



Grandio® / Grandio® Flow

SCIENTIFIC PRODUCT INFORMATION

VOCO – THE DENTALISTS

VOCO, the family-run, independent Cuxhaven business, has set new standards in the development of innovative products with intensive research and development work for almost 30 years now. With the development of Grandio®SO, another chapter will now be added to this success story.

The BMBF project “Monomer-free-based, nano-composites as biocompatible materials for dental filling materials and prosthodontics” that ran from 2000-2003 provided the basis for the know-how in the development of filling composites. The groundbreaking findings of this research project led to the development of the first nano-hybrid composites in the world: Grandio®. Seven more years of research and development work in the VOCO laboratories as well as cooperation with over 150 universities and research facilities around the world are now represented by our new restorative: Grandio®SO.

Quality made in Germany

In 1994, VOCO was one of the first businesses able to show a certified quality assurance system (EN ISO 9001/EN ISO 13485/Standard 93/42 EEC Annex II). The approximately 20 employees in our quality control department guarantee that you always receive our products in the unvaryingly high quality that you rightfully expect from us.

Innovations for dental health

Certified quality “Made in Germany” is created at our 22,000 m² 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.



Ormocer® is a registered trademark of the Fraunhofer Society, Munich.

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Introduction

Composites – yesterday and today

The first resin-based materials, methacrylates in particular, made their appearance in dentistry as early as the 1930's. The first self-curing materials also made resins attractive for use as dental fillings for the first time in the 1940's. Buonocore's etching technique^[1], introduced in 1955, provided the stimulus for the simultaneous development of the essentially associated adhesive systems. Besides the aim of providing adhesion between the tooth substance and the resin, reducing polymerisation shrinkage and increasing durability were, from the very beginning, the focus in the development of an alternative to amalgam. Therefore, the combination of resins and silanised inorganic fillers to form "composites" is deemed to be a milestone which has drastically decreased shrinkage and significantly increased the mechanical resistance, according to Rafael L. Bowen^[2] in a 1962 report. Light-curing materials were developed later in the 1970's and have been commercially available since 1977. Although the development has branched out into different philosophies and technologies, adhesively bonded composites have become an integral part of dentistry. Treatment with modern hybrid composites is also recognized today by the DGZMK (German Society of Dental, Oral and Maxillofacial Medicine) and DGZ (German Society of Conservative Dentistry) as a permanent treatment in posterior teeth^[3, 4].

Demands on the optimal restorative

The poor aesthetics of amalgam for anterior restorations were the sole motivating force behind the development in the beginning, but later toxicological, ecological and allergological concerns of patients and doctors also gained importance. Composites were now meant to represent a general alternative to amalgam. The desired broadening of the indications to include the posterior area led to a drastic increase in the demands on the material's mechanical properties.

Not only the mechanical suitability for chew loading and abrasion resistance in posterior restorations required improvements, but the aesthetic demands of the patients also continued to rise. White or tooth-shaded materials alone were no longer sufficient from the point of view of aesthetics. Today, an aesthetic filling material must deliver a perfect appearance with natural translucency.

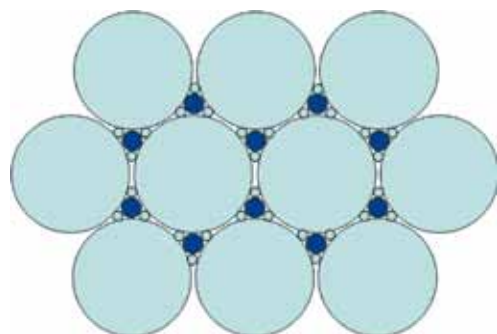
Not least, the dentist also has his/her own technical requirements for a composite, particularly with respect to handling. Only a material that is reliable and easy to handle makes for good workmanship, the foundation of all aesthetic and durable restorations.

A composite must thus meet many, very different criteria to get as close as possible to the objective of the optimal restorative.

The importance of the fillers

The resin monomers draw nearer to each other and form networks during polymerisation. Inorganic or pre-polymerised fillers are therefore utilised to counteract the resulting shrinkage. Moreover, hard fillers considerably increase the material's stability and resistance to abrasion. This is why a high filler content is important.

The supposedly simple formula states: the higher the filler content, the lower the resin content, which equals less shrinkage. In search of the maximum filler load, one quickly finds that spheres of identical size, when packed as tightly as possible, always have the same volume, irrespective of their size. In order to fill the interstices between the spheres and/or spherical fillers, the sphere sizes must be varied. This is the concept behind hybrid composites.



