New Dental Adhesives- How Universal are They

Dr. Jorge Perdigão
University of Minnesota

Conflict of Interest - Dr. Perdigão is the PI of a clinical study sponsored by 3M Oral Care

Paradigm shift

Acid-etch technique (Buonocore, 1955)

Bis-GMA composite resin (Bowen & Rodriguez, 1960 (38th IADR meeting, Chicago)

Dentin hybrid layer (Kramer & McLean, 1952; Nakabayashi et al., 1982)

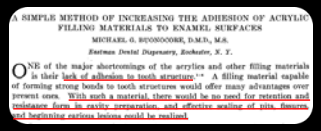
The enamel acid-etch technique

A milestone in adhesive dentistry

"With such a material there would be no need for retention and resistance form in cavity preparation and effective sealing of pits, fissures, and beginning carious lesions could be realized"

Dr. Michael G. Buonocore - a true visionary

J Dent Res 1955



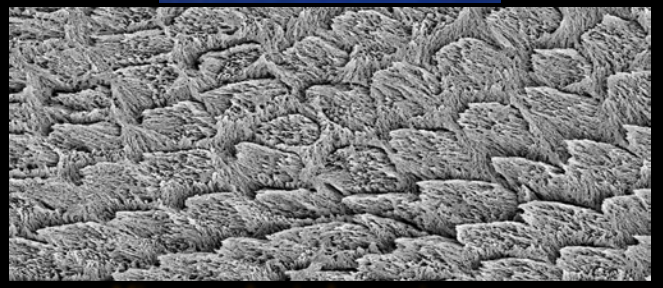
A SIMPLE METHOD OF INCREASING THE ADHESION OF ACRYLIC FILLING MATERIALS TO ENAMEL SURFACES

MICHAEL G. BUONOCORE, D.M.D., M.S.

Eastman Dental Dispensary, Rochester, N. Y.

ONE of the major shortcomings of the acrylics and other filling materials is their lack of adhesion to tooth structure.[1-4] A filling material capable of forming strong bonds to tooth structures would offer many advantages over present ones. With such a material, there would be no need for retention and resistance form in cavity preparation, and effective sealing of pits, fissures, and beginning carious lesions could be realized.

The enamel acid-etch technique



Micro-mechanical retention

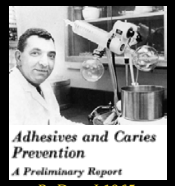
The enamel acid-etch technique

↓

Minimally-invasive Operative Dentistry

↓

Micro-invasive and non-invasive strategies



Adhesives and Caries Prevention

A Preliminary Report

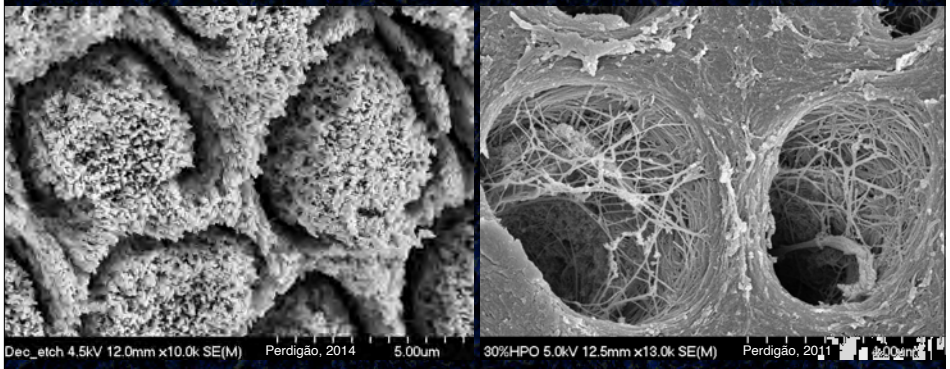
Br Dent J 1965

Micro-invasive strategies

N. Gomez, class of 2016

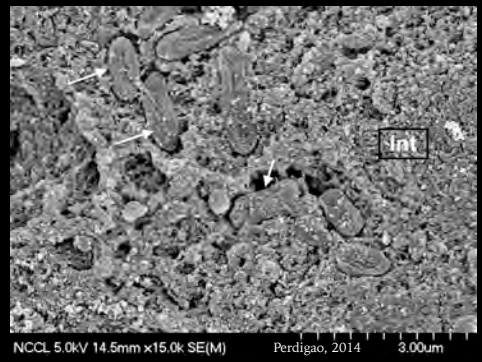
Instructor - J. Perdigao

While adhesion to etched enamel is easy and predictable…

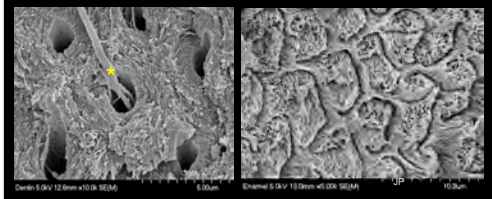


…adhesion to dentin is still a challenge

Non-carious cervical lesion



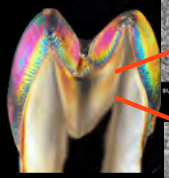
Composition

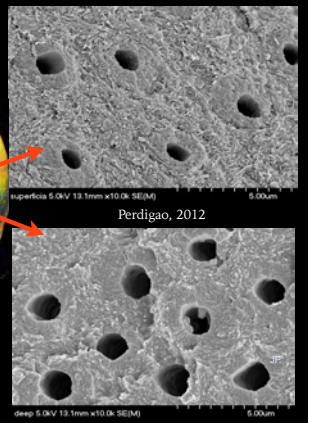


Wet substrate
50 vol% organic
Odontoblastic processes

Dry substrate
96 vol% mineral (hydroxyapatite)
No vital structures

Depth





Perdigao, 2012

Ideal dentin adhesive

- Not too expen$ive
- For all substrates
- Stable in the bottle
- Easy to use
- For direct + indirect restorations

- No allergies, including contact dermatitis
- Durable restorations, no leakage
- No post-op sensitivity
- No pulp injury
- Backed by clinical evidence

Clinical evidence?

- Dental adhesives are one of the few materials in Health Sciences that can be launched *without proof of clinical efficacy* - FDA 510(K)
- Dental adhesives may be the materials in Health Sciences that change commercial names more often; when clinical studies are completed, a new version of the same material is usually available.

Who tests them clinically?

