ExciTE® F

Click & Bond® with the VivaPen®

product design award 2010

Focus Open Gold 2009

Fluoride releasing, light-curing Total-Etch adhesive

Scientific Documentation

ivoclar vivadent
passion vision innovation

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1. Introduction

Adhesive systems establish a bond to both the filling material and the dental hard tissue, i.e. enamel and dentin. The original multi-step adhesives were followed by two-step adhesives, initially in combination with the total-etch technique. Later came the self-etching two-bottle adhesives and finally the single-step adhesives which consist only of one component that needs to be applied.

ExciTE F is the successor product of ExciTE; this light-curing single-component dentin enamel adhesive is used in combination with the total-etch technique (also called etch-and-rinse technique).

ExciTE F is offered in the new VivaPen with an improved ergonomic design and integrated fill-level indicator. The adhesive solution contains a fluoride source, which permits fluoride ions to be released.

1.1 The substrate

Ever since tooth-coloured filling materials found their way into restorative dentistry, there has been a need for adhesive systems which ensure a reliable bond to the filling material on one side and to the dental hard tissues on the other.

Dental composite restoratives consist of a hydrophobic, i.e. water repellent, matrix into which different filler particles are embedded.

In contrast, the dental hard tissue comprises two very different substrates:
enamel and dentin. Enamel essentially consists of 96% hydroxyapatite, crystalline calcium phosphate, and only 4% organic material and water [1]. Dentin consists of 70% hydroxyapatite but has a high content of organic material, essentially collagen (20%) and 10% water [2]. Therefore, enamel is essentially a dry substrate, while dentin is a wet hydrophilic substrate.

In order to establish a bond to both enamel and dentin, adhesive systems thus have to fulfil very different pre-requisites.

Furthermore, after tooth preparation with rotary instruments, the preparation is covered by a layer of debris, called the smear layer.

1.2 The technique

Effective adhesion to the tooth structure was first described by Buonocore [3]. He demonstrated that upon etching with phosphoric acid acrylic resin effectively adhered to enamel. However, bonding to dentin was not yet successful for two reasons:

- The hydrophobic bonding resins were not able to wet the hydrophilic dentin of etched dentin.
- If the smear layer was left in place, only about 5 MPa of bond could be achieved prior to cohesive fracture within the smear layer [4; 5].

The inability to bond to dentin was circumvented by limiting the indication of composite restorations to cavities with enamel margins only and by protecting the dentin with a liner. Such restorations were clinically successful as documented by long term clinical trials with Heliobond and Heliomolar [6-9].

The breakthrough in dentin bonding came with the three-step systems, which bridged the gap between the hydrophilic dentin and the hydrophobic resin-based filling material by the sequential application of three components.

1. Conditioning: etching enamel with phosphoric acid, removal or modification of the smear layer and exposure of dentin collagen

2. Infiltration of exposed collagen with resins hydrophilic enough to wet dentin, e.g. HEMA, glycerol dimethacrylate, polyethyleneglycol dimethacrylate
3. Bonding: Coating the primed dentin and the etched enamel with a hydrophobic bonding agent.

With the products of that time it was observed that bonding agents removing the smear layer achieved better retention rates in clinical trials than others which only modified the smear layer [10; 11]. Therefore, removal of the smear layer appeared to be a prerequisite for adhesion to dentin. The notion that the smear layer had to be removed for achieving effective adhesion to dentin led to the next logical step in dentin bonding: the total-etch adhesives.

To condition the preparation, enamel and dentin are etched with phosphoric acid first. As a second step, a one-bottle adhesive is applied. While this has been a simplification of the application procedure, one had to realize soon that total-etch adhesives required an optimal application technique and rigorous moisture control for clinical success. This is illustrated by the often discussed question: “How wet is wet?” The complete removal of the smear layer also increased the risk of postoperative sensitivities with this group of adhesives.

Even though total-etch adhesives are considered to be technique sensitive [12], they are clinically successful [13; 14].

1.3 The products

The table below shows the working steps required to establish a bond between restorative material and tooth structure as well as in which way multi-step, total-etch and self-etch two-component adhesives as well as self-etch all-in-one adhesives are applied:

<table>
<tr><th rowspan="2">Working step</th><th rowspan="2">Purpose of this working step</th><th colspan="4">Type of adhesive</th></tr>
<tr><th colspan="2">Total-etch</th><th colspan="2">Self-etch</th></tr>
<tr><td>Condition enamel</td><td>Expose retentive enamel etch pattern</td><td>H_3PO_4</td><td rowspan="2">H_3PO_4</td><td rowspan="3">AdheSE Primer</td><td rowspan="4">AdheSE One F</td></tr>
<tr><td>Condition dentin</td><td>Expose collagen network and dentinal tubules</td><td>Syntac Primer</td></tr>
<tr><td>Wet</td><td>Create transition between hydrophilic and hydrophobic tooth structure</td><td>Syntac Adhesive</td><td rowspan="2">ExciTE F</td></tr>
<tr><td>Bond</td><td>Bond to composite</td><td>Heliobond</td><td>AdheSE Bonding</td></tr>
</table>

Multi-step adhesives, such as Syntac, are still considered to be among the clinically most successful adhesives systems [15-17]. However, the more steps are involved, the more time is required and the more potential sources of error exist. Therefore, the priority of adhesive development has been clearly set on providing dentists with products that are faster and easier to apply. A logical consequence is thus the reduction of the steps in the application of the product. Therefore, multi-step adhesives were followed by two-step adhesives.
These adhesives were initially used in combination with the total-etch technique, while a few years later, two-bottle self-etching adhesives were introduced.

Still a few years later, one-step adhesives appeared on the market. These adhesives require only one coat of liquid to be applied, which is either mixed from several components prior to application or, such as in the case of all-in-one adhesives, is supplied ready-mixed in bottles or, as AdheSE One, in the unique VivaPen delivery form.

Due to this different etchability of enamel and dentin, many dentists still prefer total-etch adhesives, if a major fraction of the bonding area is enamel. This particularly applies for the esthetically sensitive anterior restorations. ExciTE F proves that even adhesives used in conjunction with the total-etch technique can be made more user-friendly: a fluoride source has been incorporated which enables fluoride ions to be released. Moreover, the VivaPen with the new, improved ergonomic design renders application of the adhesive more convenient.

1.4 The technological advantages of ExciTE F

1.4.1 Hydrolytically stable monomers

Just as ExciTE, ExciTE F contains hydrolytically stable monomers from Ivoclar Vivadent.

Phosphate groups exhibit a high level of affinity to positively charged ions. Because of their chemistry, these groups lend themselves to being used in dentin adhesives [18]. For this purpose, the phosphoric acid group is coupled to a methacrylate group. Because of its affinity to positively charged ions, the phosphoric acid group bonds to the calcium of enamel and dentin, while the methacrylate group establishes a chemical bond with the other polymerizable components of the adhesive.