High filler load: the large spheres are packed to maximum density, and the interstices are filled with smaller spheres.



Macro-filler composites are similar to asphalt in that large filler particles can break away from the resin matrix. This is why they are quite difficult to polish.

10 μm or more. The inhomogeneity of resin matrix and fillers causes these characteristics. Therefore, smaller filler particles are desirable, but there are limits here, too.



An overfilled micro-filled composite is similar to clay that has not received an additional matrix (water): so brittle and viscous that it cannot be modelled.

processed at all, more resin must be used instead of filler. The superior aesthetics of microfillers, in comparison to macrofillers, are obtained at the expense of the filler content, which ultimately results in higher shrinkage. Creating a hybrid filler with even smaller particles would definitely solve the shrinkage problem, but, in addition to the still unsolved problem of high viscosity, it was completely impossible for many years to purposely manufacture even smaller fillers. Nanoparticles come into play here with their unexpected properties.

In theory, nanotechnology is not necessarily mandatory to achieve a high packing density. In dental reality, however, there is definitely a natural limit as to how large the fillers can be without presenting considerable disadvantages. Classical macrofiller composites, for example, exhibit only moderate tensile strength and poor polishability where the particles have a diameter of

In microfiller composites, embedding the filler particles in the matrix provides a much more homogeneous consistency and thus good polishability. In equal filler loads, microfillers compared to macrofillers have, however, a much larger surface area and thereby more surface contact to the resin. Thus, the viscosity rapidly increases. In order to obtain a composite that can be

Nanotechnology

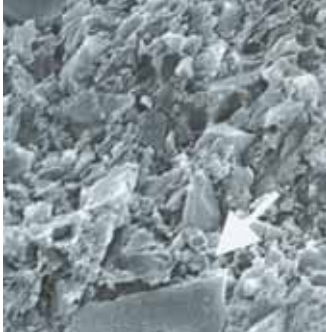
Nano is the mathematical prefix for the order of magnitude below “micro” (1 μm = 1000 nm). It is not, however, a protected term. Anyone can call anything “nano”. If, however, it was simply a case of re-naming a technology, then nanotechnology could hardly be regarded as one of the pivotal technologies of the 21st century^[5].



The size ratio of a nanoparticle to a soccer ball is the same as a soccer ball to the earth. The diameter of a nanoparticle thus corresponds to ca. 500 atoms. Biologically, this is analogous to the size of the smallest bacteria and/or the largest known enzyme.

Generally, a nanoparticle is defined as a particle with a diameter of 10 - 100 nm, thus just below the wavelength of visible light^[6]. A defining limitation for “nano” is unnecessary, though. The unusual properties of nanoscaled materials automatically provide this definition and speak for themselves: nanoscaled metals become semiconductors pigments and ceramics turn clear, glass becomes an adhesive, and much more.

The main reason this key technology has permeated a range of application areas only in recent years is that the dimension is technically difficult to access. Previously, construction in nanodimension was the domain of nature. In principle, two strategies are technically possible. The first, the “top-down” strategy, consists of reducing the size of larger particles by, for example, grinding and sifting. The second, the “bottom-up” strategy, describes the development of nanoparticles starting from atoms or molecules, with controlled sol-gel crystallisation or flame pyrolysis. Both possible strategies present a physical problem: agglomeration. Nanoparticles have quite a large surface in comparison to their volume, and thus higher surface energies. Untreated, they immediately agglutinate to the usual micro-particles of approx. 0.5 μm (500 nm) in diameter and lose the phenomenal properties of the original nanoparticles. It is therefore necessary to chemically inactivate the surface of freshly generated nanoparticles in order to enable their isolation. Their special properties can only be harnessed in this way.



Particles after grinding and sifting, the particle size distribution is inhomogeneous and not nanoscaled.



Agglomerated nanoparticles, e.g. those from flame pyrolysis, also do not exhibit the properties of isolated nanoparticles.

One of these special properties of nanoparticles is their effect on the viscosity of a surrounding liquid. Given the properties of microparticles, one would expect nanoparticles, with their again drastically increased surface, to result in an extremely viscous and non-processable mass. Surprisingly, isolated nanoparticles embedded in a resin matrix do not behave like solid matter, but rather like a liquid.

While a mixture of microfillers and resin results in a sticky mass, the same filler degree with true nanoparticles is as liquid as oil. Based on this, it is even possible to produce flowable composites with a filler degree of more than 80%.