We *test* all new dentin adhesives

Xeno Select resulted in 87.9% retention rate after **6 months** of clinical use

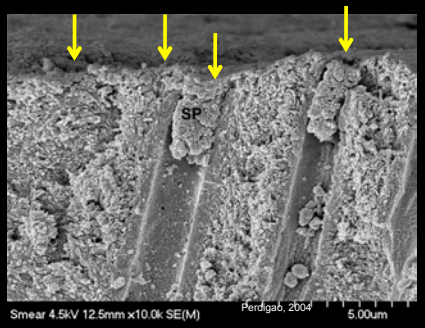
It did not fulfill the ADA criteria for provisional acceptance

Current dental adhesives

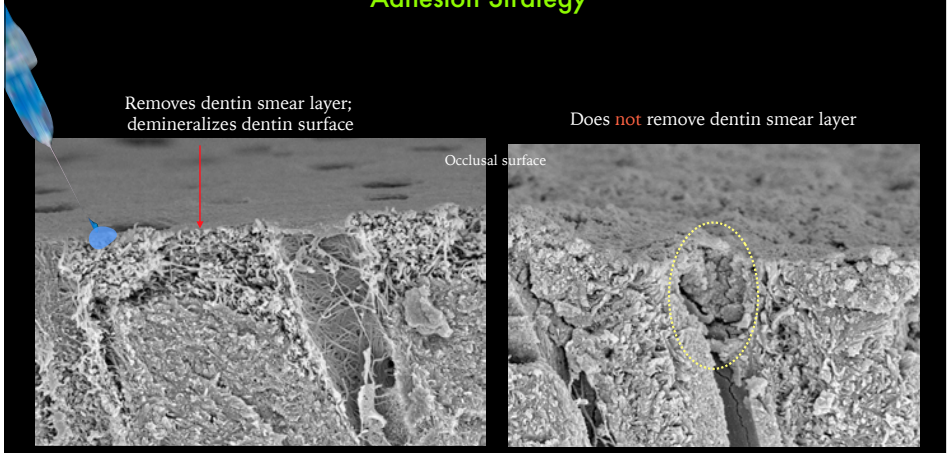
Classification

By adhesion strategy – with or without **etching**

- Easier to understand as adhesives are grouped according to their interaction with the smear layer - with OR without a separate etching step
- Very informative in regards to the different steps used in the adhesive procedure - etchant primer, bonding (alone or combined)

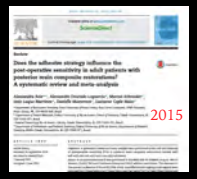


Adhesion Strategy



Adhesion Strategy

Systematic reviews and meta-analyses



Smear layer removal = Postoperative sensitivity?

- The adhesion strategy (ER vs. SE) results in similar postoperative sensitivity and similar retention in cervical restorations
- Etch-and-rinse adhesives reduce marginal discoloration

- The type of adhesive strategy (ER vs. SE) does not influence the risk and intensity of postoperative sensitivity in posterior composite restorations

Adhesion Strategy

Dentin/Enamel Adhesives		
Etch-and-rinse	3-step A + Pr + **B**	Best
	2-step A + (PrB)	
Self-etch	2-step Pr + **B**	Best
	1-step (PrB)	

A - Phosphoric acid etch; Pr - Primer; **B - Bonding (solvent-free)**

Adhesion Strategy

Etch-and-rinse

A

Pr

B

Phosphoric Acid

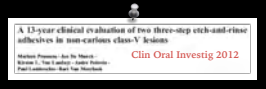
Gopher Primer

Gopher Bond

3-step etch-and-rinse

Clinically proven

The bonding is a separate solvent-free hydrophobic resin



Adhesion Strategy

Self-etch

Pr

B

Acidic Primer

Bonding

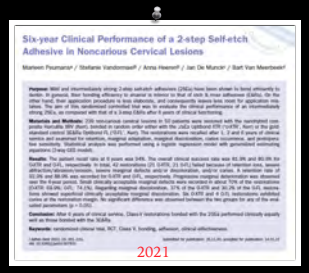
2-step self-etch

Clinically proven

The bonding is a separate solvent-free hydrophobic resin

Adhesion Strategy

2 step SE vs. 3-step ER

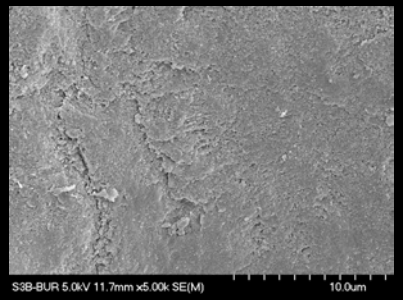

Six-year Clinical Performance of a 2-step Self-etch Adhesive in Noncarious Cervical Lesions

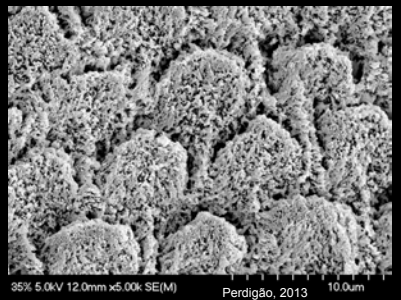
2021

- The 6-year retention rate was 92.9% for OptiBond XTR and 88.9% for OptiBond FL
- Small clinically acceptable marginal defects were recorded in about 70% of the restorations
- **There was no significant difference between the 2 adhesives for any of the criteria**

Self-etch adhesives

Major Disadvantage





Phosphoric acid etching increases enamel bond strengths and seals enamel margins

Pashley et al., Dent Mater 2001; Perdigao & Geraldeli, J Esthet Restor Dent 2003; Frankenberger et al., J Adhes Dent 2008

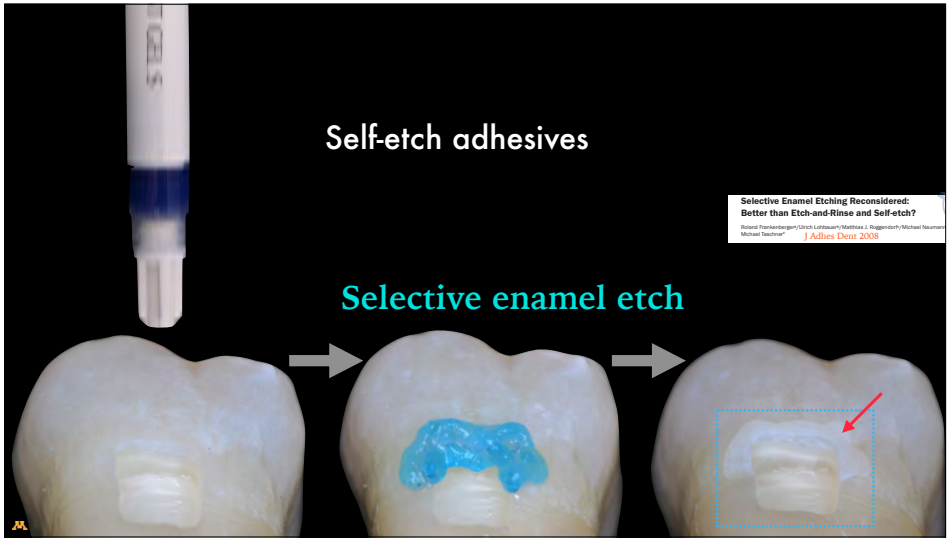
1 year follow-up

Self-etch

Etched enamel

Perdigao et al., Am J Dent

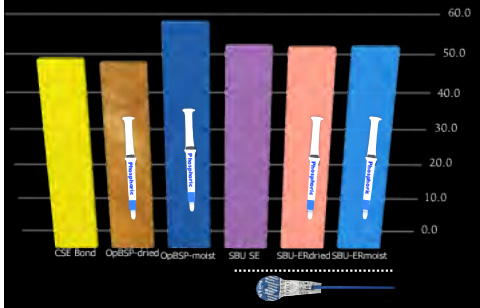
Self-etch adhesives



What if dentists used one adhesive for all bonding strategies?

