

# Futurabond® NR / DC / M

SCIENTIFIC PRODUCT INFORMATION

## VOCO – THE DENTALISTS

...is not merely a claim, but an expression of how our self-understanding has evolved. Since 1981 VOCO has been developing innovative dental materials in Cuxhaven. Meanwhile, more than 500 colleagues, from developer to dental consultant, have one thing in common: their passion for high-tech dental materials.

Numerous products that are clinically successful on a global scale are the result of many years' experience and of our close cooperation with universities and internationally renowned research associations such as the Fraunhofer Society. Products such as Bifluorid 12, Structur Premium, Rebuilda, the ORMOCER® Admira or the nano-hybrid composites Grandio and GrandioSO have become synonymous with quality "Made in Germany".

In the area of adhesives, VOCO can also now look back on many years of experience and a number of successful products: From Polibond, introduced in 1986, to the total-etch systems Solobond Plus (4th generation), Solobond M and Admira Bond (5th generation), up to Futurabond, the first self-etch bond in 1998. And within this VOCO product family, there has also been constant advancement and clinical testing over the last decade. The current representatives of the 6th generation are Futurabond NR and Futurabond DC. As a one-bottle self-etch bond, Futurabond M completes the product range.

This summary documents the results of studies on the Futurabond self-etch bonds. Performance, stability and reliability are reflected here in the numerous externally conducted in vitro and in vivo studies. The reassuringly simple and fast application, however, is best experienced through personal testing – try it with confidence and see for yourself.

## Quality made in Germany

In 1994, VOCO was one of the first companies able to possess a certified quality assurance system (EN ISO 9001 / EN ISO 13485 / Guideline 93 / 42 EEC Annex II). The about 20 members of staff in our quality control department guarantee that our products will always reach you at the consistently high quality you naturally expect from us.

## Innovations for dental health

Certified quality "Made in Germany" is created at our 22,000 m<sup>2</sup> premises here in Cuxhaven. Research, production and administration under one roof ensure that communication between the individual departments is swift and collaboration intensive. Thus we are able to set standards in the development of innovative dental products. VOCO – the Dentalists.



Aerial view of company headquarters at Cuxhaven on the North Sea coast.



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3M Singlebond 2, AdheSE, Adper Prompt L-Pop, AQ Bond Q, Cercon, Clearfil AP-X, Clearfil Protect, Clearfil S3Bond, Clearfil SE Bond, Empress, Filtek Supreme, Filtek Supreme Flow XT, G-Bond, Hybrid Bond, iBond, Maxcem, Optibond All in One, Prime & Bond NT, Prompt L-Pop, RelyX Unicem, Revolcin, Revolcin One, Syntac Classic, X-flow and Xeno III are not registered trademarks of VOCO GmbH.

# Introduction

## What must a bond achieve?

The demands made on a bond are quickly formulated: A bond should achieve sufficiently high adhesion values and exhibit long-term stability with a practice-oriented time and expense expenditure. Adhesion determined in laboratory tests is measured in MPa to allow comparative evaluation, yet, clinically a bond is only good if it shows cohesive failure in these tests, not adhesive failure.

Composite and tooth substance are chemically well-known as two different worlds. More than just simple glue is required to achieve adhesion between the hydrophobic, but homogeneous composite and the inhomogeneous and hydrophilic tooth substance. Since the molecular adhesion mechanisms are very different on each side, an adhesive must additionally be able to create a transition, the so-called hybrid layer, between the two worlds. Originally, this was only possible in steps. Current science is aware of film forming agents and self-organising layers, which create this transition through an automatic organisation of the ingredients. One-bottle bonds and modern self-etch bonds indeed show different properties on each side of the bond site. This was a first step in the direction of reliability in use, as fewer layers and simpler application protocols are synonymous with the elimination of potential faults.

Chemical adhesion to composites is comparatively simple with methacrylate-based systems: The polymerisation, the conversion of double bonds into cross-linked single bonds happens between bond and composite over the same mechanism as the polymerisation within the composite. The surfaces therefore do not require pre-treatment. The tooth, however, is different. Several requirements must be met here:

- 1.) A retentive surface that guarantees mechanical anchoring of the bond must be created.
- 2.) The surface must be totally wetted on dentine and enamel, i.e. the smear layer must be saturated and the bond should penetrate the dentine tubules to be able to form tags there after curing.
- 3.) The bond must be able to build a chemical bond to the hydroxyapatite, via complexing adhesive monomers.

In order to create a retentive surface, Buonocore introduced etching with 37 % phosphoric acid (Buonocore 1955). Etching causes calcium ions to be dissolved out (neutralisation of hydroxide ions) and removed from the chemical equilibrium through complexing by phosphate ions. As a result, the crystalline structures of the hydroxyapatite are dissolved, layer by layer. Whilst etching on enamel is unproblematic in regard to time, dentine can quickly become overetched. If the acid-etch agent is in contact for too long, the collagen fibres on the surface of the dentine are overexposed and can easily collapse. Overdrying of the dentine after the rinsing step can also lead to a breakdown of the collagen fibres. Collapsed collagen fibres form a smeary layer on the surface, interfering with the wetting of the surface and the penetration of the dentinal tubules. Overetching and overdrying in total-etch adhesive procedures are the most common causes of impaired adhesion and post-operative sensitivity.

Self-etch bonding precludes overetching. In contrast to the self-etch procedure, there is no surplus acid present. The acid groups are part of the adhesive monomers and etching is automatically halted by the neutralisation reaction with the alkaline hydroxyapatite. These multifunctional adhesive monomers are not absolutely acid resistant, but at the same time a self-etch bond must be acidic enough to be able to form a sufficiently retentive etching pattern on the enamel. Logically, the adhesion values of different manufacturers' self-etch bonds sometimes vary greatly, as not every system takes adequate account of this fact. In Futurabond NR / DC, the bonding monomers are stored separately. This ensures storage stability even at room temperature. At the same time, a low pH value is possible (pH 2), which can create a sufficiently retentive etching pattern on the enamel. Even greater attention had to be placed on the abovementioned fact in the development of Futurabond M, a one-bottle self-etch bond, as separate storage is naturally not possible for one-bottle systems. However, VOCO's scientific team still managed, through the use of monomers with increased acid resistance, to produce a one-bottle self-etch bond with a shelf-life of two years in chilled storage.

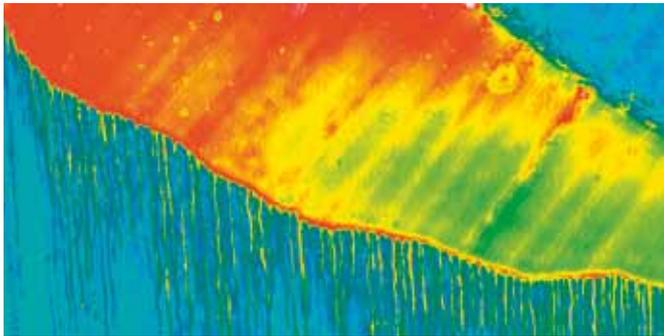
The penetration of the smear layer or exposed collagen fibers is likewise not an issue with self-etch bonds. The exposed fibres are inevitably saturated, since the self-etch bond itself exposes the fibres. The smear layer does not have to be removed. It is converted, i.e. chemically dissolved and integrated into the adhesive layer.

Scanning electron microscopy images and confocal laser scanning microscopy are highly suitable for the morphological examination of the bonding layer. In these images both the smear-layer integration and the formation of tags, up to the lateral processes, are particularly clearly visible (see section REM and CLSM examinations).

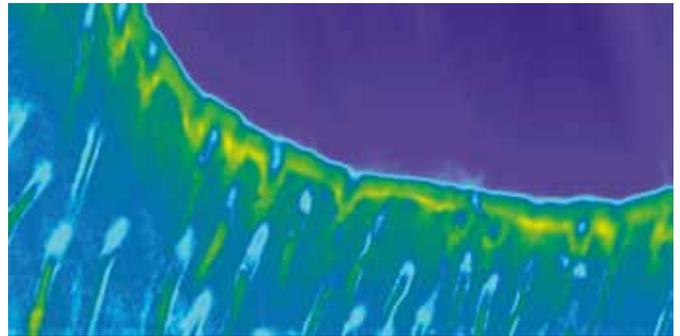
The reliable formation of these tags in the dentine is what best protects from postoperative sensitivity. Separate etching on dentine is unnecessary; it even leads to significantly poorer adhesion values (Proenca et al. 2007). Additional etching, to maximise the adhesive strength, can only be carried out on enamel that has not been instrumentally prepared. This only makes clinical sense when fixing Maryland bridges, which are exclusively fixed to enamel and which daily expose the bond to high shear forces during chewing.

Restoration fracture has by now caught up with secondary caries as the most common reason for failure in direct composite restorations (Kamann et al. 2000; Hickel 2007). This trend shows that adhesive techniques have become secure in recent years. Because of this, the adhesive technique is now deemed to be standard in cavity treatment, according to the latest statement from the German Association of Operative Dentistry (DGZ) on the application of composites for the restoration of Class II defects and the replacement of individual cusps.

## SEM and CLSM testing



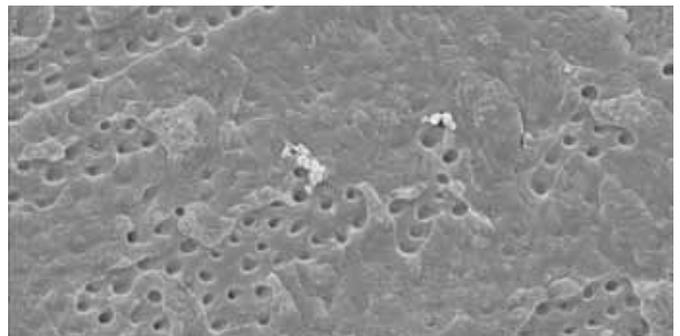
Futurabond NR and Amaris on dentine CLSM  $\times 2500$   
 Prof. Jorge Uribe Echevarría DDS, PhD, MS, Universidad Nacional de Córdoba.  
 Argentina.



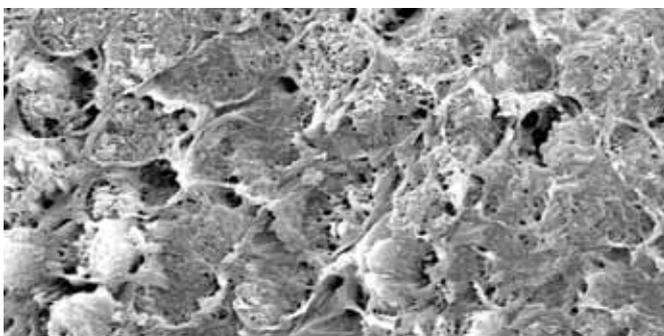
Futurabond NR and Grandio on dentine CLSM  $\times 2500$   
 Prof. Jorge Uribe Echevarría DDS, PhD, MS, Universidad Nacional de Córdoba.  
 Argentina.



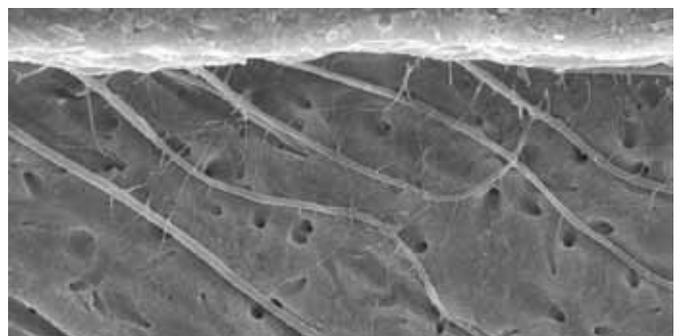
Futurabond NR and Amaris on dentine CLSM  $\times 5500$   
 The picture shows that Futurabond forms tages even in the lateral processes of the tubules.  
 Prof. Jorge Uribe Echevarría DDS, PhD, MS, Universidad Nacional de Córdoba.  
 Argentina.



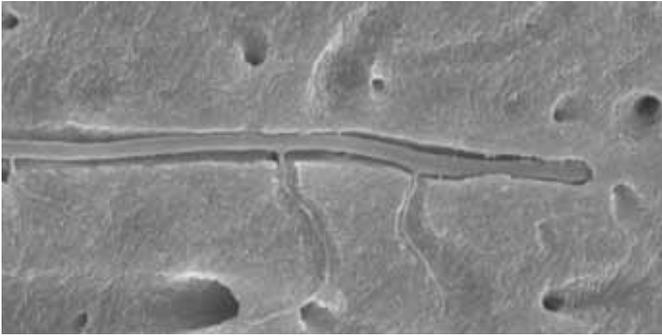
Fracture surface facing dentine in the shear bonding test after 4 years water storage. The hybrid layer is intact and good hybridisation is present.  
 Prof. A.I. Abdalla, Dept. of Conservative Dentistry, Tanta University, Cairo.



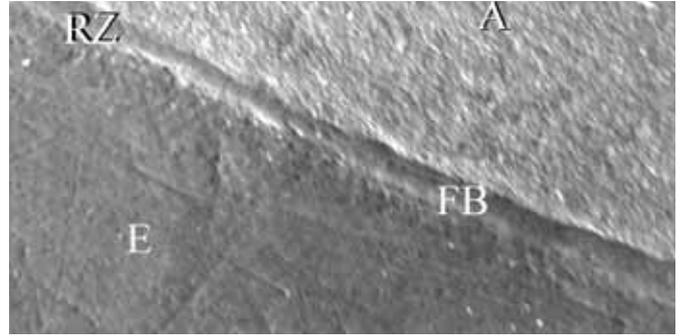
Futurabond etching pattern on enamel.  
 Exterior surfaces of the enamel prisms are demineralised and the interprismatic substance is dissolved.  
 Prof. A.I. Abdalla, Dept. of Conservative Dentistry, Tanta University, Cairo.



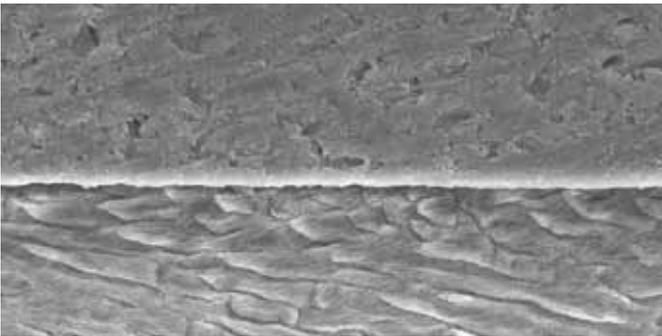
Futurabond NR in the dentine tubules, SEM image  $\times 2000$   
 Radovic I, Vulicevic ZR, García-Godoy F. Oper Dent. 2006 Nov-Dec;31(6):710-8. Report to VOCCO.



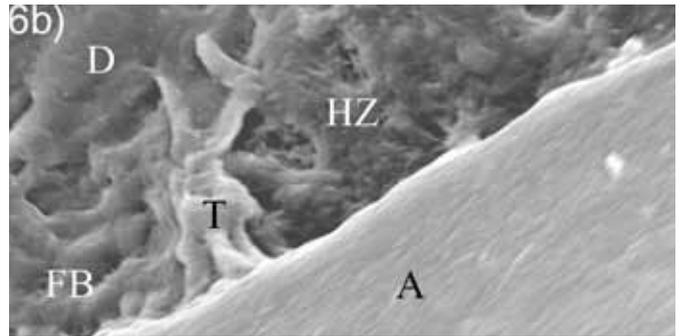
Futurabond NR in dentine tubules and lateral processes SEM image × 1000  
 Radovic I, Vulicevic ZR, García-Godoy F. Oper Dent.  
 2006 Nov-Dec;31(6):710-8. Report to VOCCO.