On the right: a resin with 38% micro-filler yields a fissured mass.
On the left: the same resin with 40% nano-filler still remains liquid.

This special property of nanofillers allows composites a never before obtained filler degree of 87%. The nano-hybrid composite Grandio has a shrinkage of merely 1.57%. Additionally, the nanoparticles inside the matrix have a cross-linking effect

which, beyond shrinkage reduction, increases fracture resistance, edge stability and abrasion resistance.

The translucency of non-agglomerating nanoparticles is another phenomenon which contributes in particular to the aesthetics of dental restoratives. Since the particles are smaller than the wavelength of visible light, absorption does not occur, and light shines through them as it would through glass.



A polymer filled with nanoparticles is clear and translucent, whereas one filled with microfillers, is opaque.

Since nanotechnology delivers high filler degrees, low shrinkage and good crosslinking, other properties like opacity, tackiness and flow properties of composites can be adjusted without technical compromises by varying the microfillers.

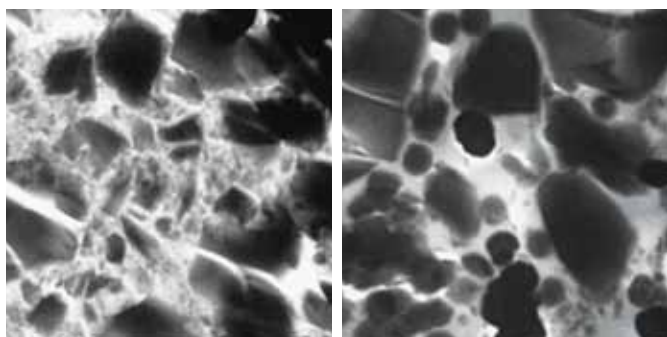
Handling properties can be optimised as required, and the material can be applied faster and safer. Thus, the

use of nanotechnology as part of the material concept leads to high physical durability, reduced shrinkage and improved aesthetics, and it simultaneously permits meeting the demands of consistency and handling requirements.