According to the respective manufacturers, dentists can use any adhesion strategy
- self-etch, etch-and-rinse, selective enamel etch

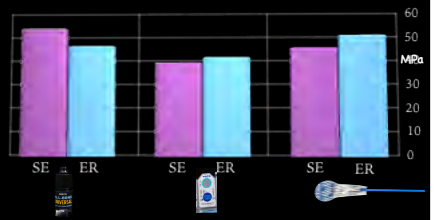
Universal Adhesives



Laboratory bonding ability of a multi-purpose dentin adhesive
Am J Dent 2012

Dentin Bond Strengths

Microtensile, 24h



J Dent 2014

Universal Adhesives

- 1-bottle adhesives, pH=1.6 - 3.2, similar to 1-step self-etch adhesives
- Most universal adhesives contain 10-MDP, a phosphate resin monomer that **bonds chemically to Ca^{2+} in hydroxyapatite** (Yoshida et al., J Dent Res 2012; 91:376-381)

New multi-bottle 'universal' adhesive

2 step **SE** or 3-step **ER**

The primer is identical to the universal adhesive G-Premio Bond
The adhesive resin contains a zinc−calcium−fluoride bioglass and a fumed silica filler

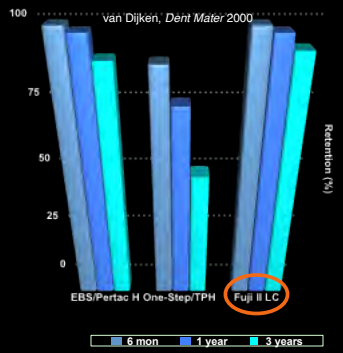
- 4-MET
- 10-MDP
- No HEMA

Bioactive Two-step Approach: Promising Bonding Str... for a One-step Self-etch Universal Adhesive
J Adhes Dent 2019

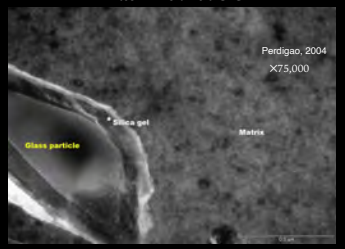
Zinc−Calcium−Fluoride Bioglass-Based Innovative Multifunctional Dental Adhesive with Thick Adhesive Resin Film Thickness

Chemical bonding

GIC



Resin-modified GIC



GIC materials bond ionically to dentin (COO^- to Ca^{2+})

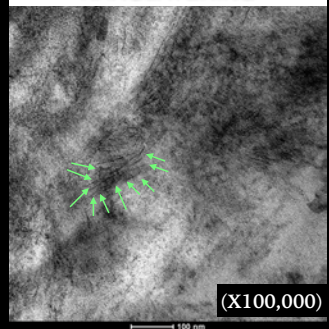
Mitra, J Dent Res 1991; 70:72-74; Lin et al., J Dent Res 1992; 71:1836-1841; Fukuda et al., Biomater 2003; 24,1861-1867; Mitra et al., Dent Mater 2009; 25;459-466; Cardoso et al., J Dent 2010;38:921-929

Universal adhesives also have the potential for chemical bonding to dentin

Chemical bonding

10-MDP establishes chemical bonds with calcium in hydroxyapatite through

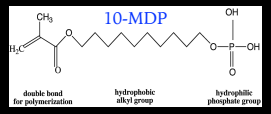
NANOLAYERING



Spohr, Perdigao, 2015

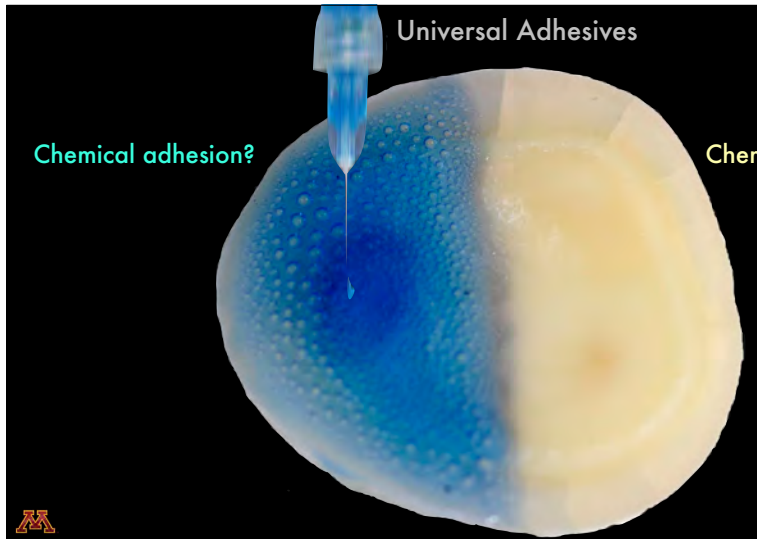
Chemical bonding

Clearfil SE Bond, a 2-step self-etch adhesive,
was the first dentin adhesive to incorporate 10-MDP (as Megabond)



10-methacryloyloxy decyl dihydrogen phosphate

The strong chemical bonding between **10-MDP** and Ca^{2+} may be responsible for the excellent clinical retention in non-carious cervical lesions at **13-years**

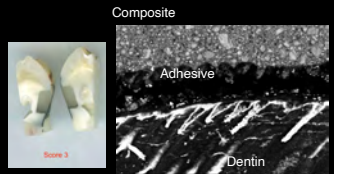


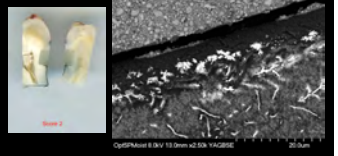
Less nanoleakage when dentin was **not** etched

	Tooth 1		Tooth 2		Tooth 3		Tooth 4		Tooth 5		Tooth 6	
CSEB	1	0	1	0	3	0	0	1	0	0	0	0
OptBSP moist	1	2	1	1	1	2	1	0	2	1	1	1
OptBSP dried	2	2	2	2	2	2	4	1	1	4	0	2
SBU-SE	0	0	0	0	0	0	0	0	0	0	0	0
SBU-etch-moist	4	0	2	3	2	3	4	3	0	2	1	1
SBU-etch-dried	0	0	2	1	2	4	2	1	1	2	1	2
SBU-enamel	0	0	0	0	0	0	0	0	0	0	0	0

Mann-Whitney Test $p<0.05$

0 – no silver infiltration observed
1 – silver infiltration up to 1/3 of the gingival wall extension
2 – silver infiltration up to 2/3 of the gingival wall extension
3 – silver infiltration up to the gingivo-axial line angle;
4 - silver infiltration reached the axial wall and/or tubules close to the pulp chamber





Sezinando & Perdigao, *J Dent Res* 2012, Abst. 469

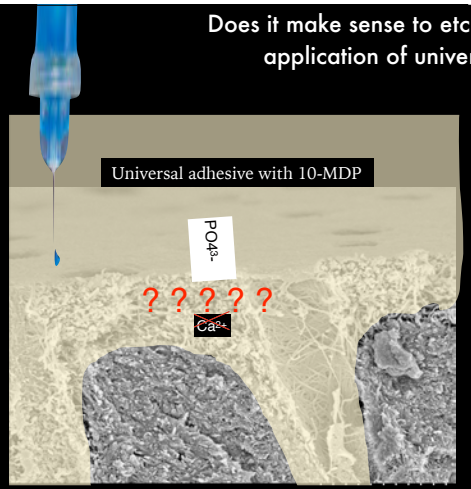
Universal Adhesives

Etch or no etch?