For this purpose, most manufacturers use what are known as phosphoric ester compounds (Fig. 2). These compounds, however, demonstrate one drawback: The C-O-P bond is not hydrolytically stable. Therefore, Ivoclar Vivadent has developed and patented a phosphonic acid compound as an adhesive monomer. This compound is decidedly more stable, as the phosphorous atom directly bonds with a carbon atom (C-P).

A phosphonic acid compound was used as the acid monomer for the first time ever in the one-bottle adhesive ExciTE, the predecessor of ExciTE F (Fig. 2).

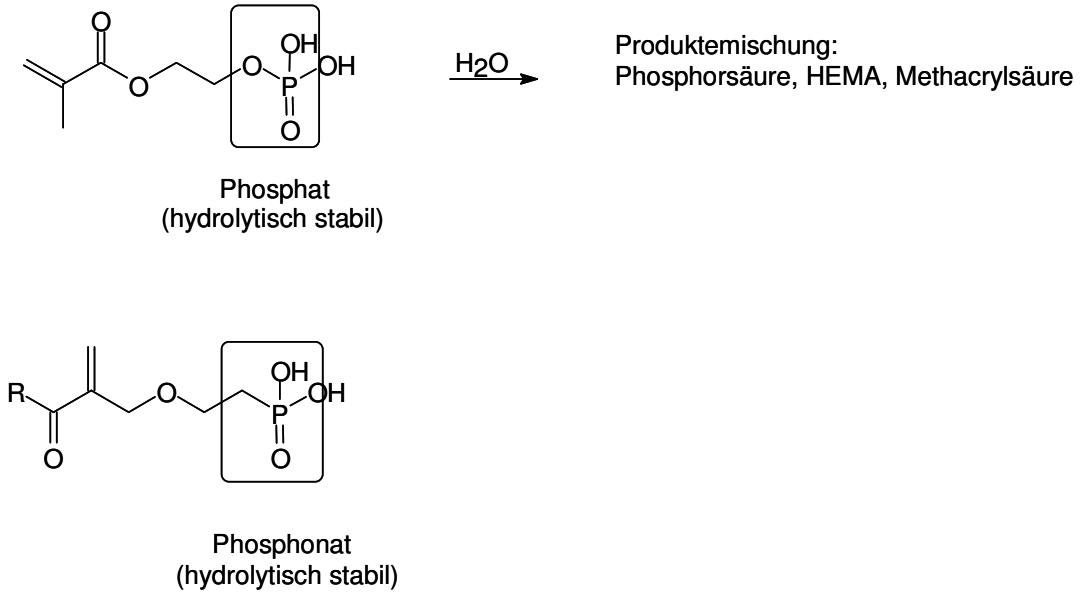


Fig. 2: Structural formula of phosphonic acid acrylate compared with that of a phosphoric acid ester compound.

High monomer content

Just as the predecessor product ExciTE, ExciTE F stands out amongst other adhesives because of its exceptionally high monomer content. While other adhesives contain up to 80% solvent, the solvent content in ExciTE F is as low as 20%. ExciTE's high monomer content (>75%) facilitates the thorough polymerization of the adhesive resin layer. Consequently, users no longer have to use strong blasts of air to disperse the adhesive layer in order to allow the solvent to evaporate. This earlier drying procedure presented the risk of blowing away adhesive monomers and excessively thinning the adhesive layer. ExciTE F requires only a weak stream of air to disperse the material to an even layer.

Acetone free

The influence of solvents on dentin adhesives has been widely discussed in the literature [19; 20]. Acetone is characterized by its high volatility, which is instrumental in drying the adhesive resin layer. However, acetone-containing adhesives are effective only on moist dentin. Although water-based adhesives are insensitive to the degree of moisture in dentin, the adhesive layer must be adequately dried to remove the water. Ethanol combines the favorable properties of acetone and water. Ethanol exhibits an additional advantage compared with acetone in that it does not evaporate as readily when the bottle is open. Therefore, the viscosity of the adhesive does not significantly change while the bottle is in use.

1.5 The delivery form – It's your choice!

Fig. 3: ExciTE F is offered in hygienic Soft-Touch Single Dose vessels, in bottles and in the ergonomic VivaPen with brush cannula.

The adhesive is dispensed from the economical multiple-use drop bottle onto a pad from where it is applied with an applicator.

The VivaPen with the disposable snap-on cannula allows the required amount of adhesive to be applied exactly where it is needed. The brush cannula serves as an applicator. Additionally, the VivaPen sleeve can be used to ensure hygienic working conditions and protect the patient from possible infection by means of cross-contamination.

The Soft-Touch Single Dose vessels are the optimal delivery form if hygienic single doses are preferred. One Single Dose vessel contains just the right amount of material needed for one average application. Furthermore, the risk of contamination of e.g. the skin is minimal. As contact with the skin can lead to a sensitization to methacrylates, allergic contact dermatitis may develop. Ensuring adequate protection for themselves is becoming increasingly important for dental staff. In this context, it should be pointed out that commercial medical gloves do not provide protection against the sensitizing effect of methacrylates.

1.6 Innovative and user-friendly – The new VivaPen

The optimized VivaPen with the new design, improved ergonomic features and integrated fill-level indicator.

The novel snap-on cannula is attached to the VivaPen.

The new VivaPen features an easy-to-operate click mechanism. A few clicks are sufficient to saturate the brush tip with an appropriate amount of material. The discoloration of the tip shows that it has been saturated with adhesive.

Even the fill-level of the VivaPen can now be visually checked. As a result, the user has consistent control over the availability of material.

1.7 Adhesive with fluoride release

The addition of potassium fluoride to ExciTE F ensures a consistent release of fluoride ions in the first days following placement of the restoration.

Potassium fluoride dissolves well in ExciTE F and the solution is not affected by temperature fluctuations and sedimentation.

The released fluoride can support the sealing of the tubules by forming calcium fluoride: This may help prevent dentinal fluid movement and the post-operative sensitivities associated with it. The addition of a source of fluoride can thus contribute to avoiding post-operative sensitivities.

2. Technical Data

Standard composition	**(in weight%)**
Phosphonic acid acrylate, Hydroxyethyl methacrylate, dimethacrylate	77.9
Highly dispersed silica	0.5
Ethanol	19.5
Catalysts, stabilizers, fluoride	2.1

Physical properties

Shear bond strength on dentin	28	MPa
Shear bond strength on enamel	25	MPa

3. In-Vitro Investigations

In the laboratory, the quality of adhesive systems can be tested by means of various methods. This type of in-vitro investigations are usually conducted with bovine teeth or extracted human teeth.