Grandio – the concept

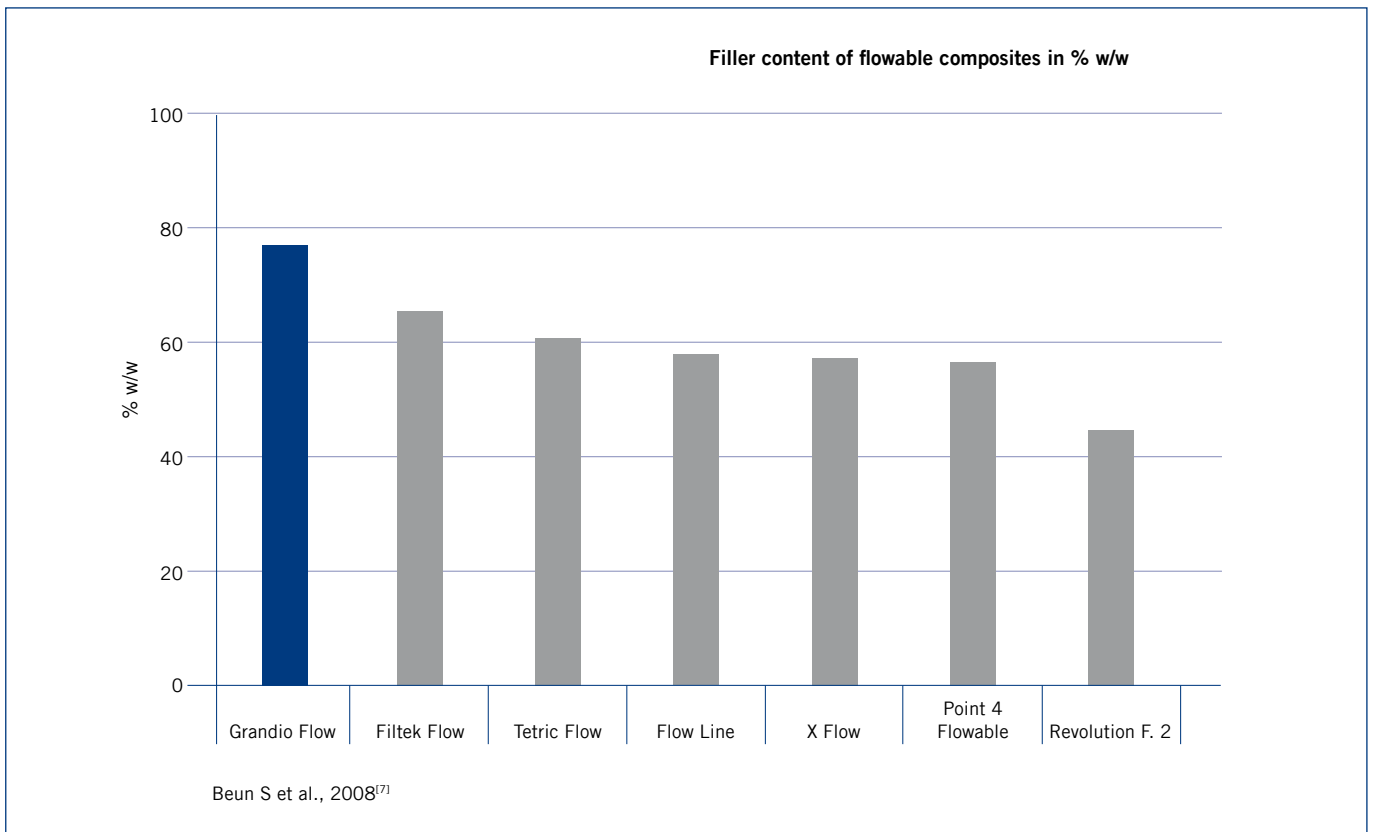
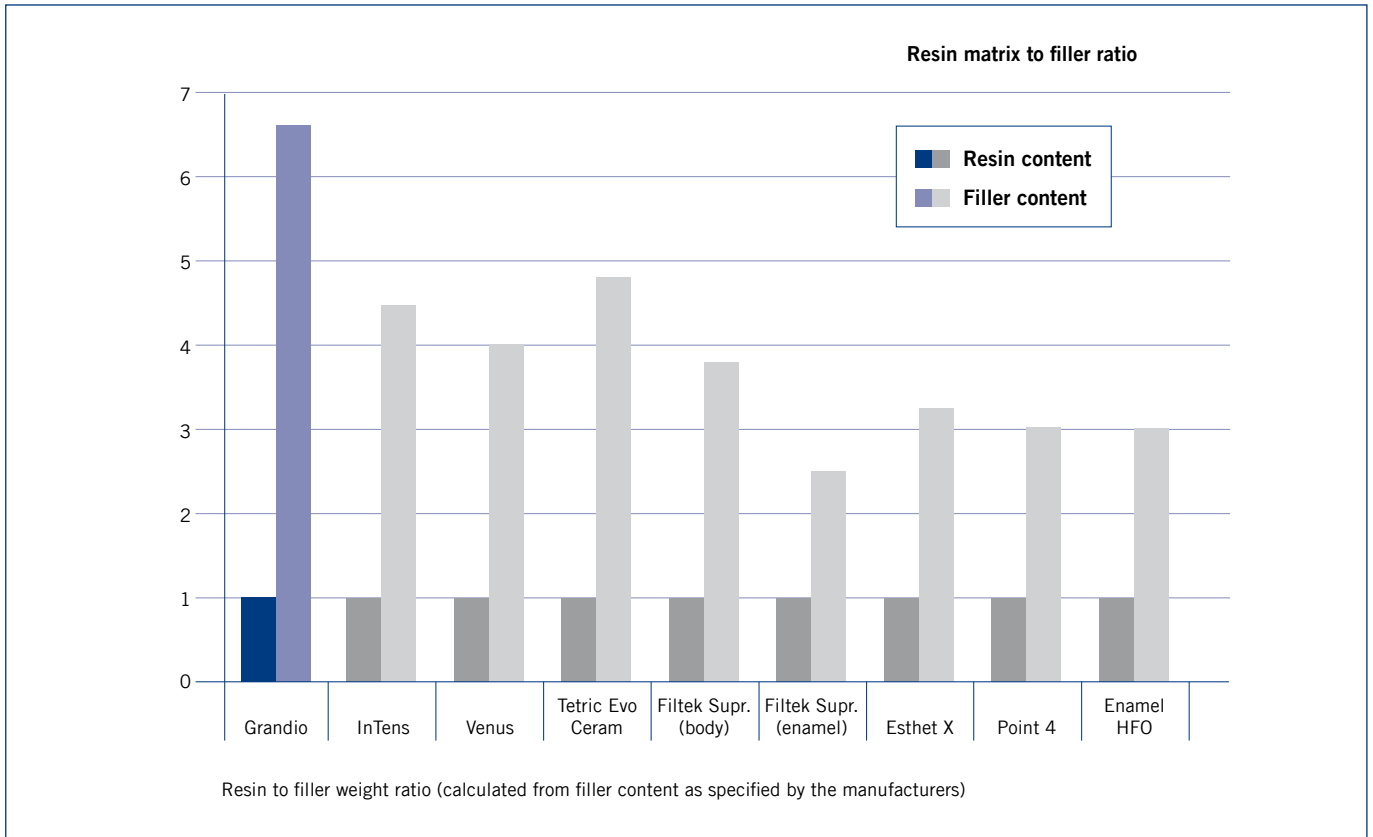
The objective for the development of Grandio, the nano-hybrid restorative, was the optimisation of physical properties to obtain a universally applicable high-performance composite. The question was: “How can we make a good micro-hybrid composite even better?” The incorporation of nanoscaled particles into a conventional composite resin matrix led to an astonishing result. While a significant thickening effect (increase in viscosity) can already be observed by adding only a relatively small amount of traditional fillers (pyrogenic silica, aerosils or finely ground glass-ceramic), the incorporation of nanoscaled fillers up to a proportion of 40% w/w of filler has absolutely no influence on the viscosity of the resin. By adding glass-ceramic microfillers to such a pre-filled resin, an extraordinary restorative was developed: the nano-hybrid composite Grandio. The surface-modified nanoparticles, which are uniformly embedded in the resin matrix, function as highly effective cross-linkers, which lend additional stability to the resin matrix.