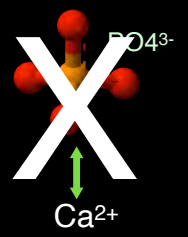
After 1 year in artificial saliva, Scotchbond Universal (SBU) self-etch resulted in less nanoleakage than SBU etch-and-rinse (Marchesi et al., J Dent 2014)

The integrity of the resin-dentin interface and the respective bond strengths of SBU self-etch did not undergo degradation after 6 months in water/37°C (Sezinando, Perdigao, 2017)

Does it make sense to etch dentin prior to the application of universal adhesives?

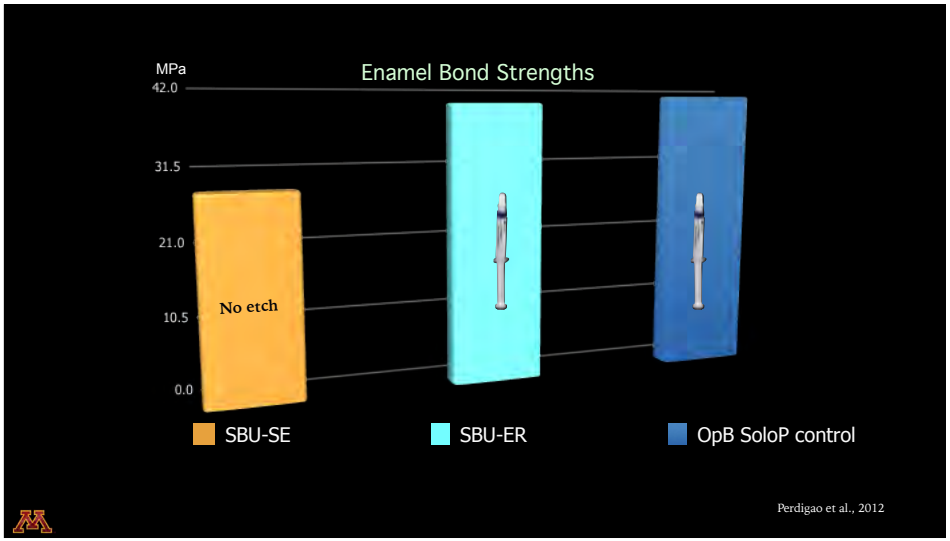


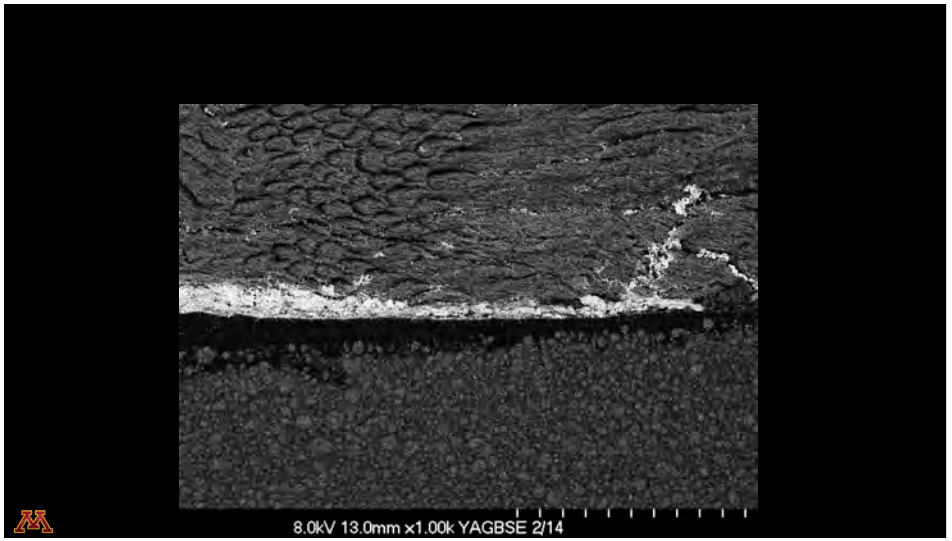
No chemical adhesion when dentin is etched!



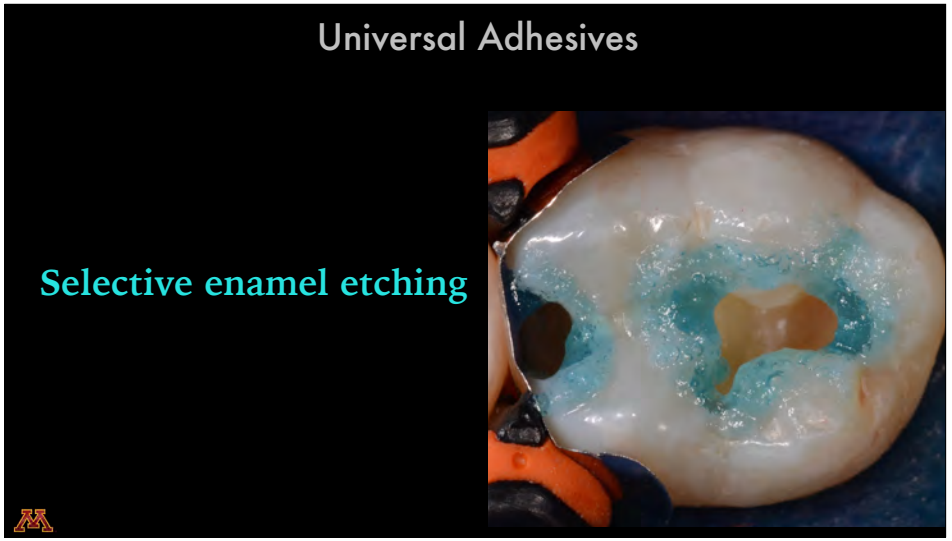
Enamel adhesion with universal adhesives

M. Meste, Class of 2021
Instructor - J. Perdigão


MPa
Enamel Bond Strengths
42.0
31.5
21.0
10.5
0.0
No etch
SBU-SE
SBU-ER
OpB SoloP control
Perdigao et al., 2012


8.0kV 13.0mm x1.00k YAGBSE 2/14


Universal Adhesives
In vitro studies
Result in higher enamel bond strengths when enamel is etched with phosphoric acid
Seal dentin better (less nanoleakage) and result in less degradation after artificial aging when used as a self-etch adhesive