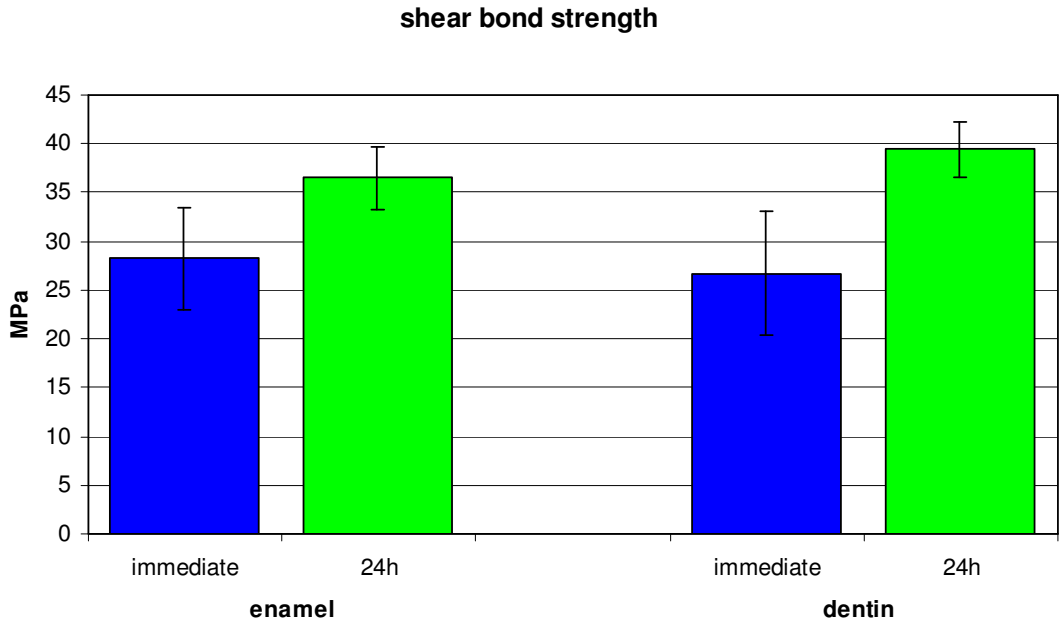
In conjunction with dental adhesives, the bond strength achieved on dentin and enamel is of particular importance. As the task of a dental adhesive is to mediate a durable and sound bond between the dental hard tissues and the restorative, marginal analysis is also a useful method to assess the performance. For this purpose, adhesives are tested in combination with restorative materials. With these test set-ups, the performance of the material can be investigated under various conditions. The results of the tests allow conclusions to be drawn on the clinical performance of the adhesive. Micro-morphological investigations under the scanning electron microscope may deliver additional information on the quality of the dentin-adhesive or enamel-adhesive interface.

The predecessor product of ExciTE F has been on the market for a very long time. Therefore, many investigations with this product are available and most of them have been presented in scientific meetings or been published in dental journals. As the formulation of ExciTE F is the same as that of ExciTE except for the fluoride source, the results of the studies are also applicable to ExciTE F.

3.1 Bond strength testing

3.1.1 Shear bond strength to dentin and enamel immediately after application and after 24 hours

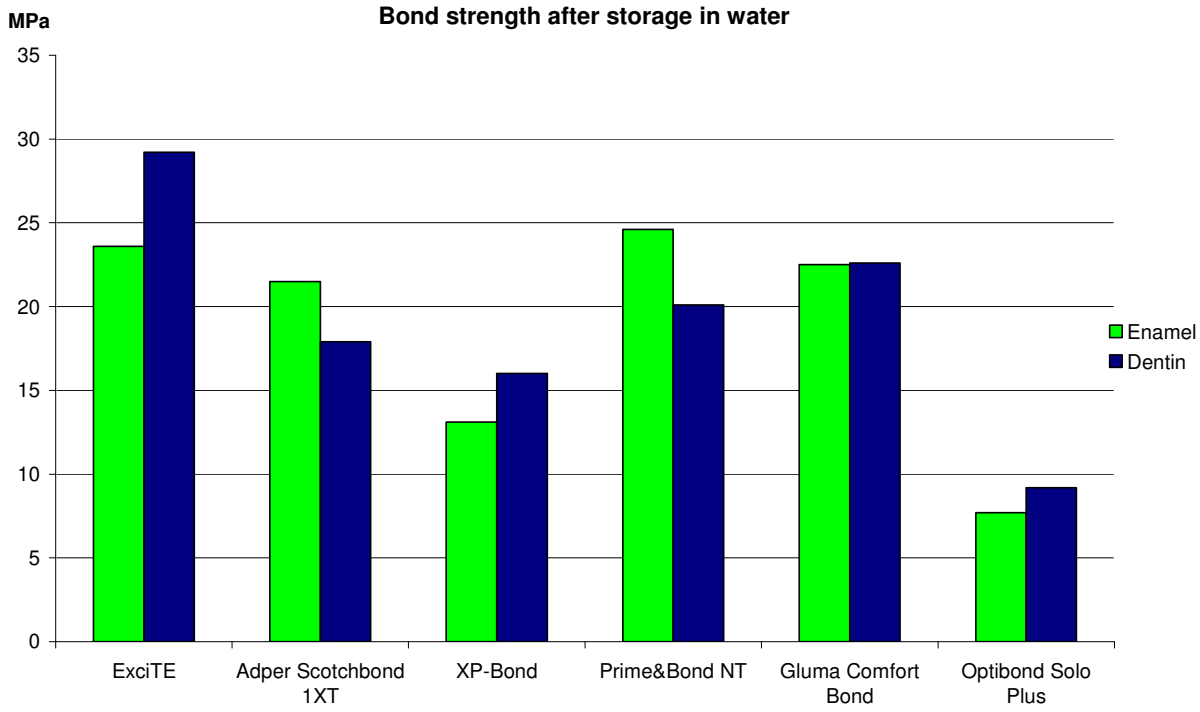
In order to measure the shear bond strength, the enamel or dentin layer of extracted human teeth was exposed using sand paper under water cooling. Subsequently, ExciTE F was applied according to the Instructions for Use and a composite cylinder was built up according to the Ultradent method using Tetric EvoCeram. Prior to measuring the shear bond strength, half of the test specimens were immersed in distilled water at 37°C for 24 hours, while in the other half the shear bond strength was measured immediately after preparation.



Investigation: M.A. Latta, D.M.D., M.S., Creighton University, Omaha, USA 2010

3.1.2 Shear bond strength to dentin and enamel in comparison with competitor products

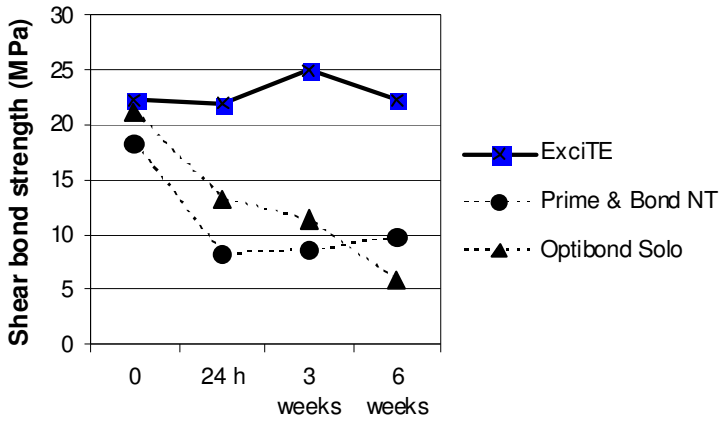
The shear bond strength of different commercially available total-etch adhesives was measured in-house on bovine dentin and enamel according to ISO TR 11405. The procedure corresponded to the respective Instructions for Use. The bond strength was determined after storage in water at 37 °C for 24 hrs.