This increase in filler content is highlighted when the filler content is put into relation with the resin content (see graphic next page). While a conventional hybrid composite has a ratio of resin (20% w/w) to filler (80% w/w) of 1:4, this ratio is 1:6.7 in Grandio. The same technology also makes the production of flowable composites with a filler degree of 80% possible, which is in the range of normal non-flowable composites. Thus, Grandio exhibits physical properties not reached so far, and the flowable Grandio Flow easily compares to high-viscosity composites in its solidity and shrinkage.



SEM images (Prof. D. Behrend, Rostock): left – Grandio, right – a hybrid composite.

With a traditional composite (right), large light areas filled with only resin can be seen between the dark fillers under the Scanning Electron Microscope (SEM). In these areas polymerisation contraction of the material is particularly strong. Grandio's resin matrix between the glass-ceramic fillers appears grey since it is interfused with nanoparticles. Shrinkage is minimised and the total system is stabilised. Nanoparticles and glass ceramic in well-matched particle size, together achieve a filler degree of 87% w/w (71.4 % v/v), a volume never reached before in a hybrid composite.



Indications

Improved handling properties

Nanotechnology not only brings higher stability and less shrinkage, but it additionally creates scope for the optimisation of handling properties of the material, which is an important factor for an optimal restoration. It was possible to design Grandio with particular emphasis on it not sticking to the instrument and on it being thixotropic, allowing it to be shaped in the cavity with simple movements and using almost no pressure.

Aesthetics

No aesthetic compromises had to be made in developing Grandio with regard to colouring and the tooth-like translucency effect. This is due to the optical properties of disperse nanoparticles. Grandio's non-opaque shades demonstrate an excellent chameleon effect and outstanding shade matching to the tooth. This perfect adaptation makes it unnecessary to use a complex shade layering technique, as it delivers an aesthetically perfect result despite using fewer shades. Choosing the correct VITA® shade is simplified by using the accompanying shade guide made from original, light-cured material. Grandio's custom shade guide provides an accurate estimate of the finished restoration's shade.

Possible applications

Being a universal composite, Grandio is suited for all classes of filling, stable in posterior teeth and at the same time aesthetic for anterior teeth. Grandio Flow provides still further possibilities since it offers very good wetting allowing the material to flow directly out of the syringe even into extremely small cavities. Optimum matching of Grandio Flow to Grandio in shade and translucency allows combined application, using, for example, the CBF (composite-bonded-to-flowable) technique, without reducing stability or aesthetics.

Grandio

- Class I to V fillings
- Reconstruction of traumatically affected anteriors
- Facetting of discoloured anteriors
- Correction of shape and shade for better aesthetic appearance
- Locking, splinting of loose anteriors
- Repairing veneers
- Filling deciduous teeth
- Core-build-up under crowns
- Composite inlays

Grandio Flow

- Filling minimally invasive cavities of all classes
- Filling small class I cavities and extended fissure sealing
- Filling class II - V cavities including V-shaped defects and cervical caries
- Blocking out undercuts
- Lining or coating cavities
- Repairing fillings and veneers
- Luting translucent prosthetic pieces (e.g. full ceramic crowns, etc.)