Universal Adhesives
Selective enamel etching

Clinical studies

3 year follow-up

- 200 NCCL restorations with SBU - 8 restorations lost - 5 SE; The SE group resulted in significant increase in marginal staining from baseline to 3 y

A new universal simplified adhesive: 36-Month randomized double-blind clinical trial
J Dent 2015

3 year follow-up

At 3y marginal staining was observed with SBU in 17/54 restorations **in the SE group** (31.5%), which was significantly different from the other groups

Thirty-six-month clinical evaluation of different adhesive strategies of a universal adhesive
Clin Oral Invest 2019

2 year follow-up

Adhese U in SE and SEE modes; no differences in retention rate; worse marginal discoloration for SE; worse marginal adaptation for SEE

J Esthet Restorat Dent 2020

18m follow-up

SBU and P&B Elect had acceptable clinical performance after 18m. However, SBU **SE** exhibited a very high incidence of marginal discoloration

Eighteen-month Clinical Study of Universal Adhesives in Noncarious Cervical Lesions
Oper Dent 2018

2 year follow-up Class I restorations

In SE mode, Gluma U, SBU and P&B Elect showed worse marginal adaptation. Gluma U resulted in significant marginal discoloration

The effect of five different universal adhesives on the clinical success of class I restorations: 24-month clinical follow-up
Clin Oral Invest 2019

4 year follow-up Class II restorations

Adhese U in SE and ER mode; marginal discoloration was statistically more frequent in SE approach

J Dent 2022

Clinical studies

5 year follow-up (NCCLs)

The retention/fracture rates were significantly worse for the self-etch group (81%) compared to 93% for etch-and-rinse and 90% for selective enamel etching

Marginal discoloration and adaptation was significantly worse for self-etch

No statistical difference between etch-and-rinse and selective enamel etching

Five-year clinical evaluation of a universal adhesive: A randomized double-blind trial
Dental Materials 2020

Clinical studies

5 year follow-up (NCCLs)

Scotchbond Universal + additional hydrophobic resin (SBMP adhesive)

- The survival rate was
  - 96.9% for 3-step ER; 96.8% for 2-step ER
  - 71.4% for 2-step SE; 81.3% for 1-step SE
- A significant decrease in retention rate was detected for 2-step SE and 1-step SE (from baseline to 5 years)
- All groups, except 2-step ER, showed an increase in marginal discoloration
- Although an extra layer of a non-solvated adhesive improves the in vitro performance of universal adhesives, there is no clinical evidence to recommend this technique

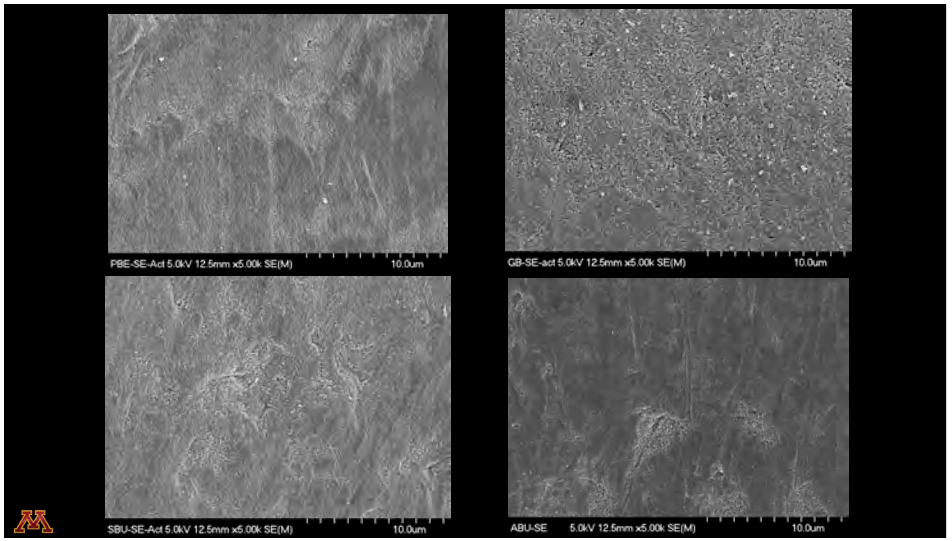
Effect of an additional bonding resin on the five years performance of a universal adhesive: a randomized clinical trial
Clin Oral Investig 2022 (accepted pending revisions)

Clinical studies - universal adhesives

Summary

1. Etch-and-rinse and selective enamel etching strategies result in higher retention rate in NCCLs compared to self-etch
2. Some universal adhesives result in a high incidence of marginal discoloration especially when applied as self-etch adhesives.

Enamel requires phosphoric acid etching



Universal Adhesives

Other suggestions to optimize their application (in vitro studies)

For older adhesives, clinical studies have shown that active application (scrubbing) is more effective than leaving dentin moist