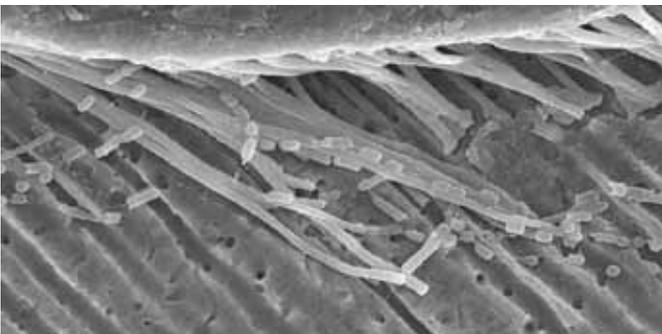
Relaxation zone (RZ) of Futurabond NR (FB) to composite (A) and enamel (E).  
 Magnification 600x, half-year report.  
 Helbig EB, Klimm HW, Rietschel J, Schreger IE, Richter G, Haufe E, DZZ 2005,  
 60(8); 457-63.  
 Courtesy of Deutscher Zahnärzte Verlag.



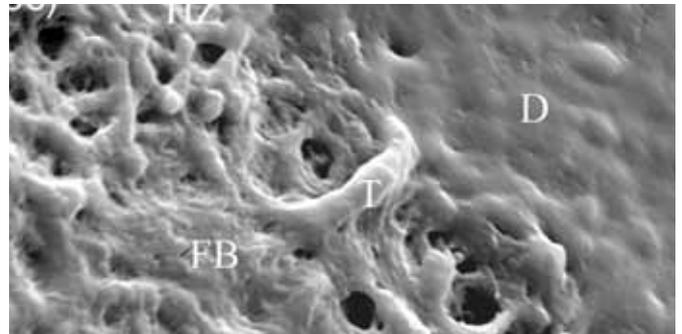
Futurabond NR in the enamel prisms, SEM image × 1000  
 Radovic I, Vulicevic ZR, García-Godoy F. Oper Dent.  
 2006 Nov-Dec;31(6):710-8. Report to VOCCO.



Hybrid zone (HZ) with tags (T) of Futurabond NR (FB) with dentine (D) and composite (A).  
 Magnification 800x, half-year report.  
 Helbig EB, Klimm HW, Rietschel J, Schreger IE, Richter G, Haufe E, DZZ 2005,  
 60(8); 457-63.  
 Courtesy of Deutscher Zahnärzte Verlag.



Futurabond NR in the dentine tubules, SEM image × 1500  
 Radovic I, Vulicevic ZR, García-Godoy F. Oper Dent.  
 2006 Nov-Dec;31(6):710-8. Report to VOCCO.



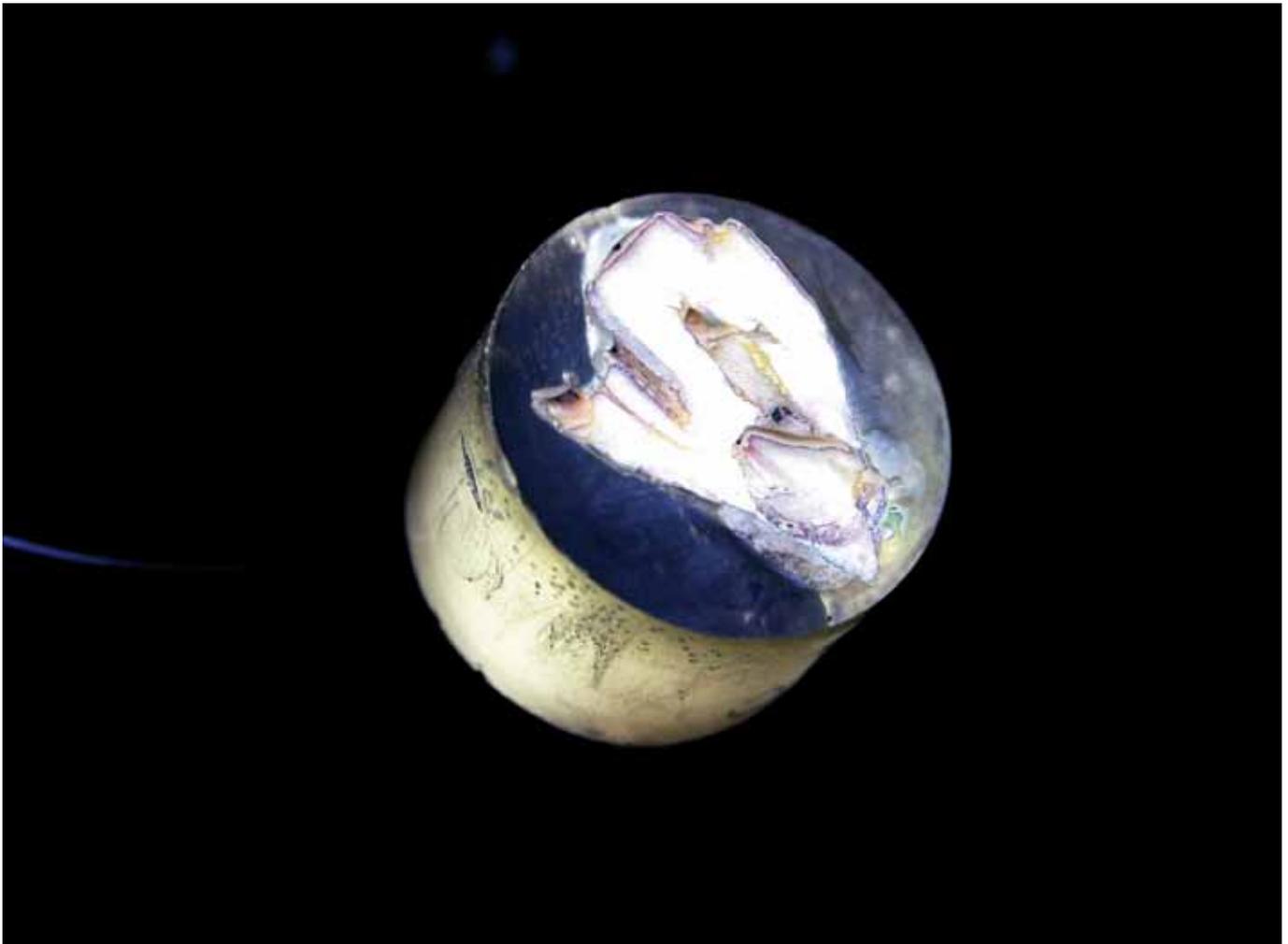
Hybrid zone (HZ) with tags (T) of Futurabond NR (FB) with dentine (D) and composite (A).  
 Magnification 1000x, half-year report.  
 Helbig EB, Klimm HW, Rietschel J, Schreger IE, Richter G, Haufe E, DZZ 2005,  
 60(8); 457-63.  
 Courtesy of Deutscher Zahnärzte Verlag.

## Total-etch or self-etch?

Adhesion values determined and compared in vitro in the form of shear bond strength or micro-tensile bond strength are a good indication for the evaluation of quality. These methods have become standard in university research and quality control by the manufacturer. There is, however, a considerable difference between the laboratory and the practice. Many bonds of varying quality are compared by a few scientists in the laboratory. Total-etch systems often perform slightly better in the lab, since the effects and imponderables of real conditions in the practice are deliberately eliminated and perfect execution is always guaranteed. Total-etch bonds actually achieve higher values than many self-etch bonds under these ideal conditions. Compared to good self-etch bonds, such as

Futurabond NR / DC / M, this advance is statistically mostly insignificant. It is particularly clinically irrelevant, however, if the failure mode for the majority is cohesive and not adhesive, i.e. the fracture surfaces already show breaks in the tooth substance or composite.

Even more decisive for the practice is, however, the degree of the reproducibility under the conditions of the practice. The exclusion of the danger of over-etching, omission of humidity control and application in one layer are reasons why these modern systems are superior to complicated multi-layer systems with separate etching.



Cohesive fracture in a test specimen. Residues of bovine dentine adhering to the test specimen can clearly be seen; the bonding layer remained intact in this experiment (VOCO 2008).

## Futurabond® differences and similarities

### Futurabond® differences and similarities

#### Application

All three Futurabond materials are one-layer bonds. While all components of Futurabond M are contained in a single bottle, the liquids in the two bottles each of Futurabond NR and DC must first be mixed. Whilst Futurabond NR and DC both require the bond to be massaged into the dental hard tissue for 20, Futurabond M achieves good adhesion values even without this step. Here, there is only a 20 s wait after coating the cavity, until the solvent can finally be dried.

#### Compatibility with self-curing composites

In self-curing composites polymerisation is generated by the meeting of two chemical substances: the co-catalyst and the co-initiator. One of these two substances is destroyed by acid, making self-curing composites incompatible with self-etch bonds and 5th generation adhesives (one-bottle total-etch bonds). Accordingly, the use of Futurabond NR and M in combination with self-curing composites is not possible. In combination with dual-curing composites, these bonds can only be used if the dual-curing material is light-cured (in suitable layer thicknesses). Futurabond DC differs from Futurabond NR in one small but important detail. Futurabond DC has an acid-resistant co-catalyst, which can take on the role of the composite's co-catalyst at the interface to the self-curing composite. This makes Futurabond DC suitable as an adhesive for all composites, whether they are light, self or dual-curing.

# In vivo studies

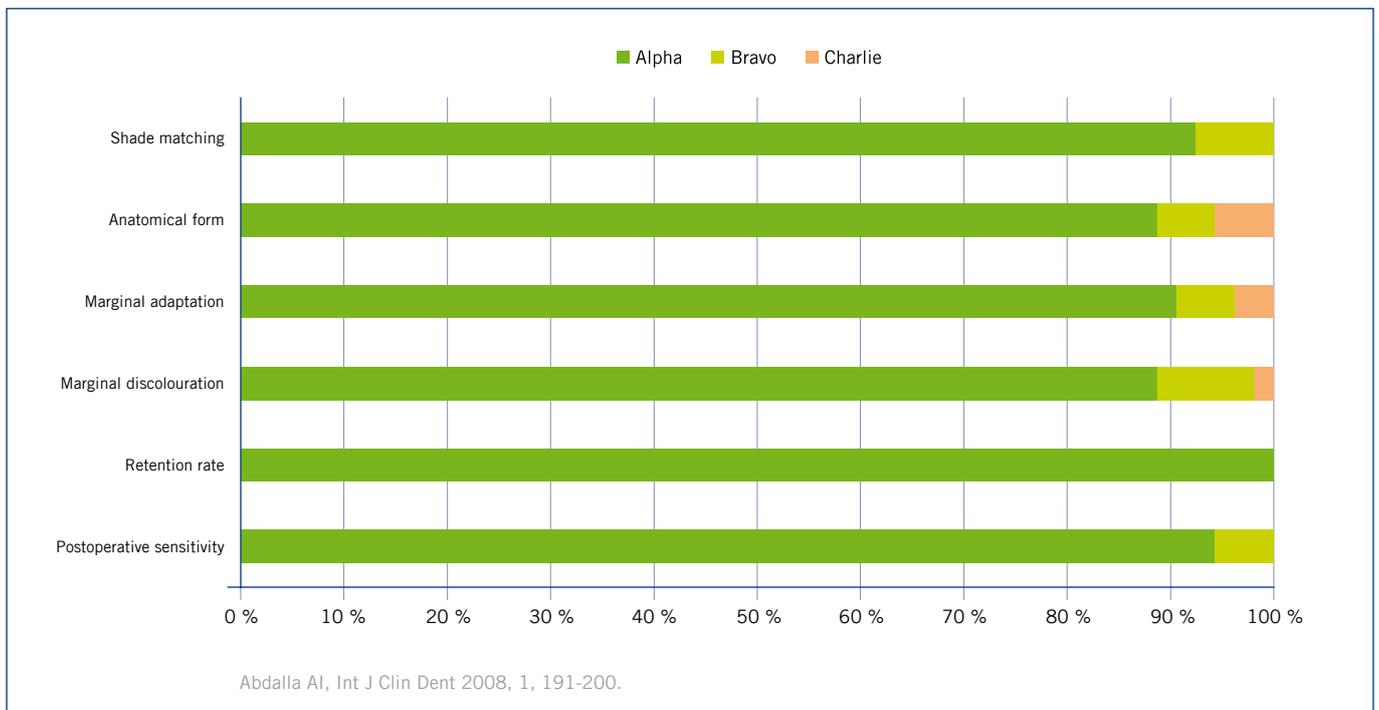
## Futurabond® NR: 4-year clinical study, Class V

### Study design

In this study a total of 61 patients with at least three Class V carious lesions were each treated with the combination of Futurabond NR and the nanohybrid restorative composite Grandio. Each received one restoration without separate etching, one restoration after separate enamel etching and one filling after a separate total-etch procedure (split-mouth design).<sup>[1]</sup> After four years it was possible to follow up on 166 of the 183 restorations placed. The evaluation was carried out in accordance with the USPHS criteria modified by Ryge.<sup>[2]</sup>

### Results

After four years the retention rate was 100 %. With regard to all assessment criteria the restorations were rated clinically sound or acceptable in 90 % or more of the cases. The different application protocols had no influence on the results of the study.