**Universal indication
for packable and flowable
composite**

Technical data

Grandio		
Filler content % w/w (% v/v)	87.0% (71.4%)	DIN 13922
Polymerisation shrinkage	1.57 Vol.%	University of Manchester
(Young's) Modulus of elasticity	17100 MPa	ISO 4049
Flexural strength	161 MPa	ISO 4049
Surface hardness (Vickers)	84 HV	University of Regensburg
Abrasion	18 µm	3-body wear ACTA
Water solubility	< 0.3 µg/mm ³	ISO 4049
Water absorption (7 days)	10 µg/mm ³	ISO 4049
Curing depth*	3 mm/20 sec	ISO 4049
Colour stability (24 h)	no discolouration	ISO 4049
Resistance to natural light	corresponds to	ISO 4049
Radiopacity	250 %AI	ISO 4049
Dentine adhesion with Solobond M	29.8 MPa	University of Münster

Grandio Flow		
Filler content % w/w (% v/v)	80.2% (65.7%)	DIN 13922
Polymerisation shrinkage	3.2 Vol.%	Dilatometric**
(Young's) Modulus of elasticity	9550 MPa	ISO 4049
Flexural strength	141 MPa	ISO 4049
Abrasion	32 µm	3-body wear ACTA
Water solubility	< 0.3 µg/mm ³	ISO 4049
Water absorption (7 days)	10 µg/mm ³	ISO 4049
Curing depth*	3.5 mm/20 sec	ISO 4049
Colour stability (24 h)	no discolouration	ISO 4049
Resistance to natural light	corresponds to	ISO 4049
Radiopacity	200 %AI	ISO 4049
Dentine adhesion with Solobond M	29.4 MPa	University of Münster

*(Polofil Lux, 500 mW / cm²) **(analog J. Prosthet. Dent. 1988, 59, 297-300)