2y clinical

Clin Oral Invest 2011

2y clinical

JADA 2011

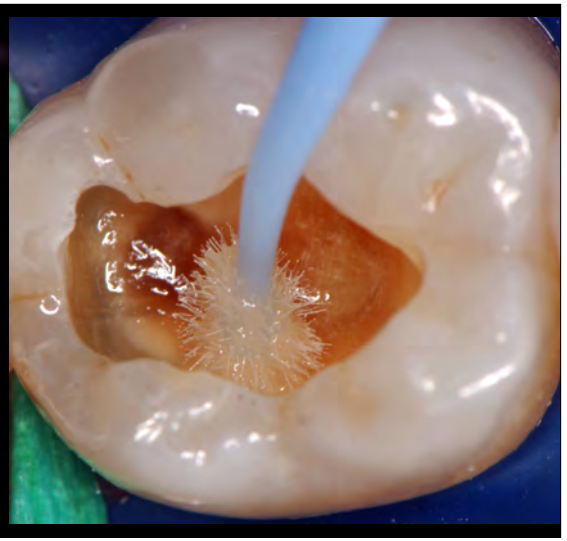
Universal Adhesives

Active application (scrubbing) increases in vitro performance

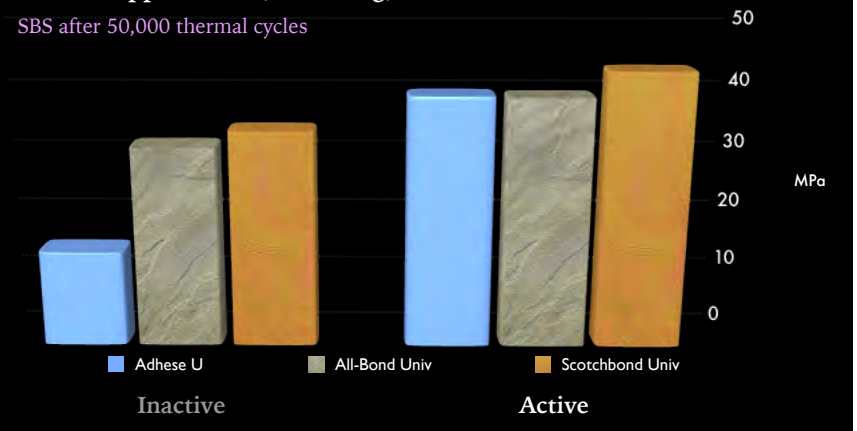
J Adhes Dent 2016

Effect of Active Application on Bond Durability of Universal Adhesives

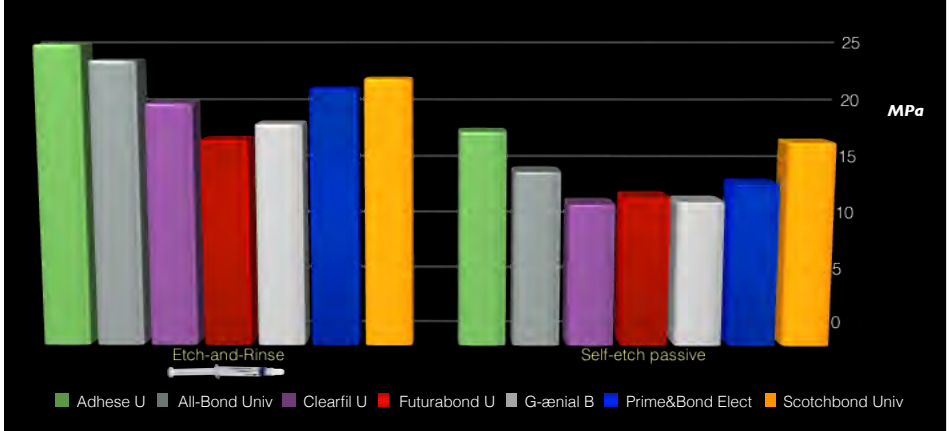
Oper Dent 2018



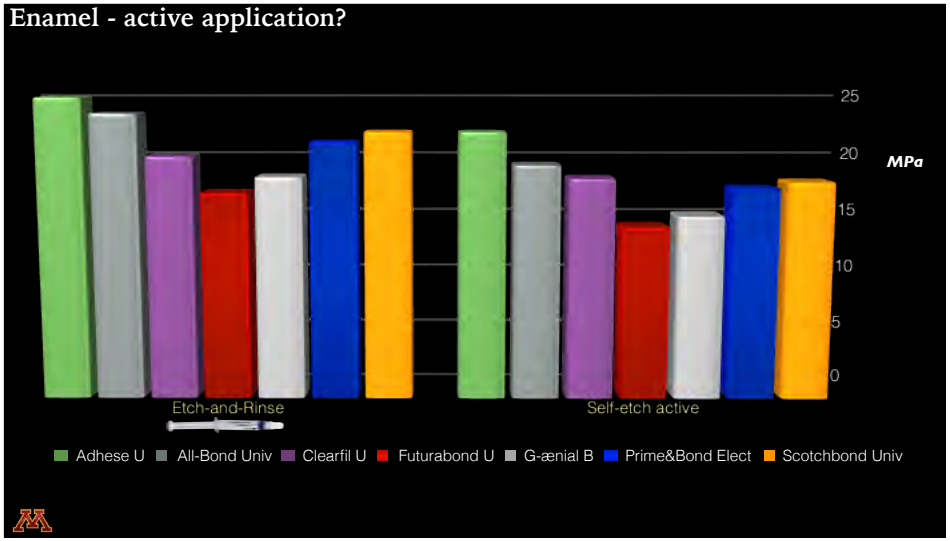
Dentin - active application (scrubbing)

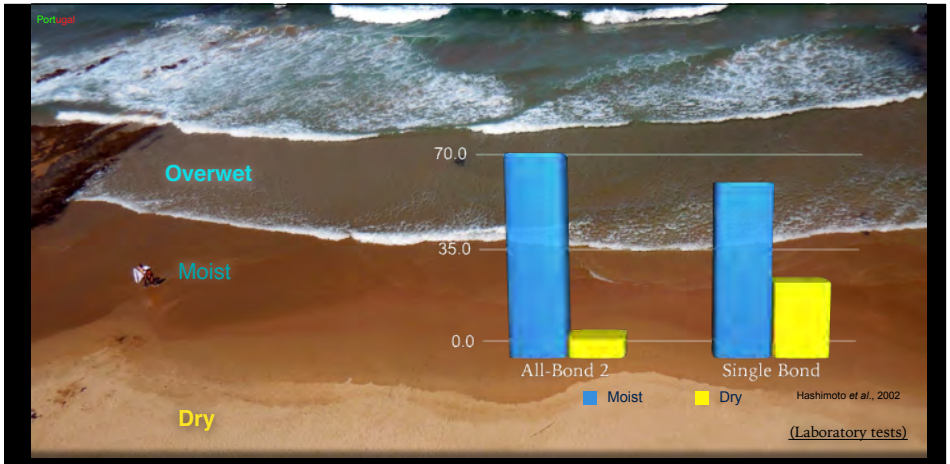


Enamel - active application?



Enamel - active application?





We leave too much water after rinsing off the etching gel
Universal adhesives contain 10-20% water

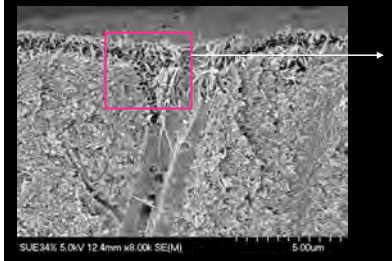
Clinically…

Eighteen-month Clinical Evaluation of Two Dentin Adhesives Applied on Dry vs Moist Dentin

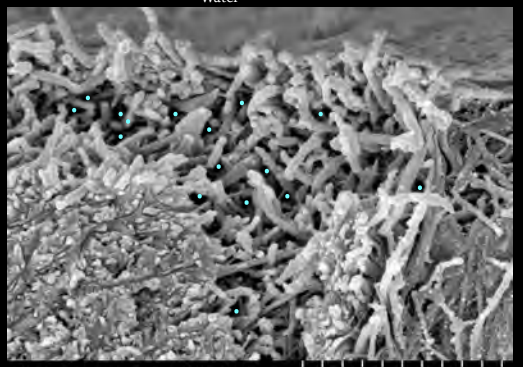
J Adhes Dent 2005

The 6- and 18-month retention rates of Single Bond and Prime&Bond NT in non-carious cervical lesions were not significantly different for dried dentin versus moist dentin

After rinsing off the acid etching gel with water, it is extremely difficult o replace all the residual water with resin monomers from the adhesive