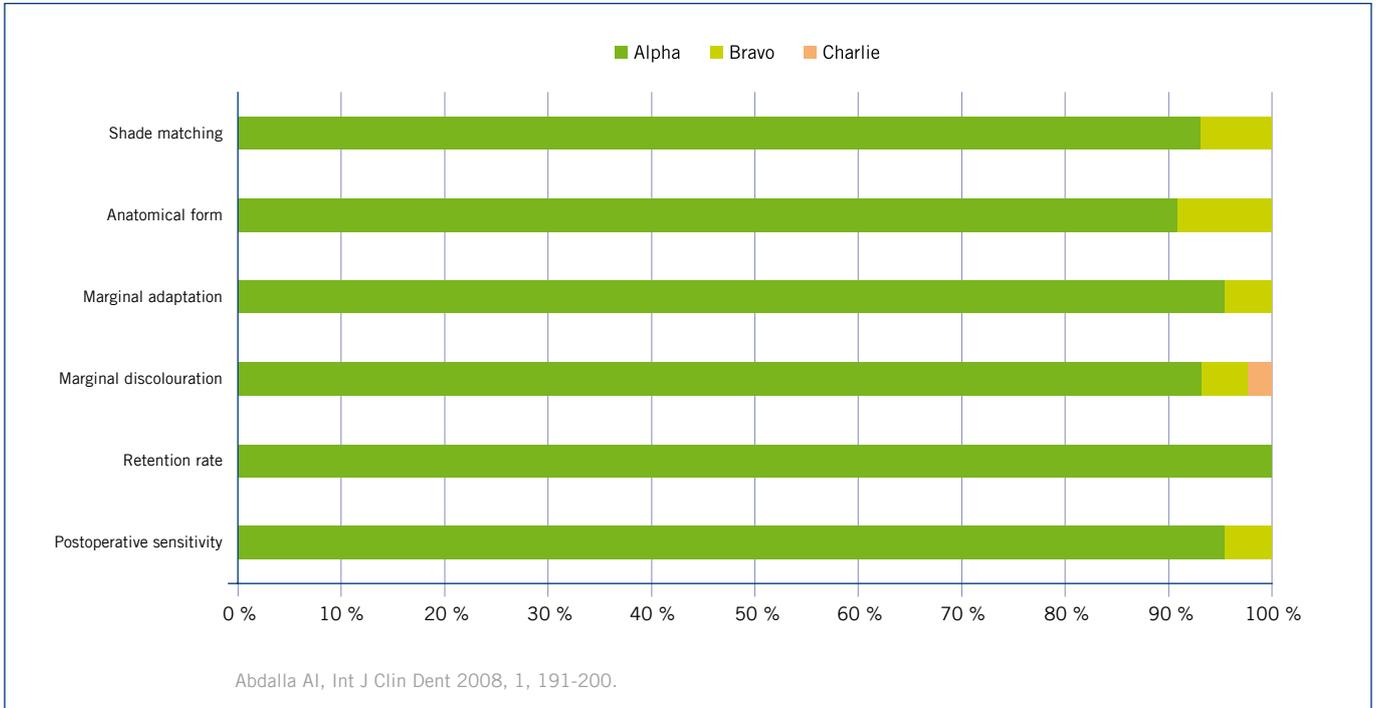


Clinical evaluation of the restorations without separate etching

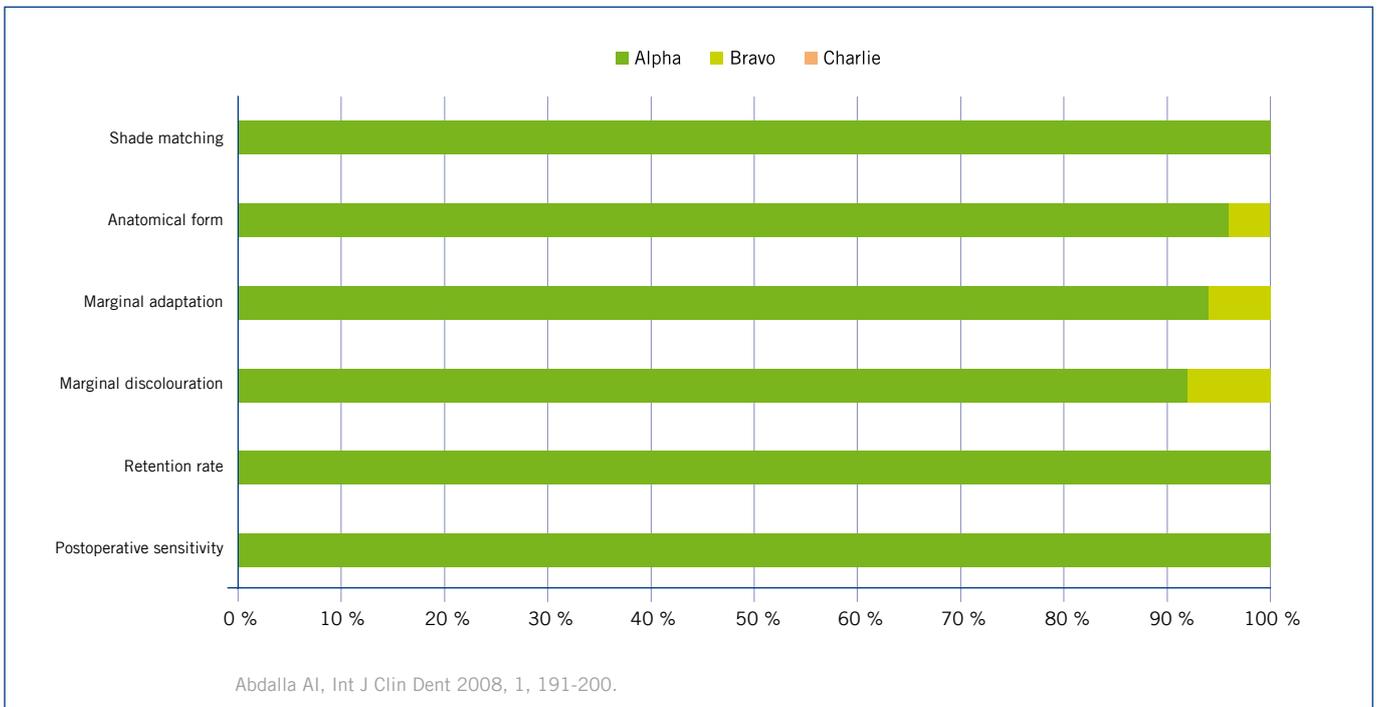
### Literature

[1] Abdalla, 2008.

[2] Cvar und Ryge, 1971.



Clinical evaluation of the restorations with separate etching of the enamel



Clinical evaluation of the restorations with separate total-etch

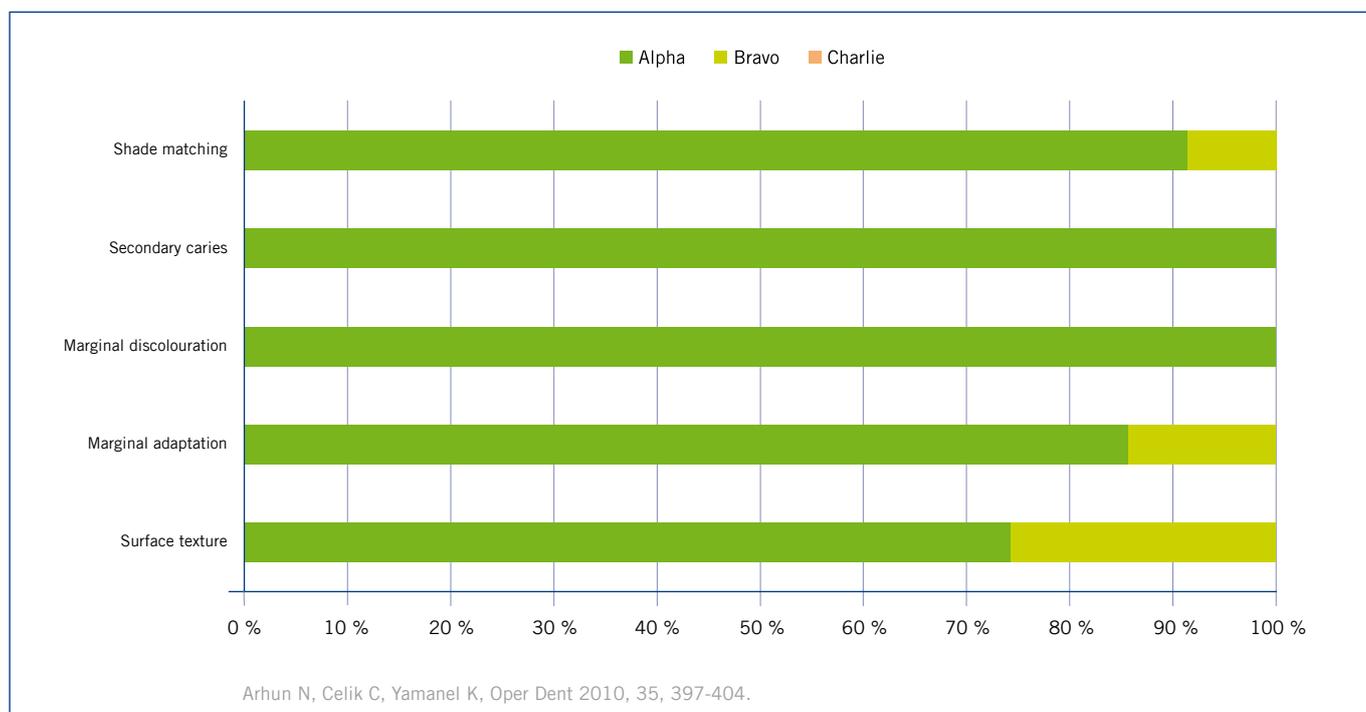
## Futurabond® NR: 2-year clinical study, Class I + II

### Study design

In the current study, 31 patients with Class I and II cavities were each treated with the combination Futurabond NR / Grandio.<sup>[1]</sup> A total of 41 restorations were placed, of which 35 were available for a follow-up examination two years later. The evaluation was carried out in accordance with the USPHS criteria modified by Ryge.<sup>[2]</sup>

### Results

After two years, all restorations were rated at least clinically acceptable with regard to all assessment criteria. The assessment of the marginal discolouration is noteworthy. Even after this period of time, all posterior restorations were classified as clinically sound in the marginal discolouration category.



Clinical evaluation of the restorations after 24 months

### Literature

[1] Arhun et al., 2010.

[2] Cvar und Ryge, 1971.

## Futurabond® NR: 2-year clinical study, Class II

### Study design

In this study, 37 patients with a total of 51 Class II cavities were each treated with Futurabond NR / Grandio.<sup>[1]</sup> After two years, the restorations were evaluated in accordance with the criteria of Hickel et al.<sup>[2]</sup>

### Results

After two years, none of the restorations showed evidence of secondary caries. The quality of the bond is clearly visible in the assessment of marginal integrity. In all restorations subjected to a follow-up examination, the margins were classified as clinically acceptable, with over 95 % being assessed as excellent or good.



Clinical evaluation of the restorations after 24 months

### Literature

[1] Schattenberg et al., 2010.

[2] Hickel et al., 2007.

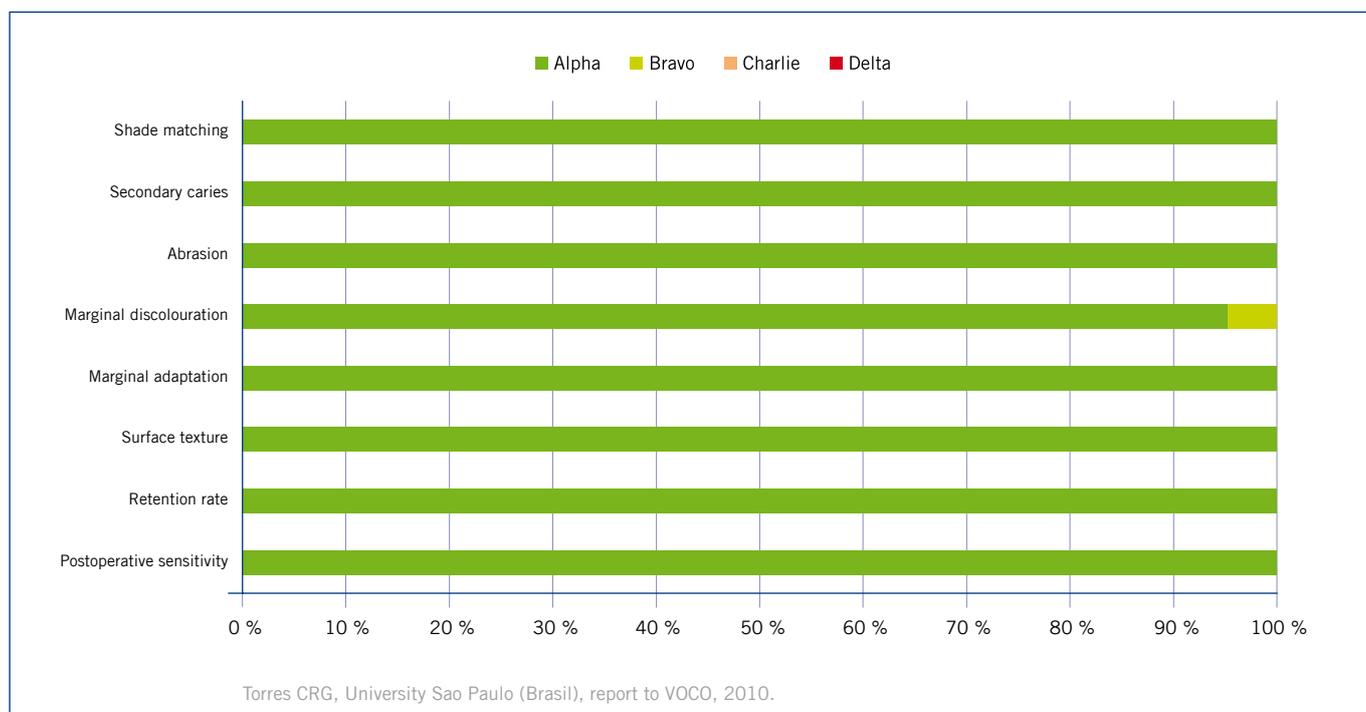
## Futurabond® M: 1-year clinical study, Class III

### Study design

For this study 50 Class III cavities were treated with the combination Futurabond M / Amaris.<sup>[1]</sup> In the follow-up examination after 12 months, 43 of these restorations were available for evaluation. The test was carried out independently by two examiners. The USPHS criteria modified by Ryge were used for the evaluation.<sup>[2]</sup>

### Results

After 12 months the retention rate was 100 %. All restorations were evaluated at 100 % with the best possible rating, in all evaluation categories. Only two restorations were given the rating “Bravo” in the evaluation of marginal discolouration.



Clinical evaluation of the restorations after 12 months

### Literature

[1] Torres, 2010.

[2] Cvar und Ryge, 1971.

## in vitro studies

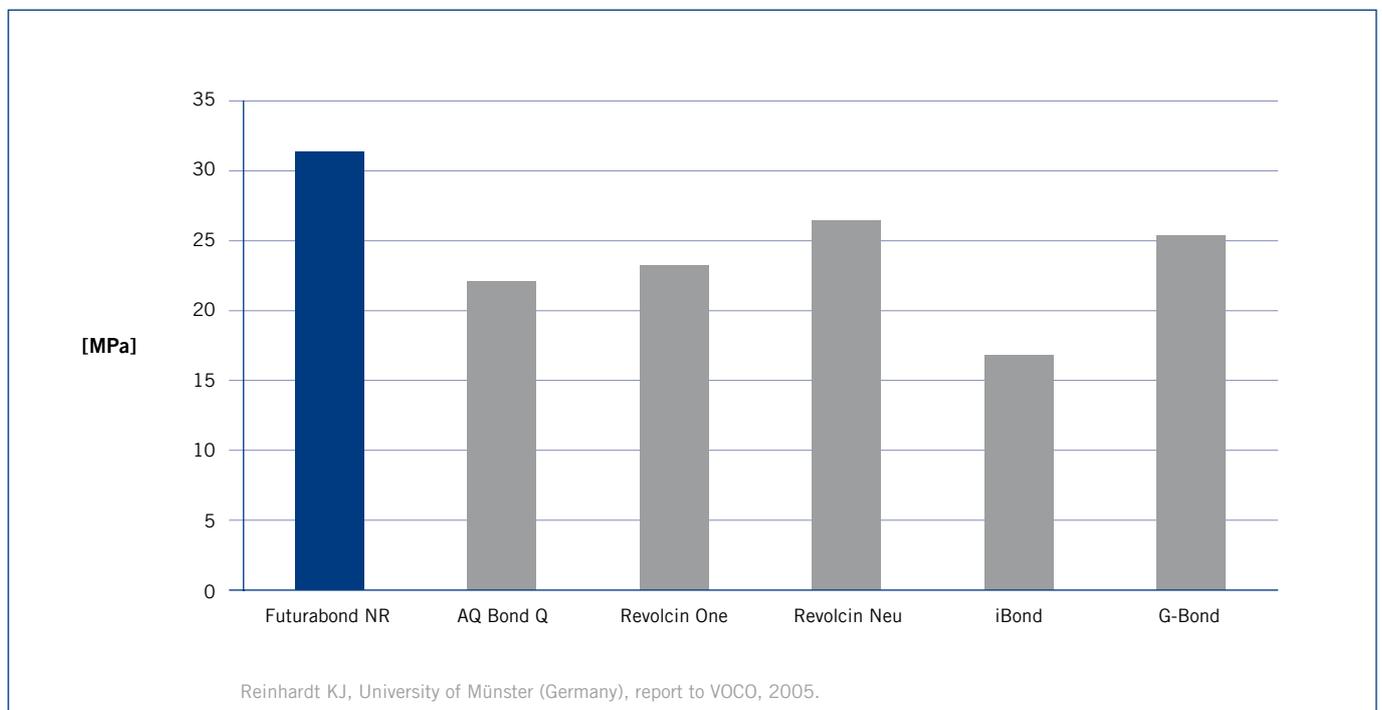
### Futurabond® NR: Shear bond strength on human enamel

#### Study design

In extracted human teeth a planar enamel area was created. The surface was then finished with wet sandpaper (800 grain). The adhesives were then applied, according to manufacturers' instructions, in combination with a composite by the same manufacturer. After storage in 37 °C warm water for 24 hours, the shear bond strength was determined.<sup>[1]</sup>

#### Results

In this study, Futurabond NR achieves significantly higher adhesion values than the other bonding systems examined.