Under these conditions it could be shown that ExciTE belongs to the group of total-etch adhesives with the highest bond strength values to dentin and enamel. For ExciTE F partly even higher values were obtained (cfr. 3.1.1).

3.1.3 Influence of open storage on bond strength

Bottles containing adhesives are frequently opened and closed, allowing the solvent to evaporate. This may impair the performance of the material. In particular products employing acetone as solvent are affected because of the volatility of this compound.



Given the high monomer content and the low volatility of ethanol compared with acetone, products such as ExciTE and ExciTE F are exceptionally stable. The above diagram confirms this fact.

At baseline 0, the bonding values achieved with fresh adhesive were measured. Subsequently, the bottles were left open and stored at room temperature. The bond strength was measured after certain intervals.

Of the materials tested, ExciTE demonstrated the most consistently high bonding values. The same can be expected for ExciTE F.

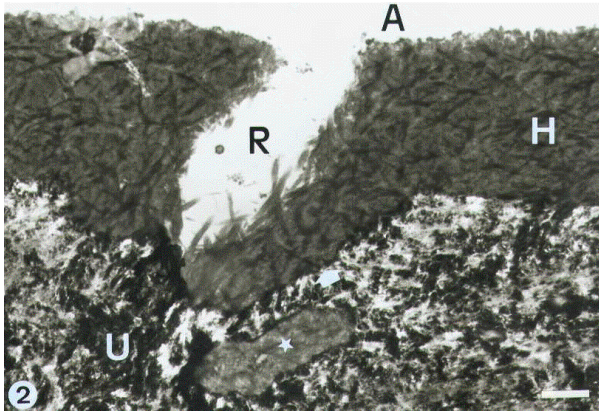
Investigation: Habib C, Kugel G, Tufts University, Boston, USA [21].

3.2 Marginal integrity and morphology

Micro-leakage may be defined as the “clinically undetectable passage of bacteria, fluids or molecules between the cavity wall and the restorative material”. Marginal leakage may cause sensitivity, discoloration of margins and secondary caries. Generally, marginal integrity is measured using extracted teeth. Marginal integrity is investigated after the restored teeth have been subjected to temperature changes or mechanical loading. Marginal quality is evaluated either in terms of functionality or morphology. In functional evaluations, the marginal seal is assessed by means of dye penetration, whereas in morphological evaluations, the marginal quality is evaluated by means of replica investigation under the scanning electron microscope.

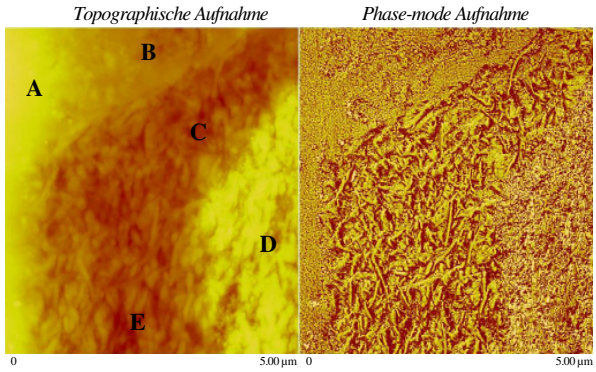
3.2.1 Morphological analysis of the interaction with dentin

Comparative analyses were conducted to investigate the bonding mechanism of ExciTE on dentin utilizing field emission scanning electron microscopy, transmission electron microscopy and atomic force microscopy.



Investigation: TEM: B. van Meerbeek et al, University of Leuven, Belgium

- A uniform hybrid layer (H) of a thickness of 3-4 µm has formed.
- The hybrid layer is clearly distinguishable from the underlying, unaffected dentin (U).
- At the surface of the hybrid layer, the collagen fibres appear as a “shag carpet”. This appearance is typical of adhesives that have been applied using active techniques such as scrubbing.



Investigation: AFM: B. van Meerbeek et al, University of Leuven, Belgium

- The dentin tubules have been unplugged from the smear layer by acid etching and resin tags have formed.
- Lateral hybridization in the dentin tubules is observed.

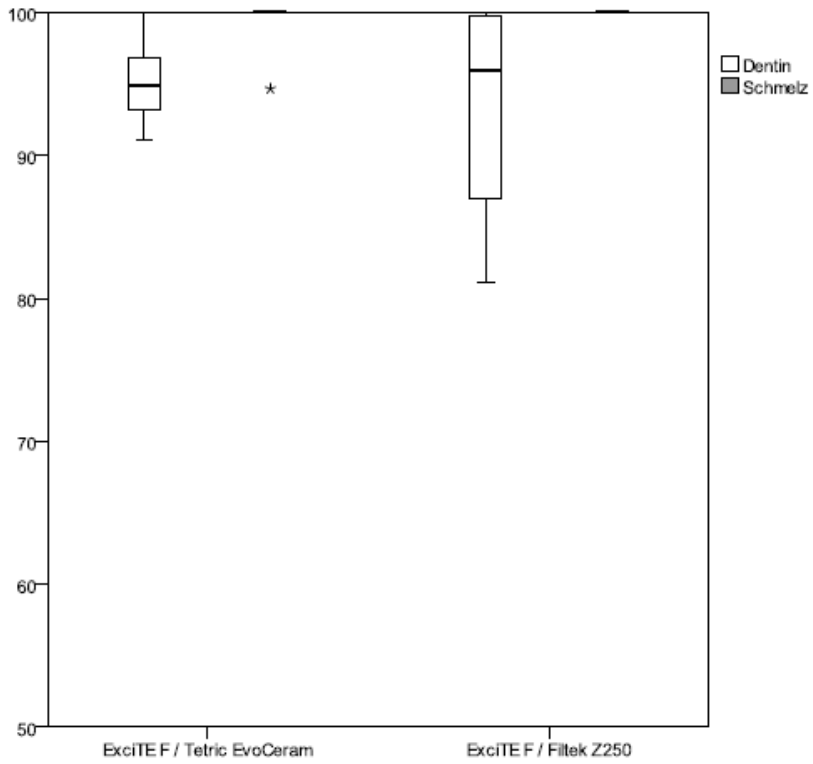
A = adhesive layer
B = resin tag
C = tubule wall hybridization
D = unaffected dentin
E = hybrid layer

ExciTE exhibits effective hybridization between and within the dentin tubules. All morphological properties associated with effective dentin adhesives are discernible.

3.2.2 Quality of ExciTE F margins in Class V cavities

Quantitative marginal analyses are conducted in the laboratory to establish the quality of restorations. A comparative evaluation of the results of the respective *in-vitro* and *in-vivo* studies has proved that the results of the procedure applied below shows a statistically significant correlation with the clinical assessment, if the tested adhesive systems are combined with the same composite materials [22].