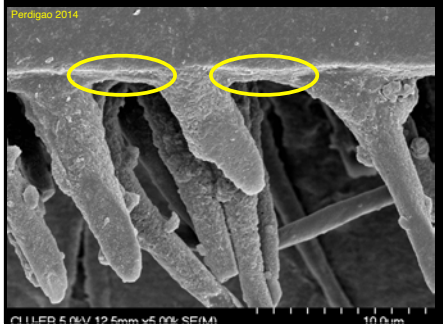


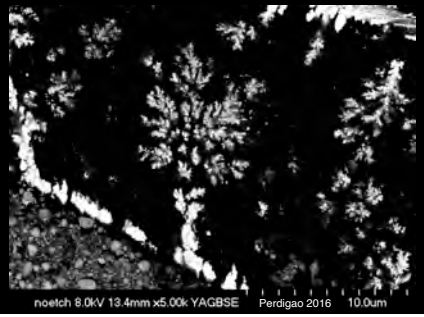
• Water

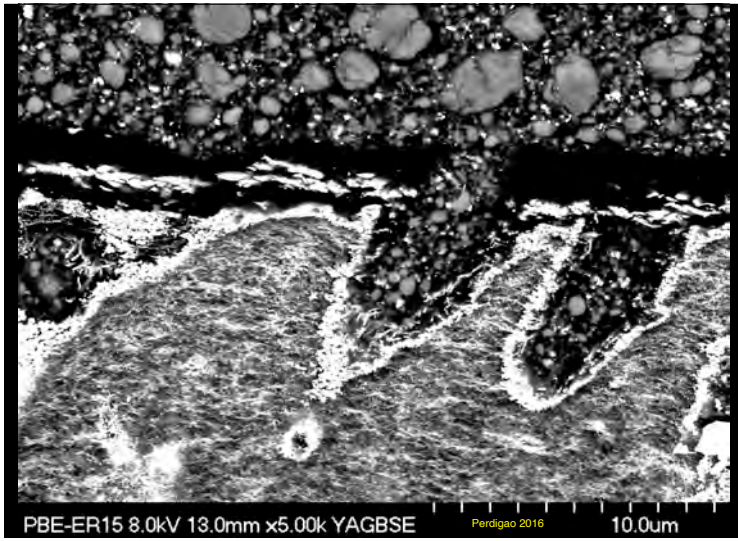


Universal Adhesives

The residual water may prevent the formation of a hybrid layer

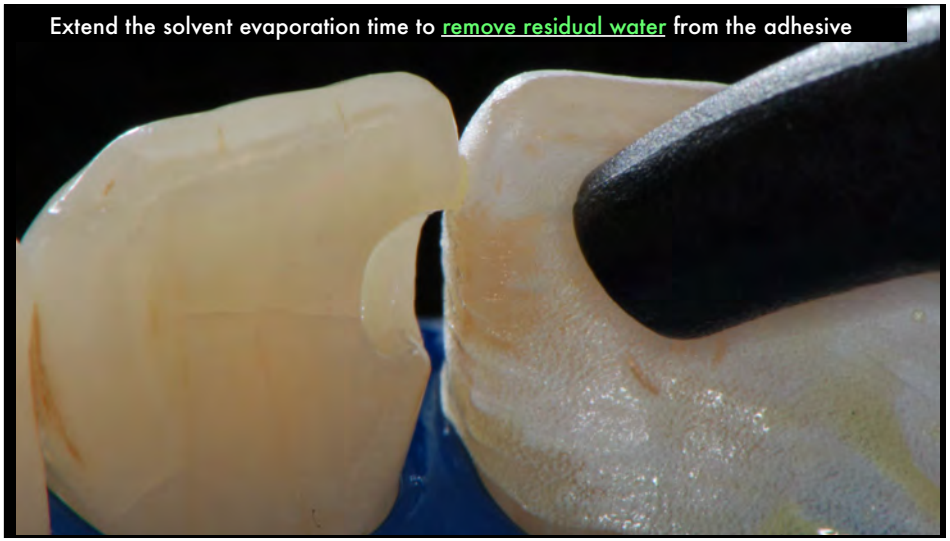




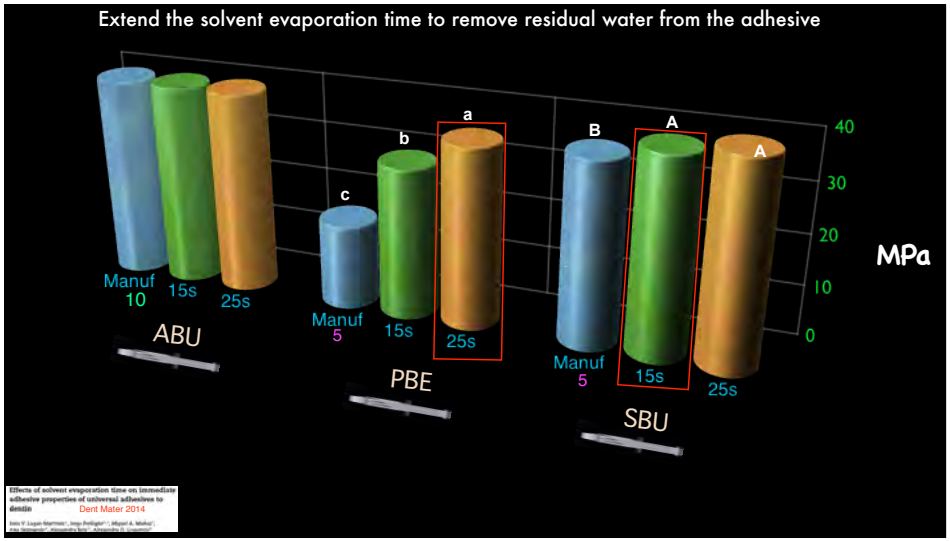


Prime & Bond Elect
ER

Extend the solvent evaporation time to remove residual water from the adhesive



Extend the solvent evaporation time to remove residual water from the adhesive

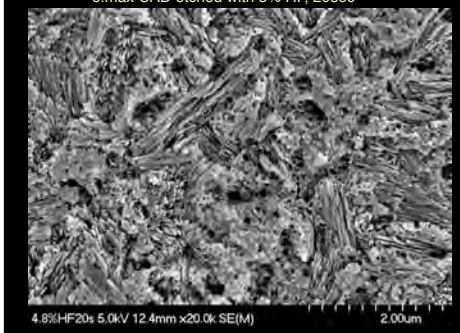


Effects of solvent evaporation time on immediate adhesive properties of universal adhesives to dentin
Dent Mater 2014

Universal Adhesives

Glass-matrix ceramics (lithium disilicate)

e.max CAD etched with 5% HF, 20sec



For traditional adhesives

- application of a silane solution
- application of a dental adhesive

A few universal adhesives include a silane coupling agent in their composition

Do we need to apply a separate silane solution to the etched intaglio?

- Scotchbond Universal results in lower bond strengths to lithium disilicate (LD) when a separate silane solution **is not used**
- Research has shown that a separate silane or a freshly mixed silane added to the adhesive is needed to restore bond strengths

Effectiveness and stability of silane coupling agent incorporated in "universal" adhesives
Dent Mater 2016

Influence of Etching Protocol and Silane Treatment with a Universal Adhesive on Lithium Disilicate Bond Strength
Oper Dent 2015

Universal adhesives

Silanes become inactive when mixed with methacrylate monomers in the same bottle

J Prosthet Dent 2013
EFFECT OF INCORPORATING BisGMA RESIN ON THE BONDING PROPERTIES OF SILANE AND ZIRCONIA PRIMERS

The use of silanes mixed with methacrylate monomers should be avoided due to silanol deactivation.