Adhesion values [MPa] on human enamel in a shear test

#### Literature

[1] Reinhardt, 2005.

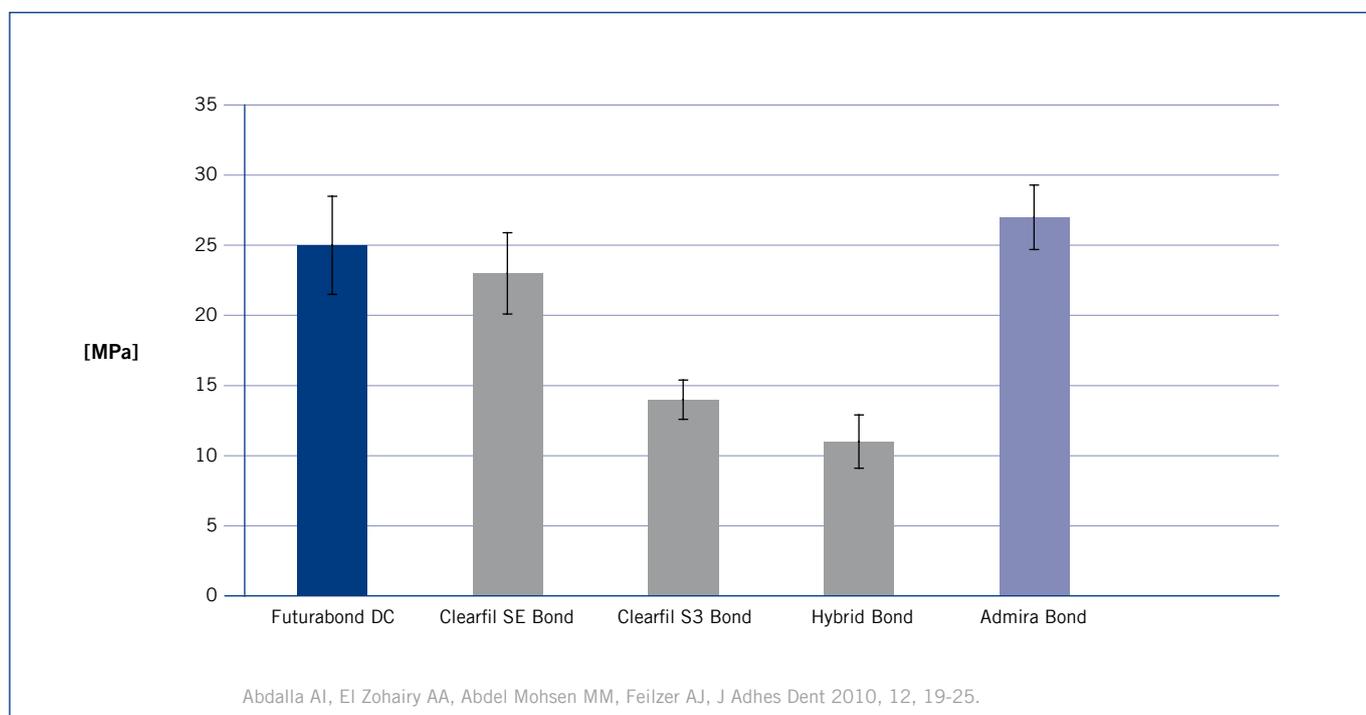
## Futurabond® DC: Shear bond strength on human enamel

### Study design

The root was severed from 30 extracted human molars and the remaining crown divided into two halves. The convex enamel surfaces were subsequently ground flat. After application of the respective bond, a hollow cylinder (4.0 mm length, 0.75 mm diameter) was placed, subsequently filled with composite and light-cured. After 24 hours of storage in water, the hollow cylinder was removed and the  $\mu$ SBS measured.

### Results

The Futurabond NR / Grandio Flow combination achieved the best adhesive values. Analysis of the failure modes did not show pure adhesive loss in any system. All systems mainly failed cohesively on enamel and dentine either from fracture of the tooth substance or composite layer.



Adhesion values [MPa] on human enamel in a shear test

### Literature

[1] Abdalla et al., 2010.

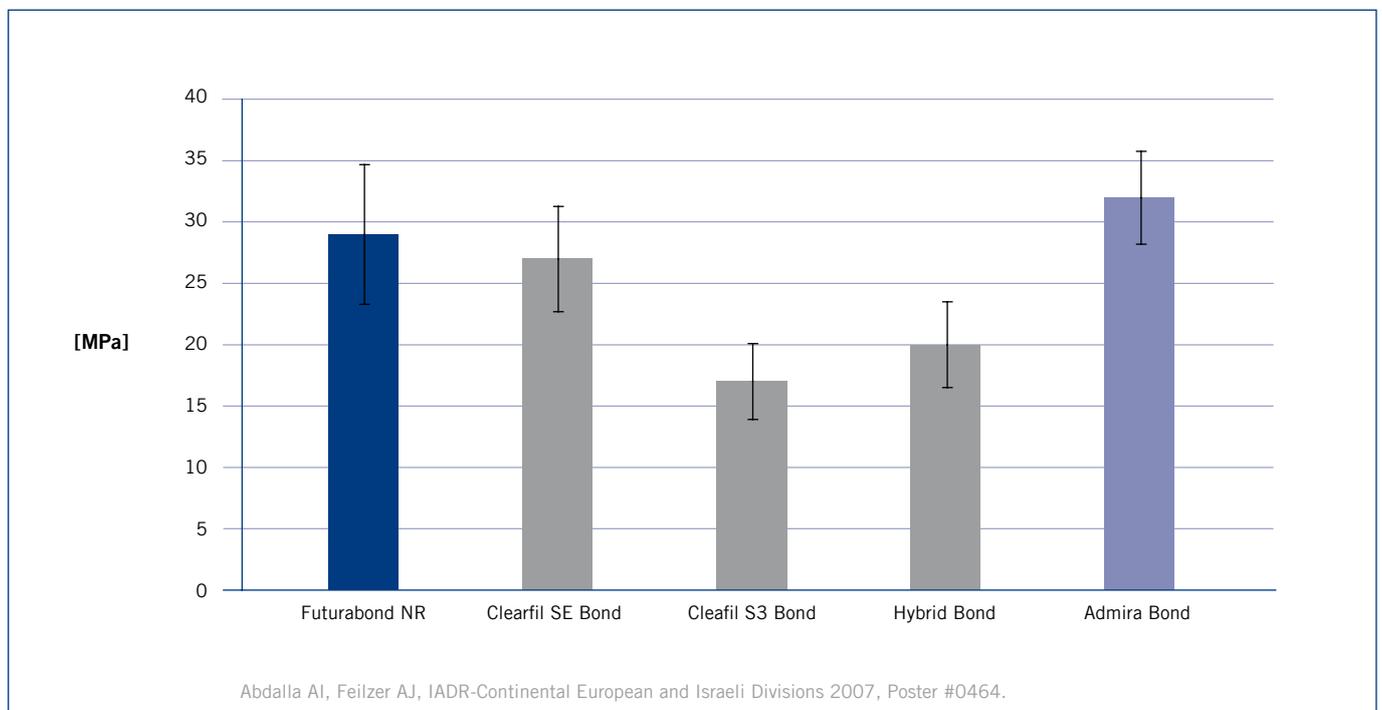
## Futurabond® NR: Micro-tensile bond strength on human enamel

### Study design

Human enamel specimens were ground flat with a silicon-carbide grinder (grit 320) and adhesively bonded to a hybrid composite test specimen from the corresponding manufacturer. The micro-tensile bond strength measurements were conducted after 48 hours of storage in water.

### Results

Only Futurabond NR and Clearfil SE exhibited adhesion values that did not differ significantly from the parallel tested total-etch system (Admira Bond).



Micro-tensile bond strength [MPa] of different bonding systems on human enamel

### Literature

[1] Abdalla und Feilzer, 2007.

## Futurabond® M: Shear bond strength on human enamel

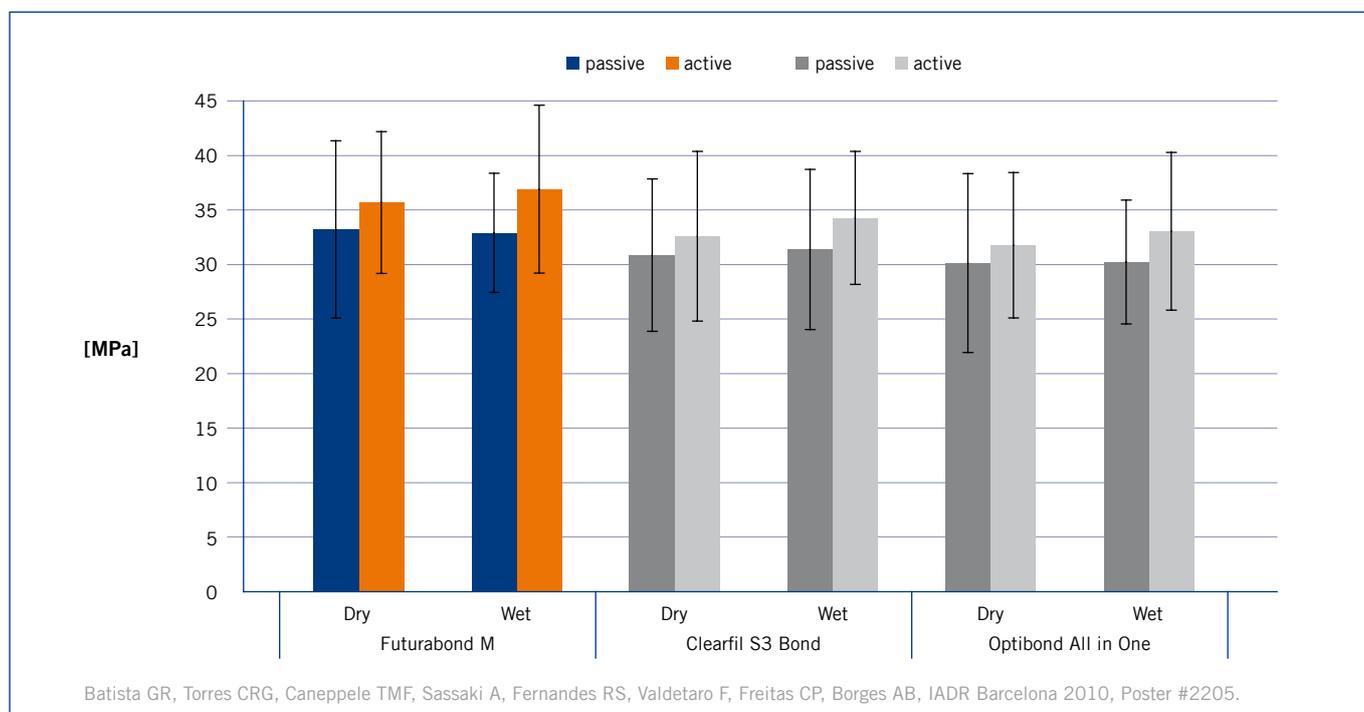
### Study design

A total of 195 extracted bovine anterior teeth were included in this study.<sup>[1]</sup> After the production of test specimens, these were divided into three groups (Futurabond M, Clearfil S3 Bond, Optibond All in One). In every group, 4 subgroups were established:

- a) dry surface, bond rubbed in (active)
- b) dry surface, not rubbed in (passive)
- c) damp surface, bond rubbed in (active)
- d) damp surface, not rubbed in (passive)

### Results

In this study, the single-bottle self-etch system Futurabond M displays the best adhesion values on enamel. The high adhesion values are tolerant in regard to residual moisture on the tooth substance and the method of application (active or passive).



Shear bond strength [MPa] of different bonding materials on human enamel, relative to the treatment procedure

### Literature

[1] Batista et al., 2010.

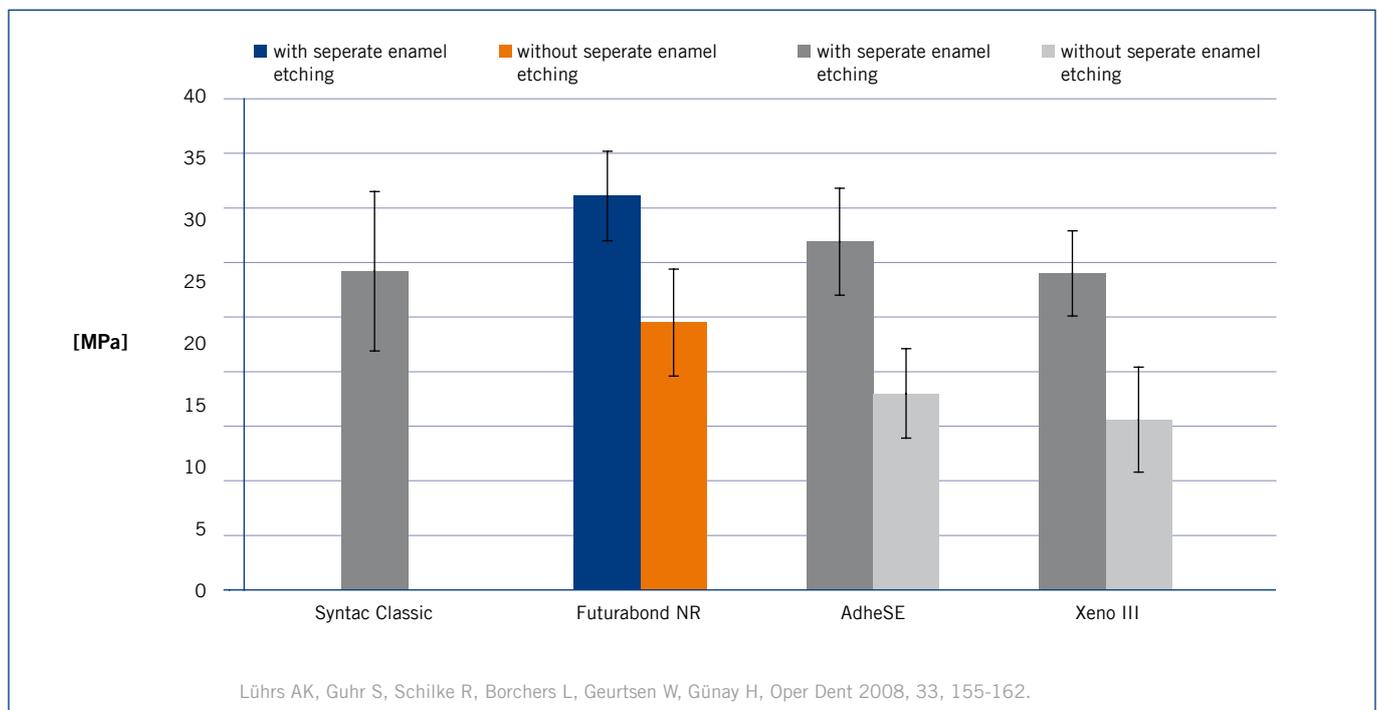
## Futurabond® NR: Shear bond strength on human enamel after etching

### Study design

The approximal surfaces of 70 human molars were ground flat in parallel to the tooth axis in the enamel. Three self-etch systems (SE) were each applied, with prior conditioning of the enamel with a 37 % phosphoric acid for 30 seconds and without, and then polymerised. Syntac Classic served as the control. Corresponding composites were subsequently polymerised as cylinders in a ring (2 mm high, 3 mm diameter) on the enamel surface. The test specimens were stored in physiological saline solution at 37 °C for 24 hours and then subjected to a shear test.<sup>[1]</sup>

### Results

No significant differences to the control group (total-etch) were visible after additional etching. Futurabond exclusively achieved comparable values, even without additional etching. Additional etching of the enamel significantly increased the shear bond strength with all of the applied systems and is thus recommended for clinical use with all cavities limited by only the enamel.