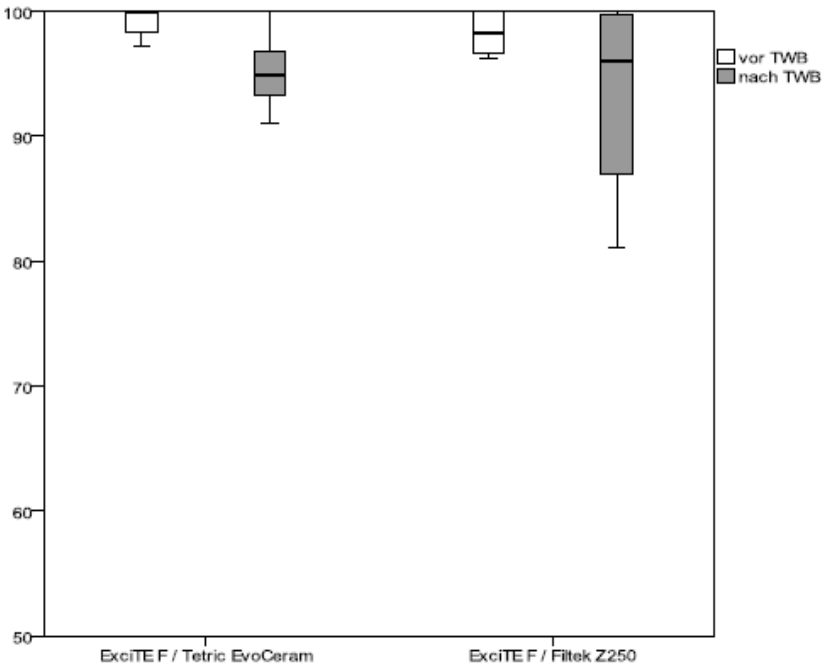
Eight class-V restorations were placed in extracted anterior teeth using ExciTE F in combination with Tetric EvoCeram or Filtek Z250. Fifty percent of the restoration margin was below the amelo-cement junction, with the depth of the cavity being 1.5 mm. The type of preparation procedure chosen ensured that both the enamel and the dentin were cut with diamond burs. After finishing of the restorations and immersion in water for three weeks, the specimens were subjected to thermocycling involving 2,000 cycles at +5° and +55 °C. Following this, replicas of the restorations surfaces were made and the marginal seal was assessed by means of quantitative marginal analysis according to defined criteria in the scanning electron microscope (SEM).



Investigation: Dr. U. Blunck, Charité Berlin, Germany, 2010

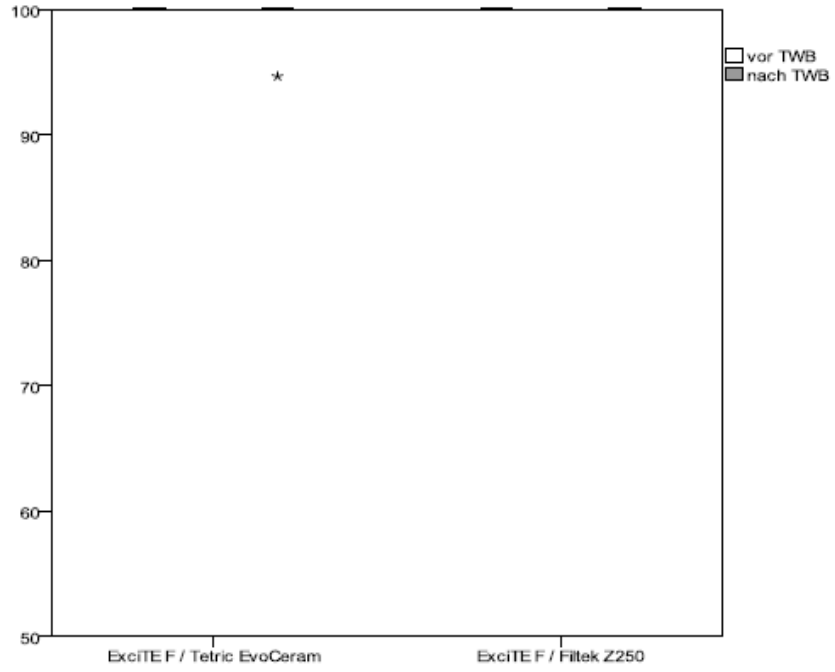
Share of continuous margin in % along the entire margin of Tetric EvoCeram restorations and Filtek Z250 restorations placed in combination with ExciTE F adhesive. The data were obtained in dentin and enamel after thermocycling.

Share of continuous margin (%) in enamel prior to and after thermocycling:



Investigation: Dr. U. Blunck, Charité Berlin, Germany, 2010

Share of continuous margin (%) in enamel prior to and after thermocycling:



Investigation: Dr. U. Blunck, Charité Berlin, Germany, 2010

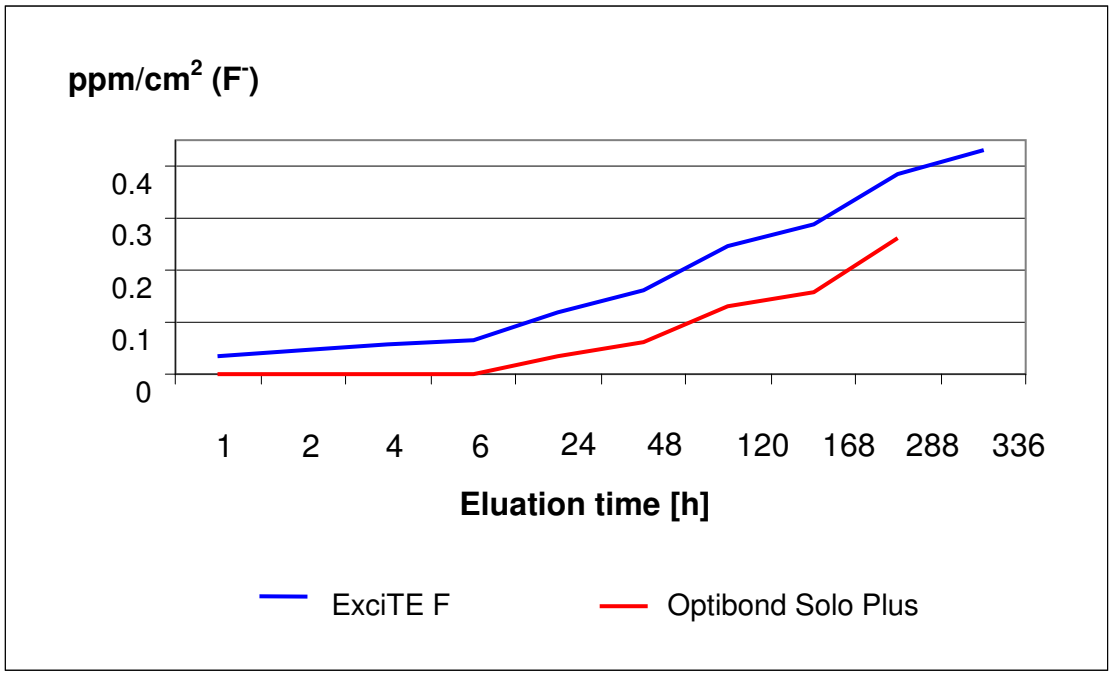
The results show that very good marginal quality can be achieved both on dentin and on enamel if ExciTE F is used in combination with Tetric EvoCeram.