Physico-chemical analyses Grandio

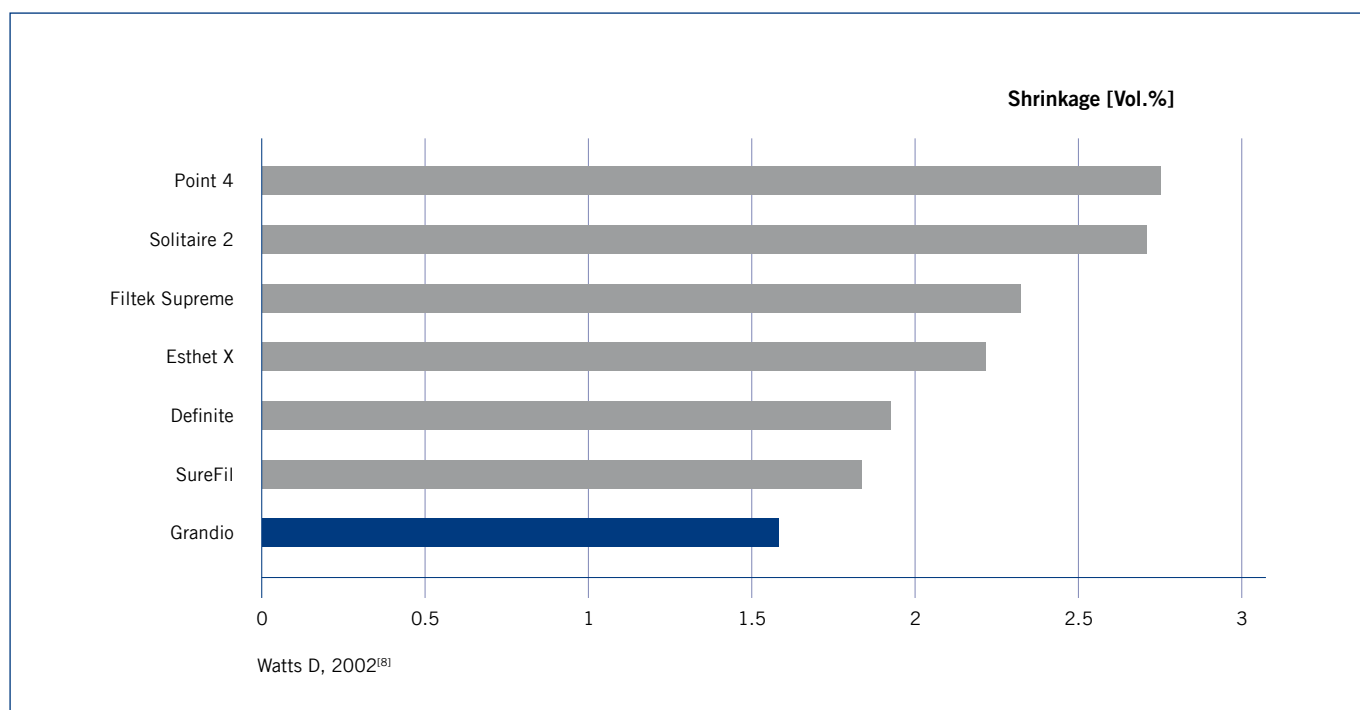
Shrinkage and thermal expansion

To be able to make a restorative pliable and subsequently curable, a resin matrix that encases the filler is mandatory. Polymerisation heat, toxicity and other negative criteria restrict the choice of suitable chemical systems. All matrices used in restoratives today shrink during polymerisation, since the monomers begin in an unsystematic condition and attain a condition of higher order. The minimisation of shrinkage is of particular importance in the development of dental restoratives, because of the associated material tensions and the development of marginal leakage. As described in the introduction, nanotechnology again offers completely new opportunities and approaches to solutions, when applied correctly and with the necessary know-how. The Grandio concept proves

its strengths here as well. Not only is polymerisation shrinkage reduced, but the thermal expansion work of the material is simultaneously lowered to a level comparable to the natural tooth; another important factor for the longevity of a filling.

Shrinkage (University of Manchester and University of Geneva)