Shear bond strength [MPa] of different bonding systems on human enamel with and without separate enamel etching

### Literature

[1] Lührs et al., 2008.

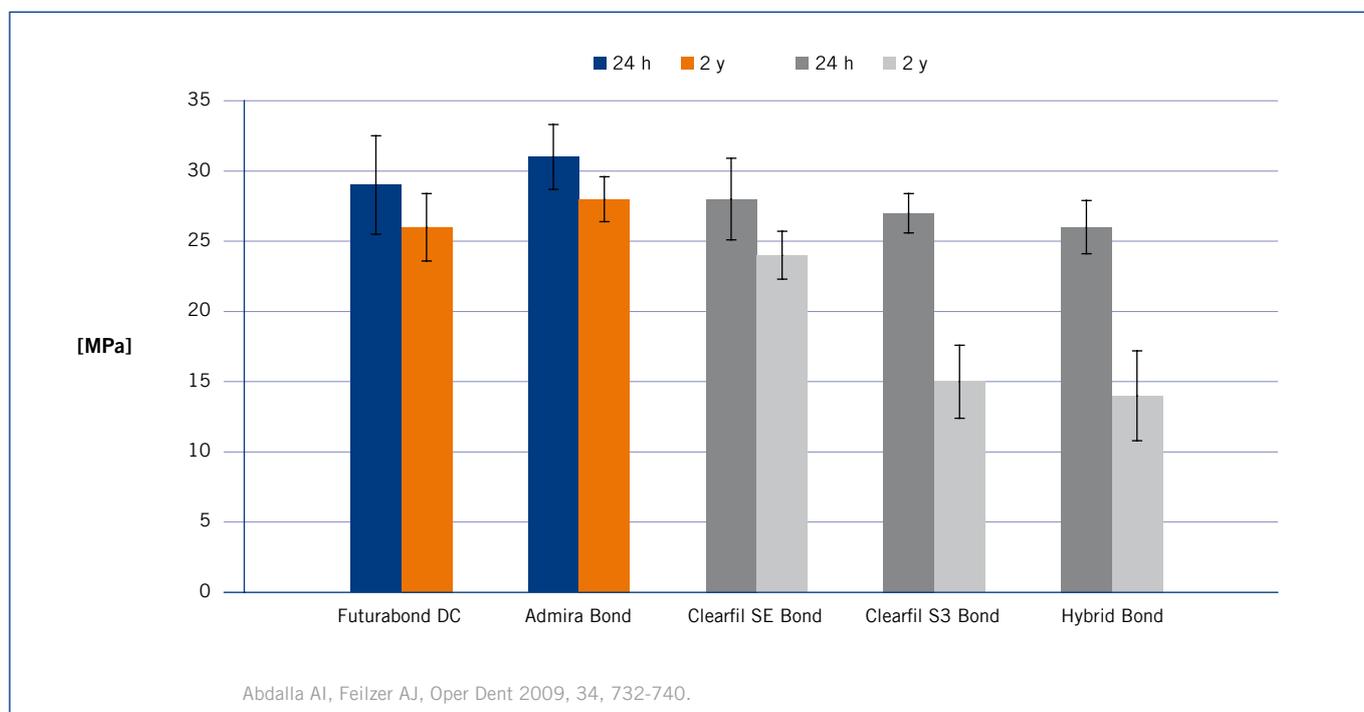
## Futurabond® DC: Shear bond strength on human enamel after storage in water

### Study design

In 60 extracted human molars, the roots were first of all detached and the tooth crown divided into two halves. The convex enamel surface was ground flat and subsequently roughened using a diamond (100 µm grain, Komet). The bonding systems were then applied according to the manufacturers' instructions. An increment of composite from the respective manufacturer (Grandio, Clearfil APX, Pecalux), with a diameter of 0.75 mm and a height of 2 mm, was applied using a cylinder. The test specimens prepared in this way were divided into two groups. Half was stored in water (+0.5 % chloramine) for 24 hours, the other half for two years. After storage in water, the micro-tensile bond strength was determined.<sup>[1]</sup>

### Results

Even after two years of storage in water, Futurabond DC shows very good adhesion values. The study shows that long-term treatment success with composites becomes possible with Futurabond DC. Despite the simplified application of Futurabond DC, the adhesion values are just as high as those reached with total-etch bonds.



Shear bond strength [MPa] on human enamel before and after storage in water

### Literature

[1] Abdalla und Feilzer, 2009.

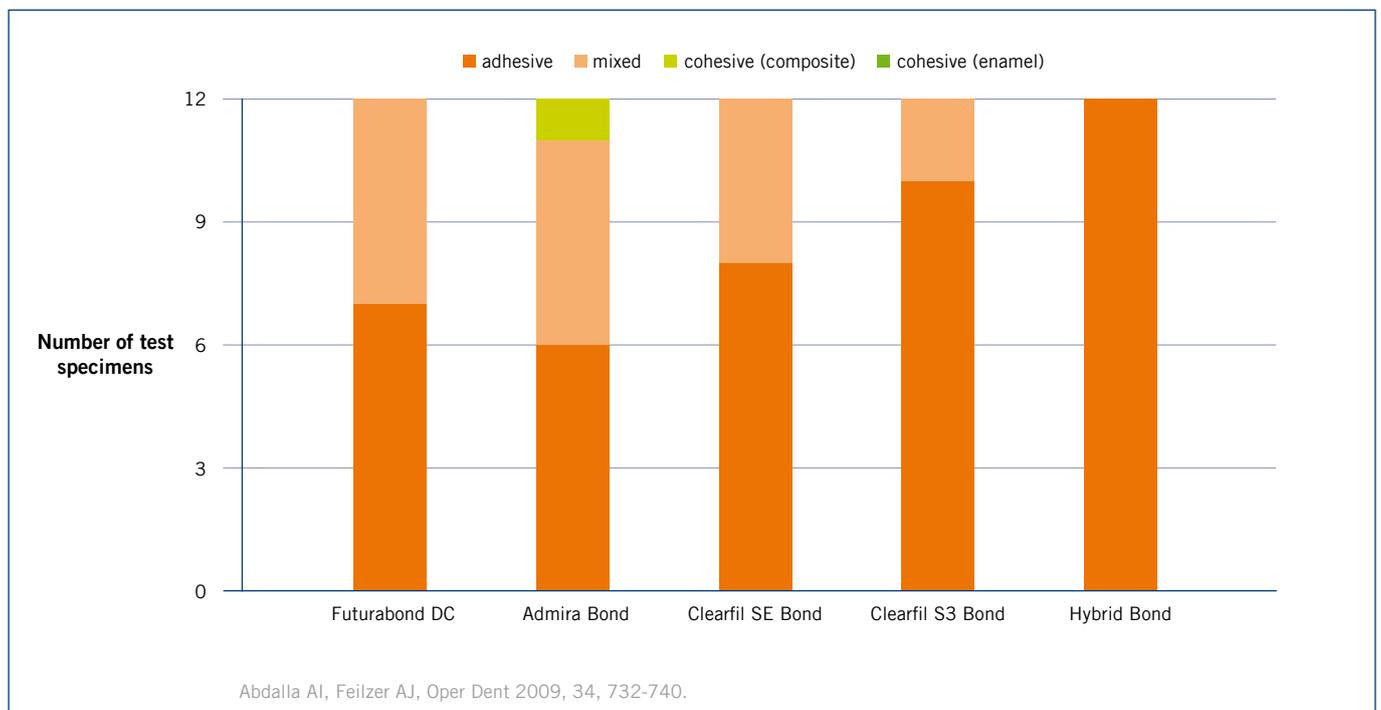
## Futurabond® DC: Shear bond strength on human enamel after storage in water II

### Study design

In the study described opposite, the fracture surface of the test specimens was examined in more detail, as well as determining the adhesion values. Replicas made of epoxy resin were created for this, coated with gold and examined by scanning electron microscopy (Philips XL 30).<sup>[1]</sup>

### Results

The analysis of the fracture types showed a significantly higher number of mixed and cohesive fractures for Futurabond DC and Admira Bond. The results can thus be reconciled with the measured adhesion values.



Shear bond strength [MPa] on human enamel after storage in water

### Literature

[1] Abdalla und Feilzer, 2009.

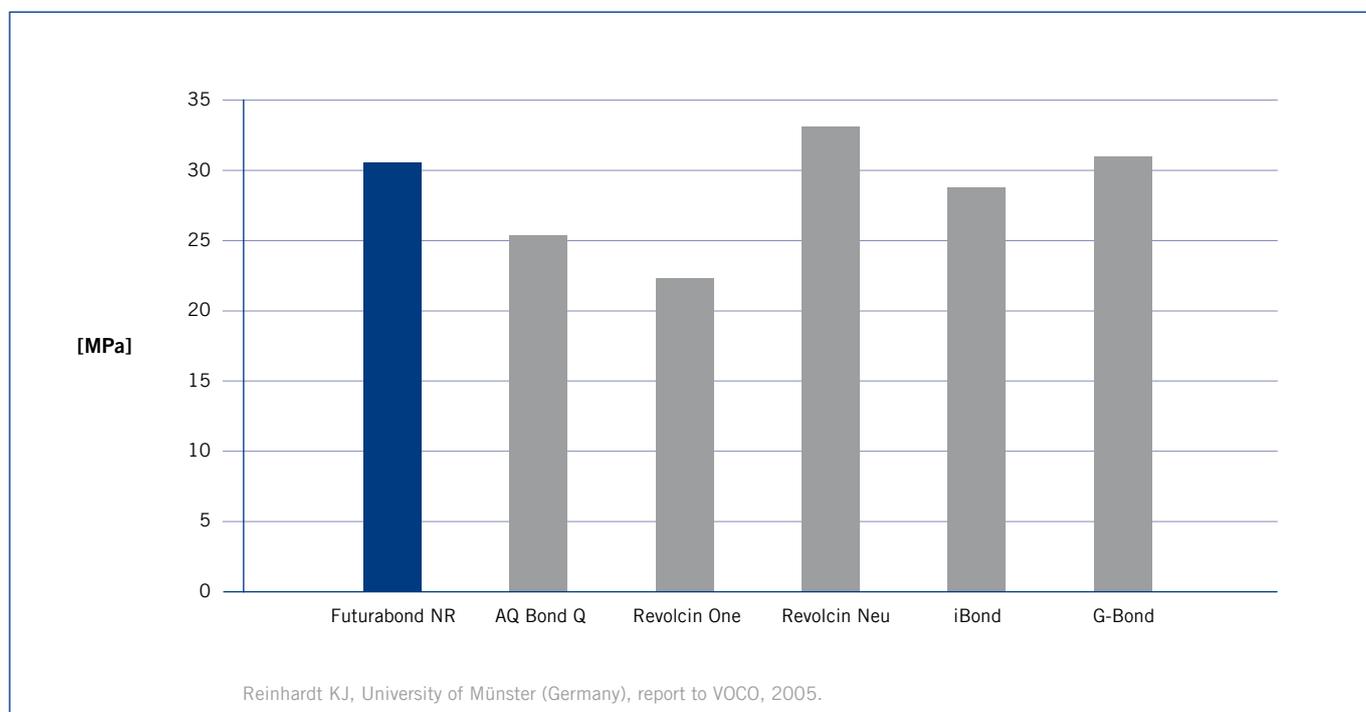
## Futurabond® NR: Shear bond strength on human dentine

### Study design

In extracted human teeth a planar surface was created in the dentinal area. The cut surface was subsequently finished using wet sandpaper (800 grain). Different adhesives were then applied, according to manufacturers' instructions, in combination with the same manufacturer's composite. After storage in 37 °C warm water for 24 hours, the shear bond strength was determined.<sup>[1]</sup>

### Results

In this study, Futurabond NR reached a dentine bond strength of 30.6 MPa.



Shear bond strength [MPa] on human dentine

### Literature

[1] Reinhardt, 2005.

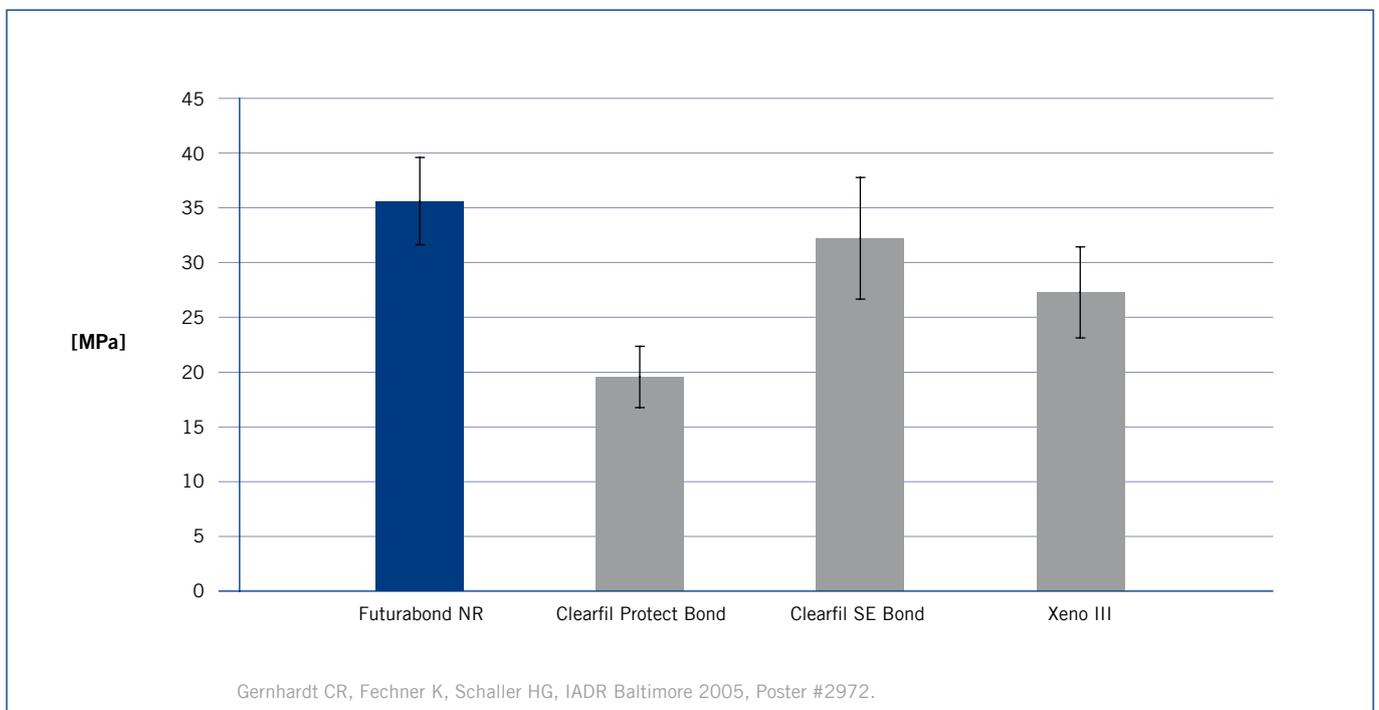
## Futurabond® NR: Micro-tensile bond strength on human dentine

### Study design

Uniform test specimens, 1.5 mm in height, were derived from 60 freshly extracted wisdom teeth. After application of the bonding systems, according to manufacturers' instructions, increments of Clearfil AP-X (Kuraray) were applied to each. The measurement of the micro-tensile bond strength was carried out 15 min. after fabrication of the specimens.<sup>[1]</sup>

### Results

The self-etch systems examined in this study can be considered a good alternative to established total-etch systems. Futurabond NR's adhesion values were significantly higher than those of the other bonding systems studied.