A statistical calculation of the results for restorations fabricated with Tetric EvoCeram or Filtek Z250 in combination with ExciTE F revealed no statistically significant differences ($p>0.05$) in the values achieved in enamel and dentin both prior to and after thermocycling.

From the results of these investigations it can thus be concluded that ExciTE F is very effective in Class V cavities and thus highly suitable for this indication.

3.3 Fluoride release

In order to measure the fluoride release, thin tabs of polymerized ExciTE F were incubated in artificial saliva at 37 °C on a vibrator. The eluation buffer was changed at regular intervals and the fluoride contents determined by means of an ion-selective electrode (ISE). The graph below shows the results in the form of a cumulated release curve:



Investigation: R&D Ivoclar Vivadent, Schaan, Liechtenstein, 2009

It is obvious that ExciTE F releases fluoride ions at a nearly constant rate during a period of at least 14 days.

4. Clinical Investigations (in-vivo)

As the formulation of ExciTE F is the same as that of ExciTE except for the fluoride source, the results of the studies are also applicable to ExciTE F.

4.1 Cervical lesions (Class V)

Most cervical defects, particularly abrasion and erosion defects, do not provide any mechanical retention to a restoration. Hence, restorations of cervical defects are uniquely suited for clinical trials with adhesives as unsuitable adhesives can be identified at a very early stage if the filling is lost.

4.1.1 Dr. Blunck, Charité, Berlin, Germany

Experimental: The aim of this study was to examine the clinical performance of AdheSE in comparison to ExciTE according to the ADA guidelines for dentin and enamel adhesive materials. Cervical defects caused by erosion or abrasion were restored without prior preparation. The defects were only cleaned with a fluoride-free polishing paste. 31 defects per adhesive were restored with Tetric Flow. The study was conducted according to the split-mouth design to as large an extent as possible.

All restorations were placed in 31 patients between November 2001 and February 2002. Evaluations have been carried out after 6, 18 and 36 months. 26 Patients (84%) completed the 3-year recall.

Results:

ExciTE	**Baseline**	**18 months**	**36 months**
Retention	100%	90%	81%
Marginal irregularities	100%A	69%A, 19%B, 12%C	76%A, 24%B
Marginal step or gap	100%A	58%A, 27%B, 15%C	52%A, 38%B, 10%C
Marginal discoloration	100%A	77%A, 15%B, 8%C	86%A, 14%B
Surface discoloration	100%A	100%A	95%A, 5%B
Postop. sensitivities	100%A	100%A	100%A
Secondary caries	100%A	100%A	100%A
Anatomical shape	100%A	96%A, 4%B	95%A, 5%B
AdheSE	**Baseline**	**18 months**	**36 months**
Retention	100%	93%	89%
Marginal irregularities	100%A	67%A, 26%B, 7%C	70%A, 26%B, 4%C
Marginal step or gap	100%A	48%A, 30%B, 22%C	57%A, 35%B, 8%C
Marginal discoloration	100%A	67%A, 30%B, 3%C	74%A, 26%B
Surface discoloration	100%A	100%A	96%A, 4%B
Postop. sensitivities	100%A	96%A, 4%B	100%A
Secondary caries	100%A	100%A	100%A
Anatomical shape	100%A	96%A, 4%B	96%A, 4%C

Conclusion: Both ExciTE and AdheSE fulfil the requirements of full ADA acceptance and exhibit an outstanding retention in non-prepared Class V defects even after 3 years. While AdheSE showed a slightly higher

retention rate than ExciTE, restorations fabricated with ExciTE were rated better with respect to marginal irregularities and discoloration.

4.1.2 Prof. J. Swift, University of North Carolina, Chapel Hill, USA

Experimental: Fifty Class V restorations have been placed in 25 patients using ExciTE and Tetric Ceram. In most cases, about 75% of the surface of the restoration was in dentin. The restorations were evaluated according to ADA criteria after 6 and 18 months.

Results:

ExciTE/Tetric Ceram	Baseline	6 months	18 months
Retention	100%A	94%A, 6%C	84%A, 16%C
Colour match	100%A	100%A	100%A
Marginal discoloration	100%A	100%A	98%A, 2%B
Secondary caries	100%A	100%A	100%A
Wear	100%A	100%A	100%A
Marginal adaptation	100%A	100%A	98%A, 2%B
Postoperative sensitivity	100%A	100%A	100%A

Conclusion: After 18 months, 8 of the 50 Class V restorations had been lost. On the whole, the clinical behaviour of ExciTE and Tetric Ceram was excel-lent. Not a single case of postoperative sensitivity or secondary caries was reported.

4.1.3 Prof. S. Duke, University of Indiana, Indianapolis, USA

Experimental: Fifty-six Class V restorations were placed in 28 patients using ExciTE and Tetric Ceram. The restorations were evaluated according to ADA criteria after 6 and 18 months.

Results:

ExciTE/Tetric Ceram	Baseline	6 months	18 months
Retention	100%A	100%A	96%A, 4%C
Colour match	86%A, 14%B	84%A, 16%B	90%A, 10%B
Marginal adaptation	100%A	100%A	100%A
Marginal discoloration	100%A	100%A	100%A
Anatomical shape	100%A	100%A	100%A
Secondary caries	100%A	100%A	100%A
Postoperative sensitivity	75%A, 25%B	100%A	100%A

Conclusion: After 18 months, only 2 restorations had been lost. This corresponds to an outstanding retention rate for Class V restorations of 96%. This result lies well within the ADA guidelines. Initial postoperative sensitivity to heat and cold disappeared after only six months.

4.2 Posterior restorations (Class I & II)

Occlusion-bearing posterior restorations are typically employed to test the clinical performance of restorative materials. Clinical trials with Class I&II cavities provide important information on the performance of an adhesive. In deep cavities, only an effective adhesive can prevent the occurrence of post-operative sensitivities. Furthermore, marginal quality is to a large part the function of the correct application of an adhesive and its clinical performance.

4.2.1 Prof. Dr. van Dijken, University of Umea, Sweden

Experimental: Four Class I and 96 Class II cavities were restored according to the split-mouth principle: half with a low shrinking composite (InTen-S, Ivoclar Vivadent) and ExciTE and half with the composite Point4 (Kerr) and Optibond Solo Plus (Kerr). Astralis 7 (Ivoclar Vivadent) was used to cure the materials.

The examinations were completed after 3 years.

