchschneidezähne benutzt. Um eine plane Oberfläche zu erzielen, wurden die Zahnoberflächen mit nassem SiC-Papier geschliffen, zuerst mit 200 grit für 20 s, dann mit 600 grit für 60 s.
Die Ergebnisse wurden analysiert mit einem ANOVA test und einem Mehrfachvergleich (korrigiert nach Bonferroni).
Ergebnisse. Die Scherkräfte (in MPa, Mittelwert ±SD) lagen zwischen;
An Schmelz. Von 18.1 bis 8.9, in abnehmender Reihenfolge: SE, LP, OB, AS, XE, SB, EP und IB.
An Dentin. Von 17.8 bis 8.2, in abnehmender Reihenfolge: SE, SB, OB, AS, XE, LP, IB und EP.
Die Abzugswerte lagen an *Schmelz* von 13.1 bis 6.7, in abnehmender Reihenfolge: SE, OB, AS, LP, XE, IB, SB und EP.
An Dentine. Von 12.1 bis 5.7, in abnehmender Reihenfolge: SE, SB, OB, AS, XE, LP, IB und EP.
Die Unterschiede zwischen den Systemen waren alle statistisch signifikant, sowohl für die Scherkräfte als auch für die Abzugskräfte.
Schlussfolgerungen. Die höchste Scherkraft wurde bei Clearfil SE an Schmelz und Dentin gemessen, die niedrigste an Schmelz nach I Bond, an Dentin nach Etch&Prime 3.0. Die höchste Abzugskraft wurde nach Clearfil SE bond an Schmelz und Dentin, die niedrigste nach Etch&Prime 3.0 gemessen. Die Scherkraftwerte waren an Schmelz höher als an Dentin bei fünf der acht Systeme; deutlich höher waren die Abzugskräfte an Schmelz bei allen bis auf zwei Systemen.

Resumen. *Objetivo*. Comparar la resistencia al cizallamiento y la tracción de ocho sistemas adhesivos al esmalte y la dentina de dientes bovinos primarios. *Material y métodos*. 256 incisivos inferiores bovinos sin caries, se recogieron y almacenaron en una solución acuosa al 1% de cloramina a temperatura ambiente, durante 3 meses como máximo después de la extracción.
Los adhesivos testados fueron Clearfil SE bond (SE), Adper Prompt L Pop (LP), Optibond Solo Plus Self-etch (OB), AdheSE (AS), Xeno III (XE), Scotch Bond 1 (SB), Etch & Prime 3,0 (EP) and I Bond (IB). Para el test de cizallamiento y el test de tracción, se usaron las superficies vestibulares de los incisivos primarios. Para obtener una superficie plana, las superficies vestibulares de los dientes se pulieron con papel de SiC húmedo, primero con grano n° 200 durante 20 segundos y luego con grano n° 600 durante 60 s. ($n = 128$, 64 para la unión por cizallamiento y 64 para la unión por tracción). Los resutados se analizaron con un test de ANOVA y un test de comparación múltiple de Bonferroni.
Resultados. Los valores de resistencia al cizallamiento (MPa, media ±SD) oscilaron;
En esmalte. Desde 18,1 hasta 8,9, en orden descendente: SE, LP, OB, AS, XE, SB, EP y IB.
En dentina. Desde 17,8 hasta 8,2, en orden descendente: SE, SB, OB, AS, XE, LP, IB y EP.
Los valores de resistencia a la tracción (MPa, media ±SD) oscilaron;
En esmalte. Desde 13,1 hasta 6,7, en orden descendente: SE, OB, AS, LP, XE, IB, SB y EP.
En dentina. Desde 12,1 hasta 5,7, en orden descendente: SE, SB, OB, AS, XE, LP, IB y EP.
Las diferencias en la resistencia a la adhesión entre los 8 sistemas realizados sobre el esmalte y la den-

tina fueron todos estadísticamente significativos. Esto fue así tanto para las resistencias al cizallamiento como a la tracción.

Conclusiones. La resistencia al cizallamiento más alta se obtuvo con la adhesión de Clearfil SE sobre el esmalte y la dentina y la más baja sobre el esmalte con I Bond y sobre dentina con Etch&Prime 3,0. La resistencia más alta a la tracción se obtuvo con la adhesión de Clearfil SE sobre esmalte y dentina y la más baja con Etch&Prime 3,0. Las resistencias al cizallamiento fueron significativamente más altas sobre el esmalte cuando se comparó con la dentina en cinco de los ocho sistemas adhesivos y las resistencias a la tracción fueron significativamente más altas sobre el esmalte cuando se comparó con la dentina para todos menos dos sistemas.

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