Micro-tensile bond strength [MPa] on human dentine

### Literature

[1] Gernhardt et al., 2005.

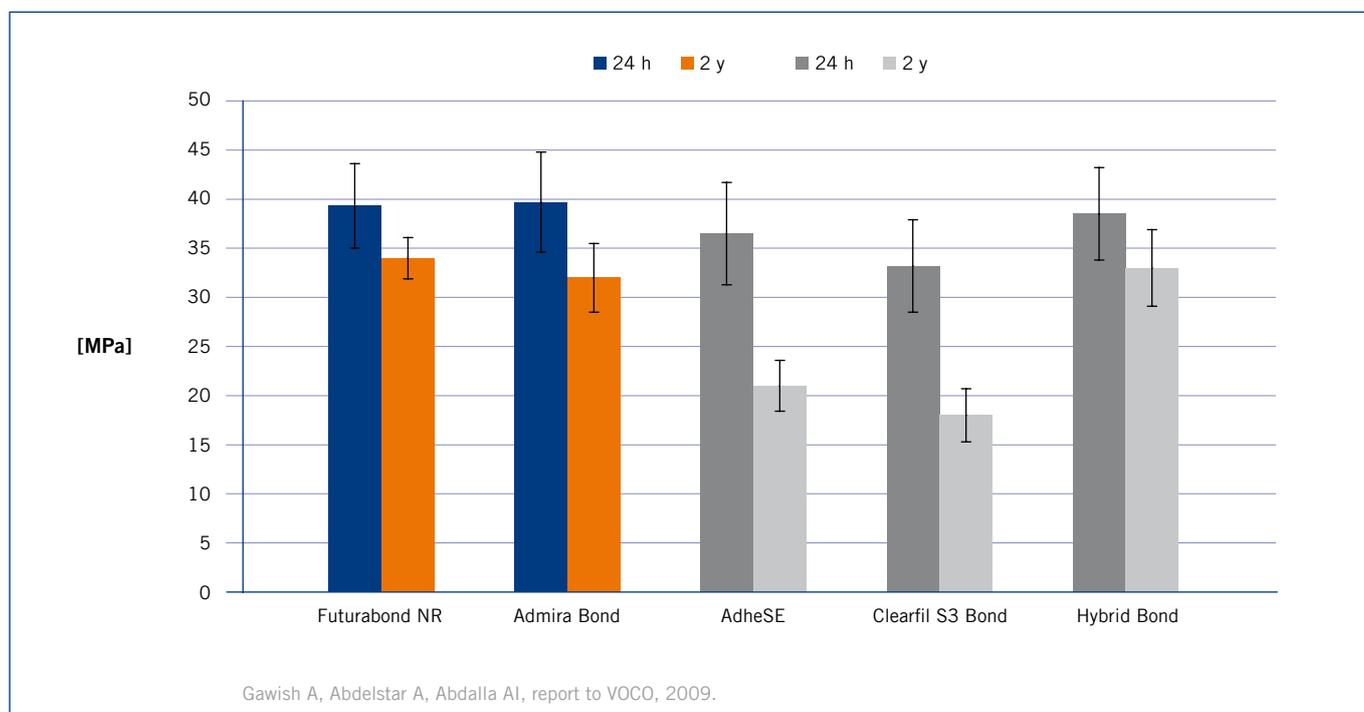
## Futurabond® NR: Micro-tensile bond strength on human dentine after storage in water

### Study design

In 60 freshly extracted human molars, the roots were first of all detached. The enamel surface was removed and the exposed dentine was subsequently roughened with SiC sandpaper (600 µm grain). The bonding systems were then applied according to the manufacturers' instructions. The Grandio composite was applied in increments using a cylinder to a height of 5-6 mm. The test specimens prepared in this way were divided into two groups. One half was stored in water (+0.5 % chloramine) for 24 hours, the other half for two years. After storage in water, the micro-tensile bond strength was determined.<sup>[1]</sup>

### Results

Even after two years of storage in water, Futurabond NR shows very good adhesion values. The study shows that long-term treatment success with composites becomes possible with Futurabond NR. Despite the simplified application of Futurabond NR, the adhesion values are just as high as those reached with total-etch bonds.



Micro-tensile bond strength [MPa] on human dentine before and after storage in water

### Literature

[1] Gawish et al., 2009.

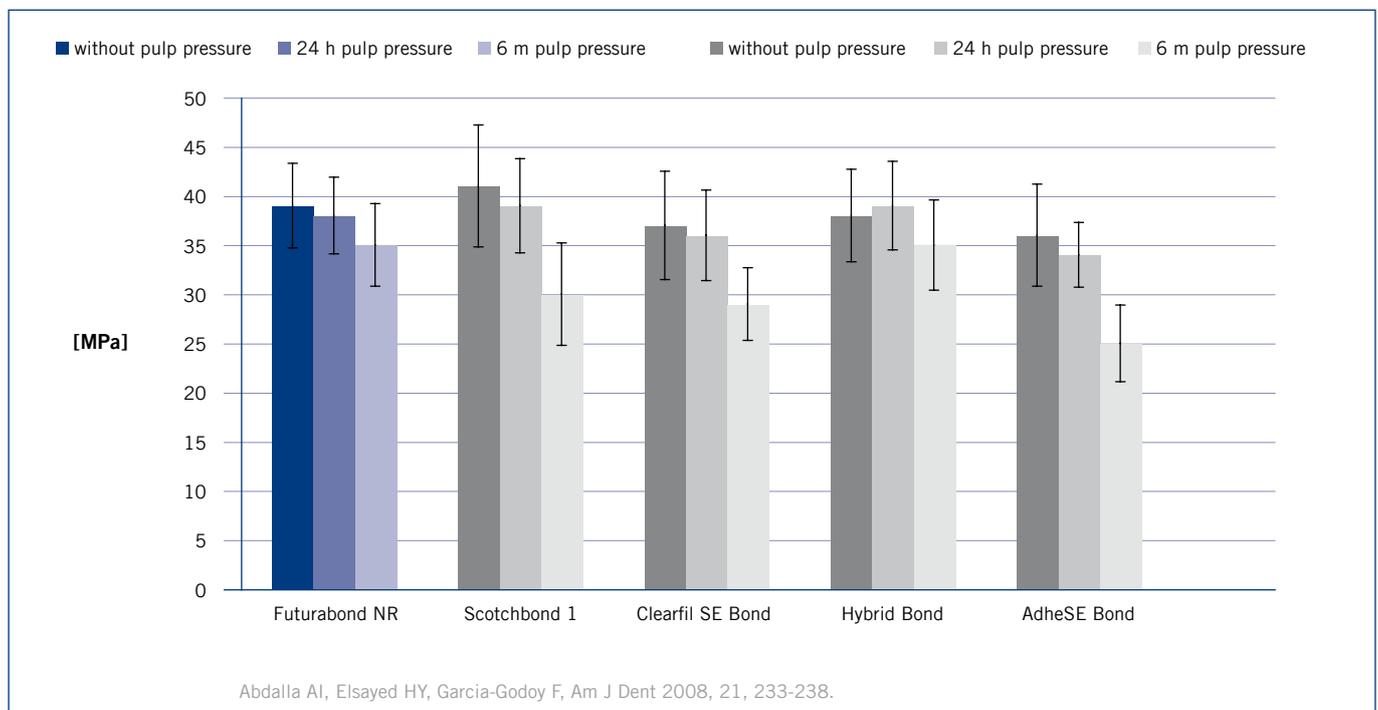
## Futurabond® NR: Micro-tensile bond strength on human dentine under perfusion

### Study design

In the current study, after suitable preparation, the hydrostatic pulp pressure on the teeth was simulated via a 20 cm high water column. For every material used in this examination, three adhesion values were determined: an adhesion value without simulated pulp pressure, a measurement after 24 h under simulated pulp pressure, as well as a measurement after six months.<sup>[1]</sup>

### Results

The nanofilled Futurabond NR bond effectively seals the dentinal tubuli and prevents the ingress of dentinal fluid into the hybrid layer. The adhesion values are barely affected by six months of storage under simulated pulp pressure, which points to a long-term intact adhesion bond.



Micro-tensile bond strength [MPa] on human dentine with simulated pulp pressure.

### Literature

[1] Abdalla et al., 2008.

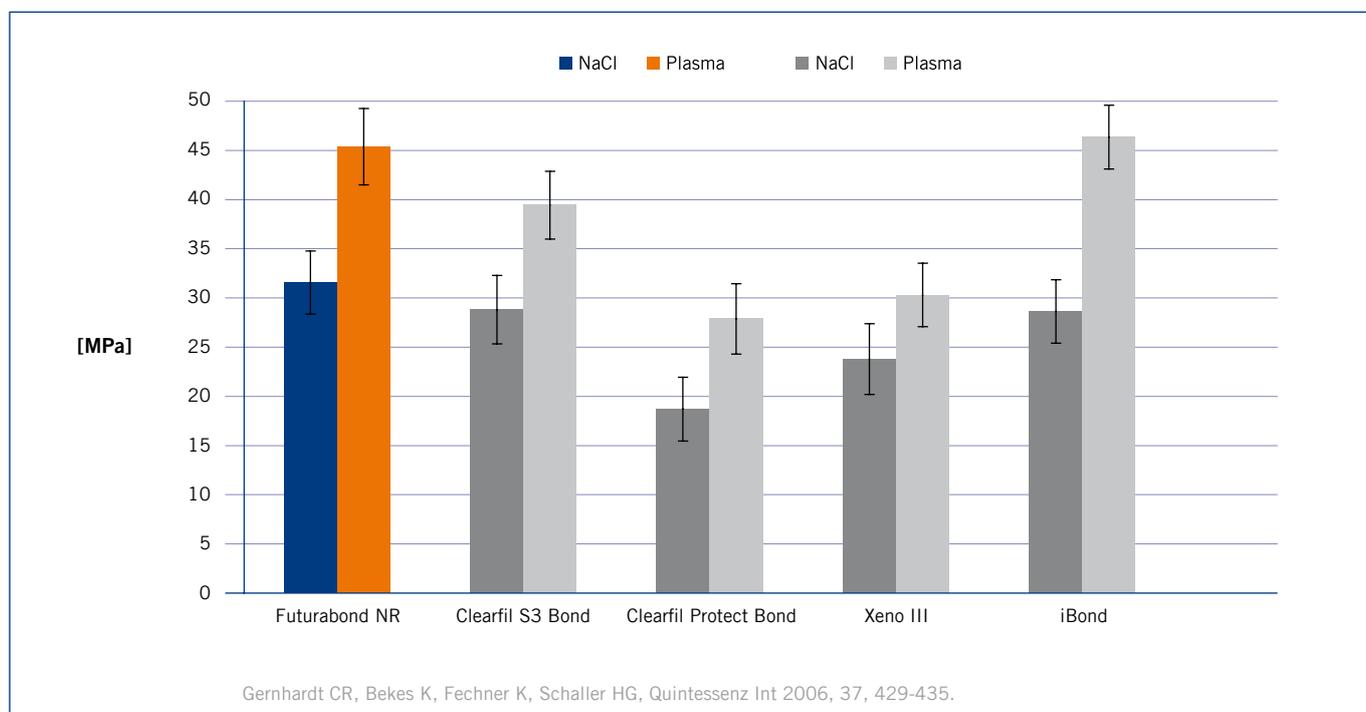
## Futurabond® NR: Micro-tensile bond strength on human dentine under perfusion II

### Study design

In 150 freshly extracted wisdom teeth the roots were first removed and the teeth were then occlusally worn down with a cylindrical, water-cooled diamond bur. The remaining dentinal thickness over the pulp chamber was adjusted to approx. 1.3 mm. These test specimens were treated with different bonding systems, onto which the Clearfil AP-X (Kuraray) composite was applied. The test specimens prepared in this way were connected to equipment that allows perfusion with physiological solutions. A micro-tensile bond strength experiment was carried out ten minutes after the preparation of the test specimens.<sup>[1]</sup>

### Results

Even under simulation of perfusion with physiological fluids, Futurabond NR shows very high adhesion values.



Micro-tensile bond strength [MPa] on human dentine under perfusion

### Literature

[1] Gernhardt et al., 2006.

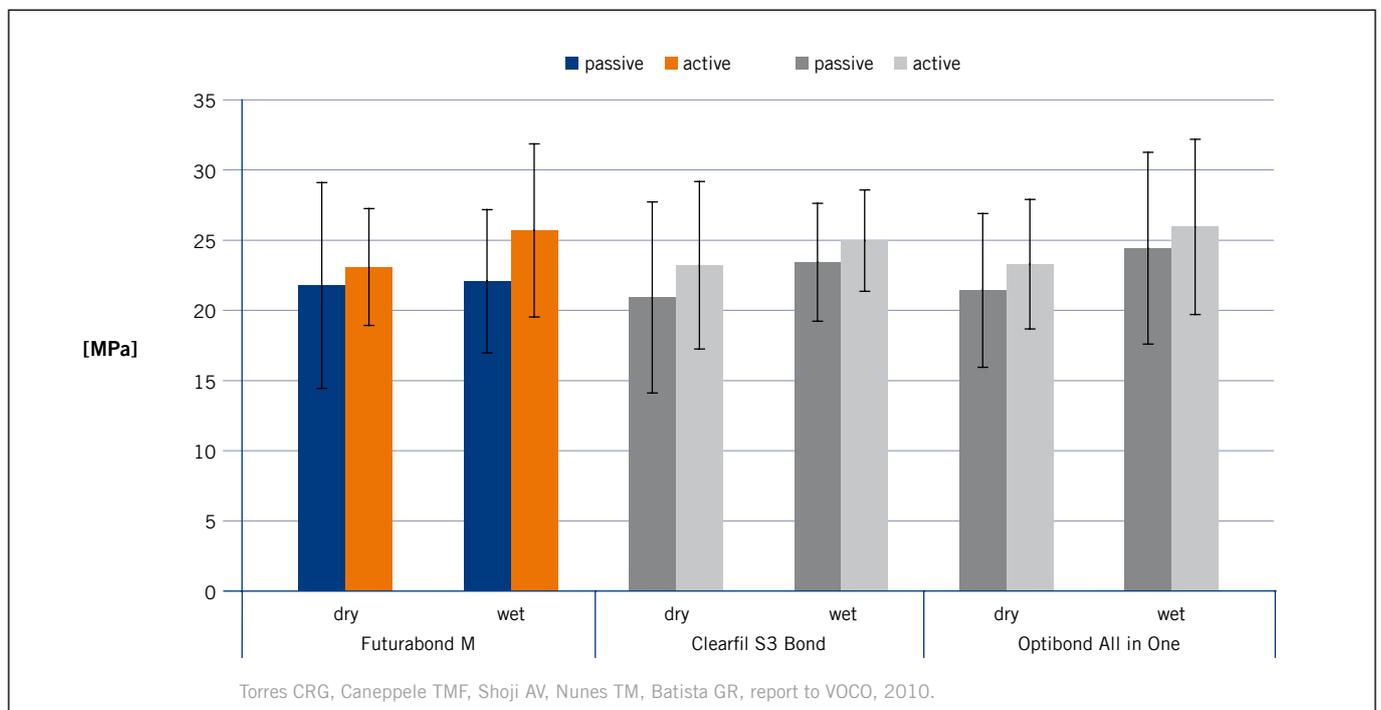
## Futurabond® M: Micro-tensile bond strength on human dentine

### Study design

195 bovine teeth were worn down, on the buccal side, to a remaining dentinal thickness of 2 mm. The surfaces produced in this way were subsequently roughened with sandpaper (600 grain) and divided up between the three adhesives tested. Within the adhesive test groups, subgroups were formed in which the bond was differently applied: on damp or dry dentine, as well as with movement of the bond or with a resting phase after coating. The test specimens prepared in this way were tested in a micro-tensile bond strength experiment.<sup>[1]</sup>

### Results

Irrespective of the application procedure, Futurabond M achieves good adhesion values on dentine.