Results:

ExciTE	**Baseline**	**12 months**	**36 months**
Anatomical shape	98%A, 2% B	92%A, 6%B, 2%C	90%A, 5%B, 5%D
Marginal adaptation	100%A	72%A, 26%B, 2%D	80%A, 15%B, 5%D
Colour match	54%A, 46%B	32%A, 68%B	30%A, 70%B
Marginal discoloration	100%A	92%A, 8%B	91%A, 9%B
Secondary caries	100%A	98%A, 2%D	96%A, 4%D
Surface quality	96%A, 4%B	82%A, 18%B	95%A, 5%B
Postop. sensitivity	96%A, 4%B	100%A	100%A
In situ	100%A	98%A, 2%D	93%A, 7%D
OptiBond Solo Plus	**Baseline**	**12 months**	**36 months**
Anatomical shape	94%A, 6 %B	92%A, 6%B, 2%C	93%A, 5%B, 2%D
Marginal adaptation	100%A	82%A, 14%B, 4%D	78%A, 20%B, 2%D
Colour match	60%A, 40%B	27%A, 73%B	23%A, 77%B
Marginal discoloration	100%A	90%A, 10%B	88%A, 12%B
Secondary caries	100%A	100%A	98%A, 2%D
Surface quality	94%A, 6 %B	90%A, 10%B	95%A, 5%B
Postop. sensitivity	100%A	100%A	100%A
In situ	100%A	96%A, 4%D	95%A, 5%D

Conclusion: In the 3 years of the experimental, only 5 restorations had to be replaced. Two amalgam replacement fillings, i.e. one InTen-S and one Point 4 restoration, were lost due to cusp fractures. Two restorations fabricated with InTen-S and one with Point 4 had to be replaced because of secondary caries.

4.2.2 Prof. Dr. Merte, University Clinic Leipzig, Germany

Experimental: The clinical performance of ExciTE and 4 Seasons in restoring Class I or II cavities was tested over a 2.5-year period. Forty-one restorations were placed. After 6, 12 and 24 months, 40, 40 and 37 restorations could be evaluated, respectively.

Results:

Artemis/ExciTE	**6 months**	**12 months**	**24 months**
Colour match	85%A, 15%B	68%A, 32%B	78%A, 22%B
Marginal discoloration	98%A, 2%B	75%A, 25%B	76%A, 24%B
Marginal quality	76%A, 24%B	73%A, 27%B	41%A, 59%B
Secondary caries	100%A	100%A	100%A

Anatomical shape	93%A, 7%B	98%A, 2%B	87%A, 10%B, 3%C
Surface roughness	83%A, 17%B	75%A, 25%B	68%A, 32%B
Postoperative sensitivity	100%A	100%A	100%A
Cumulative survival rate	100%A	100%A	97%A, 3%D

Conclusion: Since only shades A2 and A3 were available, it was not possible to achieve an optimal shade match. Only one restoration was not successful after 2 years. This result is proof of the favorable clinical performance of ExciTE in restorations for the posterior region.

4.2.3 Dr. Gernhardt, Prof. Dr. Schaller, University of Halle, Germany

Experimental: The aim of this study was the clinical evaluation of the self-etching AdheSE in combination with Tetric Ceram HB in Class I & II cavities. The total-etch adhesive ExciTE served as control. One hundred cavities in 50 patients were treated. Twenty-seven of the cavities were classified as Class I and 72 as Class II. All the treated teeth were vital.

Sixty-seven of the 100 placed restorations were evaluated after two years. After 4 years, only 60 restorations were available for recall. Fifteen of them were Class I restorations and 45 of them Class II restorations.

Results:

ExciTE	6 months	12 months	24 months	48 months
Recalled restorations	50	43	33	30
Tooth vitality	98%A, 2%C	98%A, 2%C	97%A, 3%C	97%A, 3%C
Postoperative sensitvity	96%A, 4%B	100%A	100%A	100%A
Marginal irregularities	96%A, 4%B	88%A, 12%B	94%A, 6%B	93%A, 7%B
Marginal discoloration	98%A, 2%C	91%A, 9%B	91%A, 9%B	87%A, 13%B
Surface texture	98%A, 2%C	98%A, 2%C	100%A	100%A
Secondary caries	100%A	100%A	100%A	100%A
Anatomical shape	100%A	100%A	100%A	100%A
Filling defects	100%A	98%A, 2%C	97%A, 3%C	97%A, 3%C
AdheSE	**6 months**	**12 months**	**24 months**	**48 months**
Recalled restorations	50	43	34	30
Tooth vitality	98%A, 2%C	98%A, 2%C	97%A, 3%C	100%A
Postoperative sensitivity	98%A, 2%C	98%A, 2%C	97%A, 3%C	100%A
Marginal irregularities	94%A, 6%B	91%A, 9%B	85%A, 15%B	83%A, 17%B
Marginal discoloration	98%A, 2%C	88%A, 12%B	82%A, 18%B	83%A, 17%B
Surface texture	98%A, 2%C	98%A, 2%C	100%A	97%A, 3%C
Secondary caries	100%A	100%A	100%A	100%A
Anatomical shape	100%A	100%A	100%A	100%A
Filling defect	100%A	100%A	97%A, 3%C	100%A

Conclusion: At baseline, the restorations did not exhibit any deficiencies. Two teeth, one in each group, required endodontic therapy between baseline and 6 months. After 24 months one filling placed with ExciTE and one placed with AdheSE fractured. The overall clinical success of the Tetric Ceram HB restorations summing up A and B ratings was 97% after 2 years. No statistically significant difference was found between the 2 test groups within the observation period.

4.2.4 Dr. Tassery, Avignon, France

Experimental: Thirty-five Class II cavities were restored using Tetric Ceram HB and the dentin adhesive ExciTE. Tetric Ceram HB was applied in incre-ments. Recall examinations were conducted after 3, 6, 12, 24 and 36 months. Thirty-two Restoration could be evaluated throughout the full study period.

Results:

Tetric Ceram HB	1 year	2 years	3 years
Surface texture	91%A, 9%B	94%A, 6%B	81%A, 19%B
Colour match	23%A, 77%B	16%A, 84%B	16%A, 84%B
Marginal integrity	100%A	100%A	81%A, 19%B
Anatomical shape	100%A	100%A	94%A, 6%B
Postop. sensitivity	100%A	100%A	100%A
Secondary caries	100%A	94%A, 6%B	94%A, 6%B
Marginal discoloration	94%A, 6%B	81%A, 19%B	28%A, 72%B
Retention	100%A	100%A	100%A
Survival rate	100%A	100%A	100%A

One tooth with two Tetric Ceram HB restorations, i.e., a MO and a DO, required endodontic treatment after 3 weeks because the pulp was exposed during preparation and was directly capped with ExciTE without using a liner. The restorations remained in place and were not af-fected by the trepanation cavity. No other losses were registered throughout the study.

Conclusion: Tetric Ceram HB and ExciTE provided reliable clinical service over a 3-year period.

4.3 Anterior restorations (Class III & IV)

4.3.1 Prof. Dr. Munoz, Prof. Dr. Dunn, Loma Linda University, California, USA

Experimental: Forty-four anterior restorations, including direct veneers, were placed with Tetric EvoCeram to treat e.g. Class III and IV defects in central/lateral incisors and canines, damaged incisal edges and diastemata. Both ExciTE and Tetric EvoCeram were cured with bluephase.