Stability and reactivity of γ-MPTMS silane in some commercial primer and adhesive formulations
Dent Mater 2018

In addition, the low pH of universal adhesives decreases the effectiveness of some silanes

Silane solutions with 10-MDP

Silane solutions for glass-matrix ceramics, such as lithium disilicate
They can also be used as zirconia primers - 10-MDP bonds chemically to zirconia

3-Methacryloxypropyl trimethoxysilane
10-Methacryloxypropyl dihydrogen phosphate (MDP)
Ethanol

Universal Adhesives

Scotchbond Universal Plus adhesive contains two silane molecules that are compatible with the acidity of the solution

No separate silane is recommended

Optimizing glass-ceramic bonding incorporating new silane technology in an experimental universal adhesive formulation
Dent Mater 2021

3-(aminopropyl) triethoxysilane (APTES)
γ-methacryloxypropyltriethoxysilane (γMPTES)

Universal Adhesives

R. Upriti, senior student
Instructor - J. Perdigão

Do we *even* need to apply a universal adhesive to the intaglio of glass-matrix ceramics (lithium disilicate)?

Universal Adhesives

MBS

MB Plus

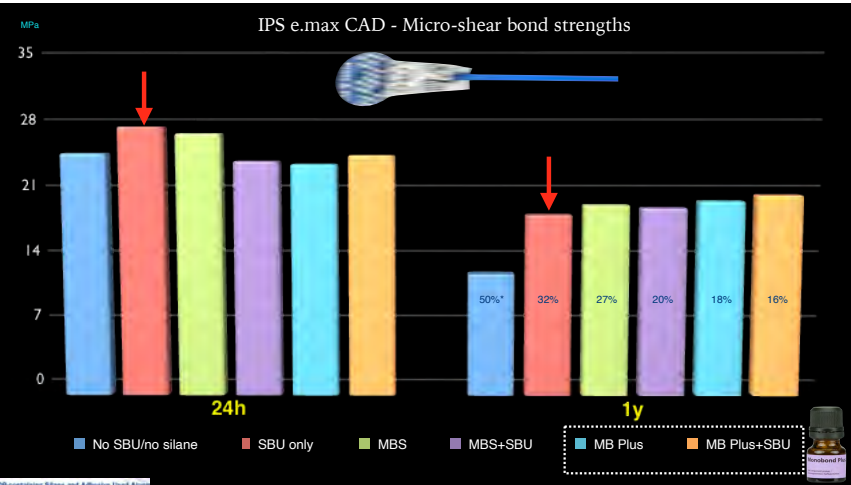
Silane

Silane+MDP

SBU
(contains silane+MDP)

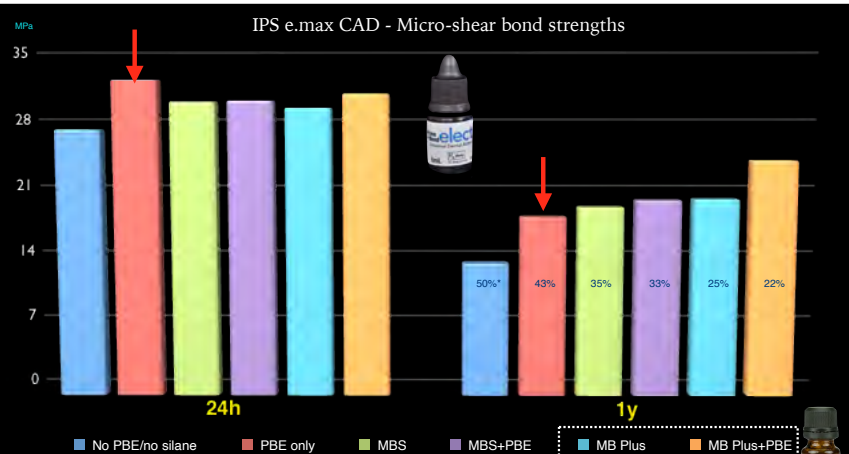
PBE
(no silane+ no MDP)

IPS e.max CAD - Micro-shear bond strengths



* % of reduction in bond strengths after 1 year

IPS e.max CAD - Micro-shear bond strengths



* % of reduction in bond strengths after 1 year

Universal adhesives with dual-cured resin composite materials

Universal adhesives are acidic, which may inhibit the polymerization of **chemically- or dual-cured composites that contain a tertiary amine in the curing initiator**

The chemical setting mechanism of traditional dual-cure composites, such as core-buildup materials and resin cements, is usually based on redox reaction of benzoyl peroxide (catalyst paste) with aromatic tertiary amines (base paste).

Higher pH = compatible with chemically-cured composite materials

Universal Adhesive	Functional Monomer(s)
All-Bond Universal (ABU) (BISCO Inc.)	10-MDP
AdheSE Universal (AU) (Ivoclar Vivadent)	10-MDP, MCAP
Optibond Universal (OBU) (Kerr)	GPDM
One Coat 7 Universal (OC7U) (Coltene)	10-MDP
Scotchbond Universal (SBU) (3M ESPE)	10-MDP, PAC
Prime&Bond Elect (PBE) (Dentsply Sirona)	PENTA
Clearfil Universal Bond (CFU) (Kuraray Noritake Dental Inc.)	10-MDP
Futurabond U (FBU) (VOCO GmbH)	10-MDP
iBOND Universal (IBU) (Kulzer GmbH)	10-MDP, 4-MET
G-Premio Bond (GPB) (GC Corp)	10-MDP, 4-MET

pH = 2.8-3.2

No chemical activator needed

Only indicated for light-cured composite materials

pH = 1.5.-2.2

Chemical activator recommended

Tertiary amine-free dual-cure resin cements

The respective universal adhesive **does** not need a DC activator

Universal Adhesives

Advantages

- Indicated for a wide variety of restorative procedures and adhesion strategies
- May bond chemically to hydroxyapatite in dentin when used in SE mode
- Application of the adhesive in SE mode with a scrubbing movement increases enamel bond strengths
- No need to leave dentin moist when used in ER mode
- They do not seal dentin margins well in vitro when dentin is etched

Universal Adhesives

Disadvantages

- High enamel bond strengths are only achieved after phosphoric acid etching
- They are not true 1-step adhesives as separate enamel acid-etching step is needed for better clinical outcomes
- Most universal adhesives require mixing with the respective dual-cure activator when used with self- or dual-cure composite materials
- Most still need a separate silane solution for bonding to glass-matrix ceramics even if they contain a silane in their composition
- Their use as zirconia primers is still debatable.

Universal Adhesives

How Universal?

- Zirconia*
- Glass-ceramics*
- Composite repair
- CAD-CAM composite blocks
- Core Buildup*
- Enamel*
- Dentin*
- Resin cements*