Micro-tensile bond strength [MPa] on human dentine following different treatment protocols

### Literature

[1] Torres et al., 2010.

## Futurabond® NR: Analysis of tag formation and quality of the hybrid layer

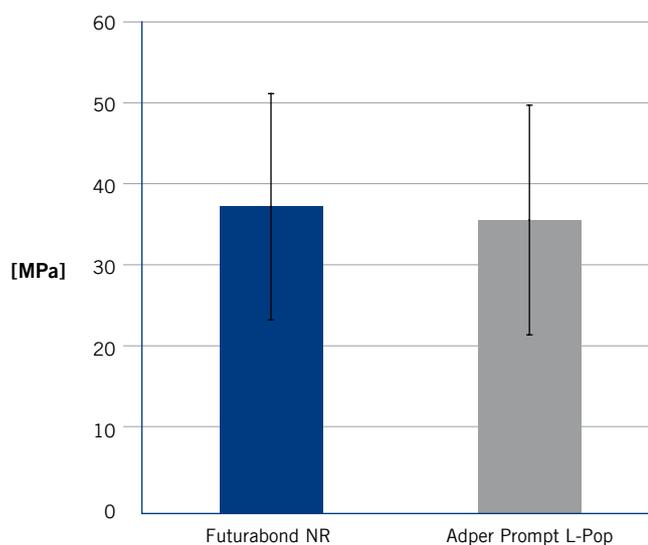
### Study design

In freshly extracted human wisdom teeth the occlusal surfaces were separated off and the exposed dentine was roughened with sandpaper (80 grain). Subsequently, Futurabond NR in combination with Grandio, was applied in one group whilst Adper Prompt L-Pop and Filtek Supreme were applied to a second group, all according to manufacturer's instructions. The test specimens produced in this way were treated with the fluorescent dye rhodamine B isocyanate. After the dyeing process, the test specimens were analysed using confocal laser scanning microscopy. The tensile bond strength was also determined.<sup>[1]</sup>

### Results

In the Futurabond NR group, the hybrid layer was most often awarded the mark "good" (3 = good, 2 = medium, 1 = poor). For the majority, the hybrid layer was homogenous and even. Per examined area on a surface of 500 µm, an average of 103.8 tags was found. This secure seal of the dentinal tubuli is a basic prerequisite for avoiding postoperative sensitivity. Formations in terms of nanoleakages were not found in any specimen.

	Futurabond NR	Adper Prompt L-Pop
thickness of the hybrid layer	11,35 µm	14,14 µm
quality of the hybrid layer	2,32	2,24
number of tags	103,8	89,2



Ding P, Oikonomou C, Wolff D, Staehle HJ, report to VOCO, 2006.

Micro-tensile bond strength [MPa] on human dentine

### Literature

[1] Ding et al., 2006.

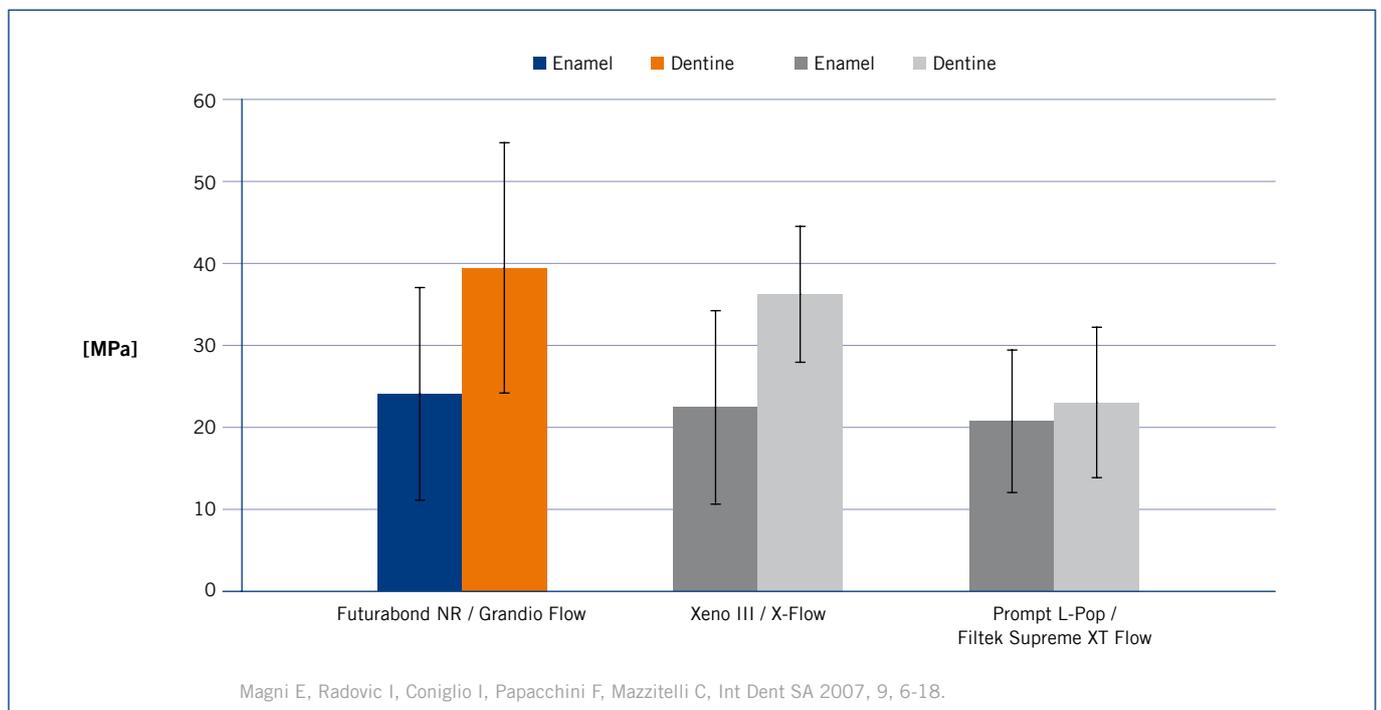
## Futurabond® NR: Micro-tensile bond strength in combination with a flowable composite

### Study design

The buccal enamel was ground flat on six caries-free human molars. The middle coronal dentine on six more teeth was exposed by dissecting the crown of each. A clinically relevant smear layer was achieved in both groups by post-treatment with SiC paper (grit 180). After application and light-curing of the adhesive / flowable combinations, a composite cube (5 mm edge length) was incrementally polymerised on each. Before measurement of the micro-tensile bond strength, the test specimens were stored in a physiological saline solution at 37 °C for 24 hours and subsequently divided into 0.9 × 0.9 mm diameter bars.

### Results

The Futurabond NR / Grandio Flow combination achieved the best adhesive values. Analysis of the failure modes did not show pure adhesive loss in any system. All systems mainly failed cohesively on enamel and dentine either from fracture of the tooth substance or composite layer.



Micro-tensile bond strength [MPa] on human enamel and dentine, respectively

### Literature

[1] Magni et al., 2007.

## Futurabond® NR: Margin quality analysis

### Study design

In extracted, caries-free human anterior teeth, standardised Class V cavities (17 groups of 8 specimens each) were prepared and subsequently treated with composite. The specimens were then stored in water for 21 days and subjected to thermocycling at 2000 cycles between 5 and 55 °C. This thermocycling process was repeated after one year.<sup>[1]</sup> The margin quality was assessed using scanning electron microscopy, according to the following criteria:

Margin quality 1: Margin indiscernible or barely discernible (continuous margin)

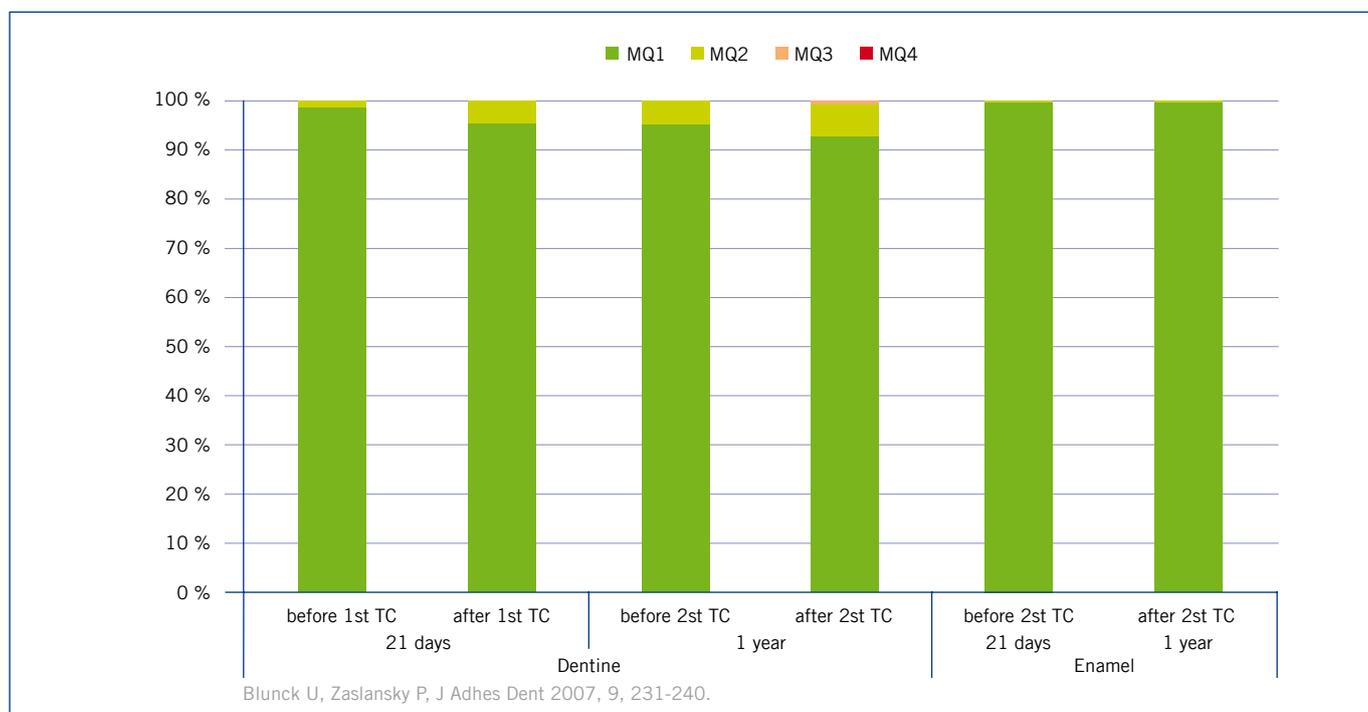
Margin quality 2: No marginal leakage, massive margin anomalies

Margin quality 3: Discernible marginal leakage („fissure“ up to 2 µm)

Margin quality 4: Massive marginal leakage

### Results

Except for only one statement margin quality 3 finding in the dentine area, all of the restorations with Futurabond NR were marginally tight after storage in water for a year and two cycles of thermocycling. Significant deterioration did not occur on dentine during the one-year time period either.



Margin quality analysis before and after thermocycling (TC)

### Literature

[1] Blunck und Zaslansky, 2007.

## Futurabond® M: Margin quality analysis

### Study design

Class V cavities were prepared in extracted human upper anterior teeth, according to the preparation guidelines for the adhesive bonding technique. The teeth prepared in this way were treated with a combination of Futurabond M and Grandio. After 21 days of water storage the test teeth were subjected to thermocycling (5 / 55 °C, 2000 cycles).<sup>[1]</sup> The margin quality was assessed using scanning electron microscopy, according to the following criteria:

Margin quality 1: Margin indiscernible or barely discernible (continuous margin)

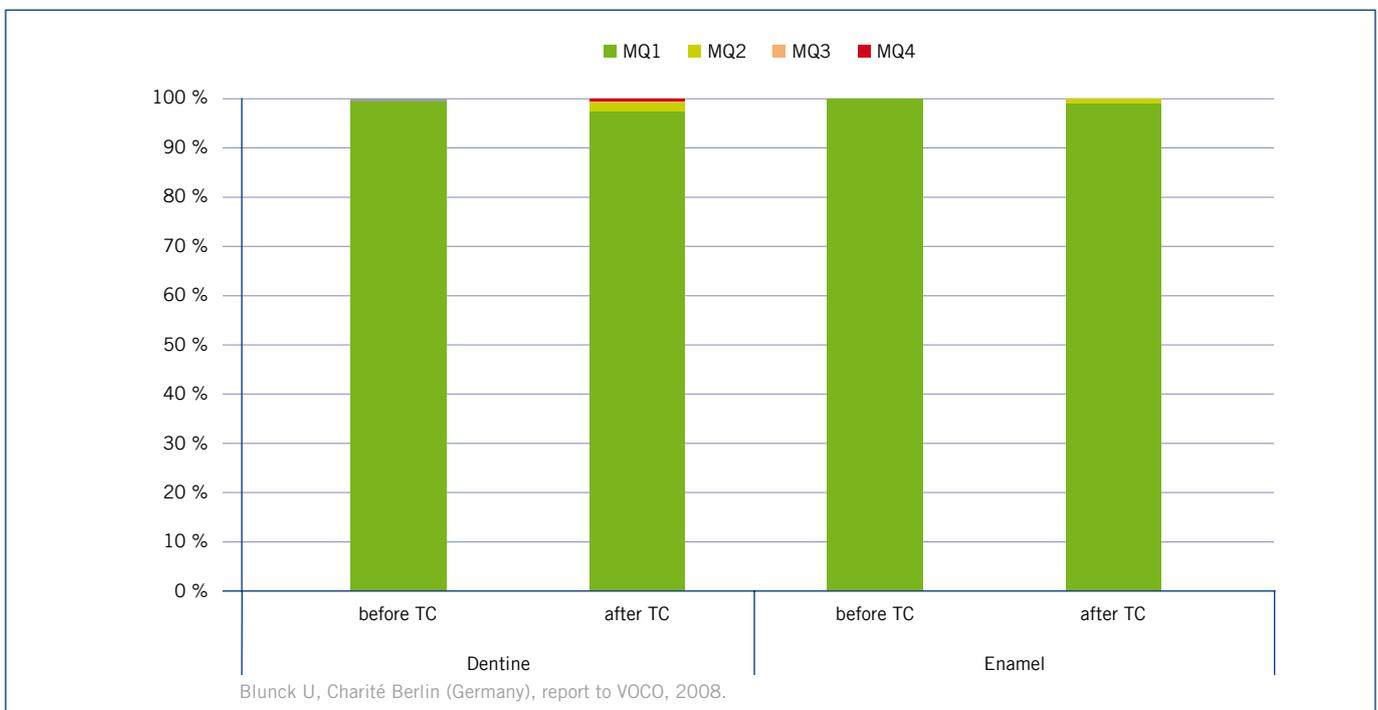
Margin quality 2: No marginal leakage, massive margin anomalies

Margin quality 3: Discernible marginal leakage ("fissure" up to 2 µm)

Margin quality 4: Massive marginal leakage

### Results

Even after thermocycling, 95 % of the Futurabond restorations placed showed intact restoration margins.