The study was completed after 2 years.

Results:

Tetric EvoCeram	Baseline	6 months	1 year	2 years
Anatomical shape	100%A	100%A	100%A	100%A
Colour match	100%A	96%A, 4%B	76%A, 24%B	100%A
Marginal adaptation	100%A	100%A	100%A	100%A
Marginal discoloration	100%A	100%A	94%A, 6%B	96%A, 4%B
Surface discoloration	100%A	100%A	85%A, 15%B	100%A
Secondary caries	100%A	100%A	100%A	100%A
Surface polishing	100%A	92%A, 8%B	61%A, 39%B	73%A, 27%B
Retention	100%A	100%A	100%A	100%A

Conclusion: When placing the restorations, clinicians appreciated the good processing properties of Tetric EvoCeram. Dr. Dunn wrote: “On the basis of the preliminary results after 12 months, it can be said that Tetric EvoCeram is a good clinical choice for anterior restorations. It

shows excellent physical and esthetic properties." This has been confirmed with the 2-year data [23].

4.4 Indirect restorations

4.4.1 Prof. M. Ferrari, University of Siena, Siena, Italy

Experimental: Forty patients received IPS Empress 2 inlays. The inlays were placed with ExciTE / Variolink II. Postoperative sensitivity was assessed after 1, 7 and 30 days. The restorations were evaluated according to USPHS criteria after 6 and 18 months.

Results:

Empress 2 Inlays	Baseline	6 months	18 months
Postop. sensitivity	98%A, 2%B	98%A, 2%B	100%A
Retention	100%A	100%A	100%A
Marginal discoloration	100%A	93%A, 7%B	88%A, 12%B
Marginal adaptation	100%A	93%A, 7%B	88%A, 12%B
Surface quality	100%A	100%A	100%A

Conclusion: All the inlays were *in situ* after 18 months. One patient experienced light postoperative sensitivity during the first few months. At the 18-month recall, however, these complaints had disappeared. Therefore, ExciTE is suitable for the adhesive luting of inlays in combination with Variolink II.

4.4.2 Clinical field trial: Indirect restorations (veneers and inlays)

Head of study: D. Hornbrook (San Diego, USA), T. Trinkner (Columbia, USA), R. Ritter (Palm Beach, USA), E. Lowe (Vancouver, Canada), PAC Live

Experimental: At the end of 1998, four experienced operators used ExciTE to seat a total of 691 restorations. Furthermore, 321 additional restorations were placed by 30 different users on the occasion of the PAC training event (Pacific Aesthetic Continuum) in March 1999. Only indirect restorations were placed. These restorations were luted utilizing either a purely light-curing (veneers) or a dual-curing cement. Three weeks after insertion, all the patients were surveyed regarding postoperative sensitivity.

Results: Of the 1012 restorations seated, 983 (97%) were given an "alpha" rating. In 29 cases, postoperative sensitivity was evaluated with a "bravo" rating. In 27 of these cases, however, postoperative sensitivity disappeared after occlusal adjustments were made. Only in two cases did postoperative pain persist for more than three weeks.

Conclusion: In large-scale field trials involving a large number of restorations, ExciTE caused postoperative sensitivity in only a few cases. In most cases, it was possible to alleviate postoperative pain by making occlusal adjustments.

4.5 Summary

ExciTE has been the subject of clinical studies at various European and American universities. Thereby, it has proven to be effective for the restoration of cervical lesions, posterior and anterior restorations and luting of inlays, onlays and veneers.

5. Biocompatibility

Solid specimens of ExciTE F were fabricated by placing liquid ExciTE F into a mould of defined size (2 cm diameter and 1 mm height). Then the samples were polymerized between Mylar foils. Subsequently, these tabs were incubated in defined, suitable media to produce extracts. Following this, toxicological and mutagenicity tests were carried out with concentrations series of these extracts.

5.1 Cytotoxicity

Extracts of the test item ExciTE F possess a cytotoxic potential only at a concentration of 100% (undiluted extract). No cytotoxic activity was observed at lower concentrations [24]. For adhesives, which are generally known to be cytotoxic, this is a very good result.

5.2 Mutagenicity

ISO 10993-3 requires that the mutagenicity of a medical device is tested *in-vitro* by a bacterial test and also by a test employing eukaryotic cells. For these tests, test methods are employed which are in accordance with OECD guidelines.

Ames test

A reverse mutation assay was carried out employing four strains of Salmonella typhimurium and one of Escherichia coli with ExciTE F. It was found that the test item did not induce gene mutations by base pair changes or frameshifts in the genome of the strains used. Therefore, ExciTE F is considered to be non-mutagenic in this Salmonella typhimurium and Escherichia coli reverse mutation assay [25].

Mouse lymphoma assay

The study was performed to investigate the potential of extracts of ExciTE F to induce mutations in the mouse lymphoma thymidine kinase locus using the cell line L5178Y. The assay was performed in two independent experiments using two parallel cultures each. The first main experiment was performed with and without liver microsomal activation and a treatment period of 4 h. The second experiment was solely performed in the absence of metabolic activation with a treatment period of 24 h.

No substantial and reproducible dose-dependent increase in mutant colony numbers was observed in both main experiments. No relevant shift of the ratio of small versus large colonies was observed up to the maximal concentration of the test item which was undiluted extract [26].

Therefore, ExciTE F is considered to be non-mutagenic in this mouse lymphoma assay.

Conclusion on mutagenicity

All tests carried out with ExciTE F employing bacteria, eukaryotic cells did not reveal mutagenic activity. Therefore, ExciTE F is non-mutagenic according to the information available.

5.3 Irritation and sensitization

By nature, adhesives are irritant to some extent, because they have to be able to etch dental hard tissue. This can only be achieved by the use of acid. The irritation potential of ExciTE, the predecessor of ExciTE F, was evaluated with a HET-CAM test. Mean time to coagulation (mtc) of 138/150 and an irritation score (IS) of 6.6/5.0 for duplicate experiments were measured [27]. Therefore, ExciTE is a moderate irritant. The same can be assumed for ExciTE F. Many dental adhesives exhibit shorter mtc times and higher IS values [28]. Therefore, ExciTE is less irritant than the majority of dental adhesives.

Like all resin-based dental materials, ExciTE F contains methacrylate and acrylate derivatives. Such materials may have an irritating effect and may cause sensitization. This can lead to allergic contact dermatitis. Allergic reactions are extremely rare in patients but are increasingly observed in dental personnel, which handle uncured composite material on a daily basis [29; 30]. These reactions can be minimized by clean working conditions and avoiding contact of unpolymerized material with the skin. Commonly employed gloves, e.g., latex or vinyl gloves, do not provide effective protection against sensitization to such compounds.

5.4 Conclusions

ExciTE does not present a risk if it is properly used. Nevertheless, the well-known sensitizing effect of methacrylates must be taken into account when treating people with a hypersensitivity to these materials.

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