Margin quality analysis before and after thermocycling (TC)

### Literature

[1] Blunck, 2008.

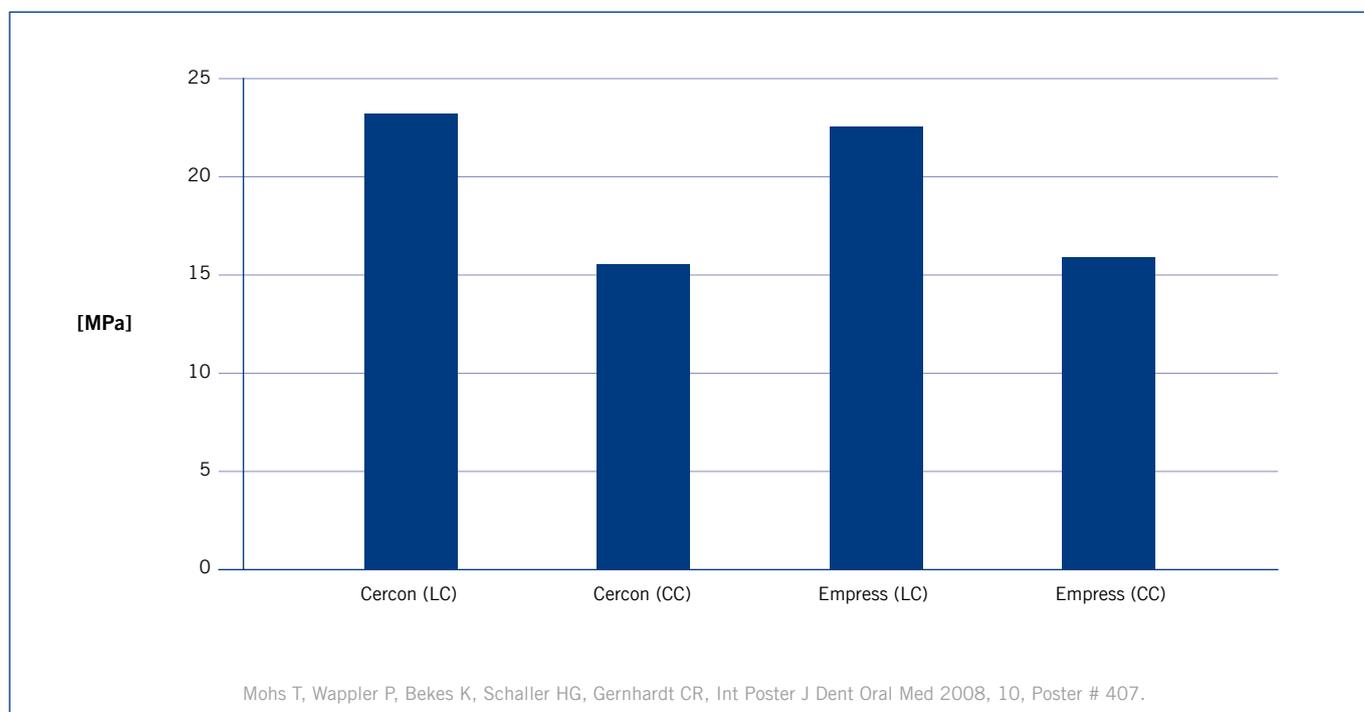
## Futurabond® DC: Luting of indirect restorations

### Study design

This study determined the bond strength under simulation of natural perfusion<sup>[2]</sup>. The ceramics Cercon (zirconium oxide ceramic, DeguDent) and Empress (lithium disilicate ceramic, IPS) were used and cured both purely chemically (CC), and by exposure to light (LC). Bifix QM was used as a luting composite.<sup>[1]</sup>

### Results

The results show outstanding adhesion values on both ceramics used. Even in those areas into which the light cannot penetrate, the chemical curing achieves a secure bond.



Micro-tensile bond strength [MPa] on Cercon and Empress (LC = light-cured, CC = chemically cured)

### Literature

[1] Mohs et al., 2008.

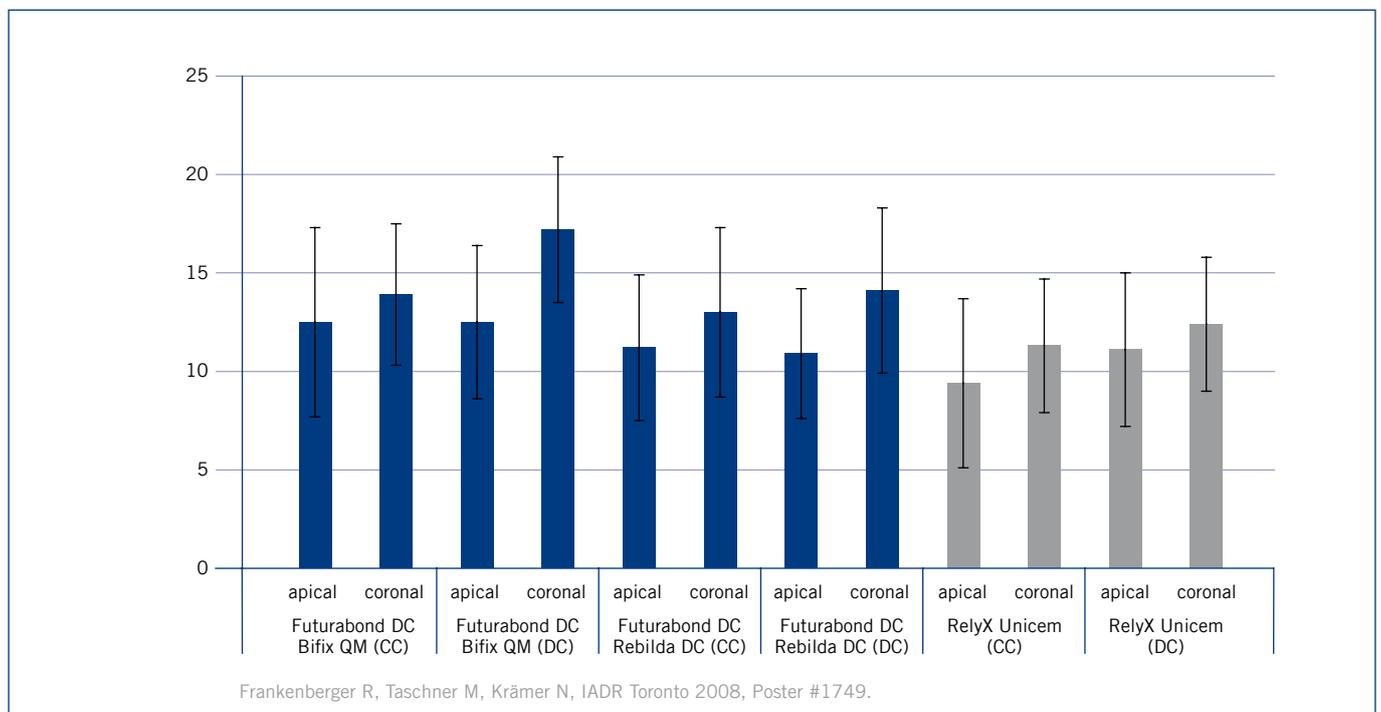
**Futurabond® DC: luting of root posts**

**Study design**

In 200 freshly extracted upper incisors the crown was removed and the remaining tooth root was endodontically treated. Glass-fibre posts were subsequently adhesively attached, using different luting systems. Several test specimens were also light-cured, in addition to pure chemical curing. After 24 hours of water storage, 1 mm thick coronal and apical discs were separated out, from which the fixed post was centrally extruded.<sup>[1]</sup>

**Results**

Futurabond DC exhibited promising adhesion values for luting fibre-glass posts in the root canal with both Bifix QM, the dualcuring composite-based luting cement, and with Rebilda DC, the core build-up material. The attained adhesion values particularly document the safe curing of bond and composite cement in the apical region, even in the chemical curing mode.



Push-out bond strength [MPa] on root dentine (CC = chemically cured, DC = dual cured)

**Literature**

[1] Frankenberger et al., 2008.

## **Futurabond® NR: Cytotoxicity**

### **Study design**

CHO-K1 cells were exposed to different concentrations (0.00025 % - 0.05 % w/v) of the bonds or a control medium. The cytotoxicity was determined over a CFA (colony formation assay) with subsequent flow cytometry (FACS) and issued a ranking.<sup>[1]</sup>

### **Results**

Futurabond NR exhibited the lowest cytotoxicity out of all the bonds tested. It was further determined here that nanoparticles do not represent a substantial contribution to the cytotoxicity. The study group summarises the results of the toxicity study in the following ranking of the examined systems:

1. Futurabond NR
2. Solobond M
3. Xeno III
4. 3M Singlebond 2
5. Prime & Bond NT

### **Literature**

[1] Yeh et al., 2008.

## Clinical tests

### Dental Advisor

#### Futurabond® NR bottle version



Futurabond NR was tested by Dental Advisor in the USA. Futurabond NR was tested and rated by 29 dentists tested in over 200 treatment procedures. The product earned a clinical rating of 93 % and 4 1/2 out of 5 stars.

The ease of mixing the liquids, low viscosity and simple handling were particularly praised as well as its lack of having a pungent odor.

There were no reports of negative effects on soft tissue or post-operative sensitivities. All test dentists found the product to be comparable or better than their current bond, 80 % would change to Futurabond NR and 92 % would recommend it to others.

#### Futurabond® DC SingleDose



Futurabond DC SingleDose was also tested by Dental Advisor. It was tested and evaluated here by 18 dentists in over 370 cases. The product achieved a clinical rating of 96 % and 5 out of 5 stars.

The compact packaging, simple activation and that the amount of the product in the blister was adequate for multiple restorations were positively emphasised. Its user-friendly storage at room temperature was likewise positively highlighted. The entire bonding procedure was described as time-saving and the consistency regarding viscosity and wetting behaviour was praised.

In addition to use, the versatility was commended for its compatibility with luting composites. The limited burden in terms of odor was also appreciated.

Post-operative sensitivities were not reported in any of the cases.

### Dental Product Shopper (USA)

#### Futurabond® DC SingleDose

#### Rating 4.3 out of 5 – Best Product 2009



Futurabond DC SingleDose was rated by a group of 12 test dentists with a combined total of 267 years of practical experience (mean 22.25 years). The simplicity of the application and the excellent initial adhesion were rated with an average score of between very good (4 points) and excellent (5 points). All other test criteria, such as polymerisation time, elasticity in application and the duration of the application were also rated with an average of at least 4 points.

The universality of Futurabond DC and the test point “postoperative sensitivity” were especially praised.

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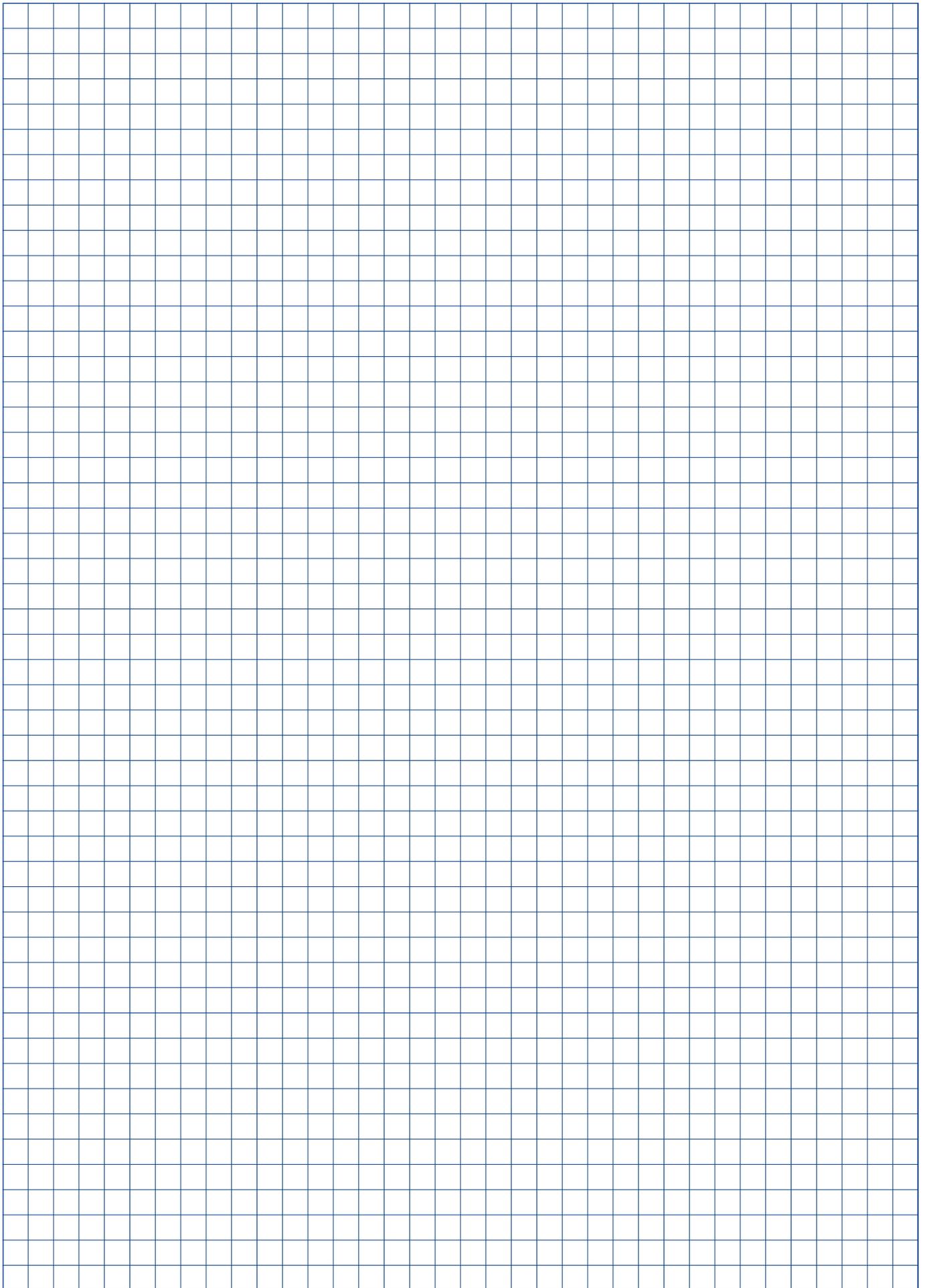
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Anton-Flettner-Straße 1-3  
Postfach 767  
27472 Cuxhaven  
Germany

Tel.: +49 (0)4721-719-0  
Fax: +49 (0)4721-719-140

[info@voco.com](mailto:info@voco.com)  
[www.voco.com](http://www.voco.com)