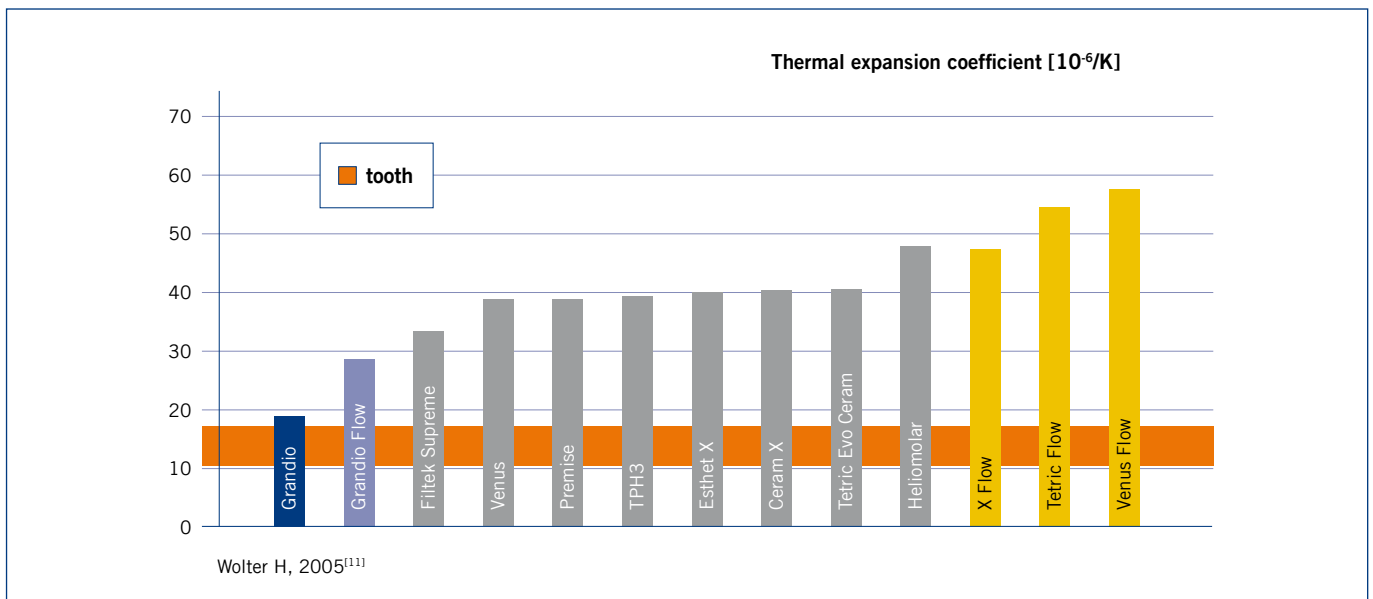
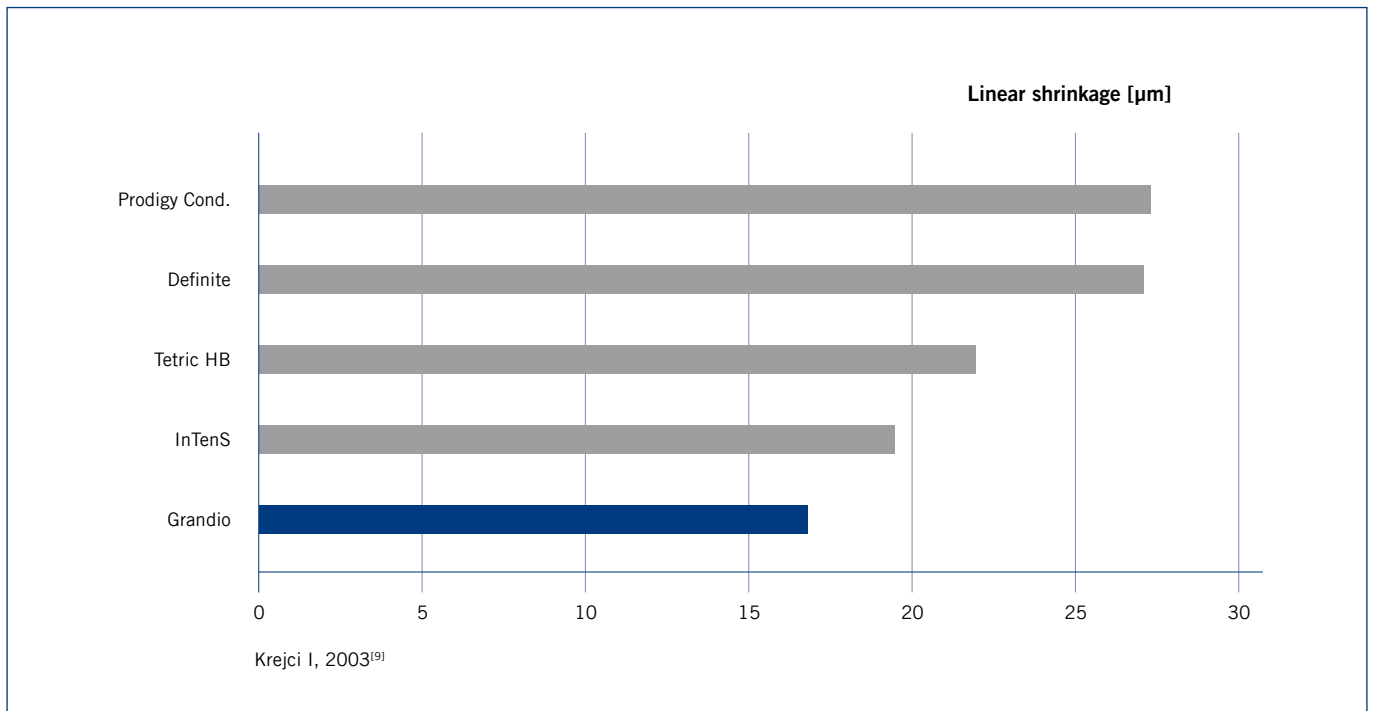
The polymerisation shrinkage of composites was independently tested using different methods at the University of Manchester^[8] and the University of Geneva^[9].



Thermal Expansion (Fraunhofer Institute ISC Würzburg)

Although thermal expansion behaviour depends on mechanisms completely other than polymerisation shrinkage, quite similar problems can result. If a restorative contracts or expands from temperature changes in the mouth in a manner significantly different than the tooth substance, there is a risk that the occurring stress may cause discomfort or even lead to micro-leakage and marginal failure. The load caused

by polymerisation shrinkage only occurs once, and it can be influenced by layering the material. The alternating thermal loading, however, occurs every day and cannot be influenced by the dentist. Therefore, a toothlike thermal expansion coefficient (dentine=11; enamel=17 [10-6K-1])^[10] should be the goal. Restoratives were examined for these criteria at the Fraunhofer Institute for Silicate Research in Würzburg^[19].



Conclusion: Grandio exhibits extremely low polymerisation shrinkage during placement of the filling, and toothlike thermal expansion in situ. Thus, stress on the cavity walls is significantly reduced. A durable restoration with a tight marginal seal results from using Grandio in combination with proven bonding materials like Futurabond NR or Solobond M.

Restoratives are exposed to great forces, especially in areas bearing masticatory loads. The physical properties of the restorative must be optimised according to conclusive mechanical parameters in order to construct a durable and resistant filling material. A set of test procedures has been established for rating the quality of a filling material.

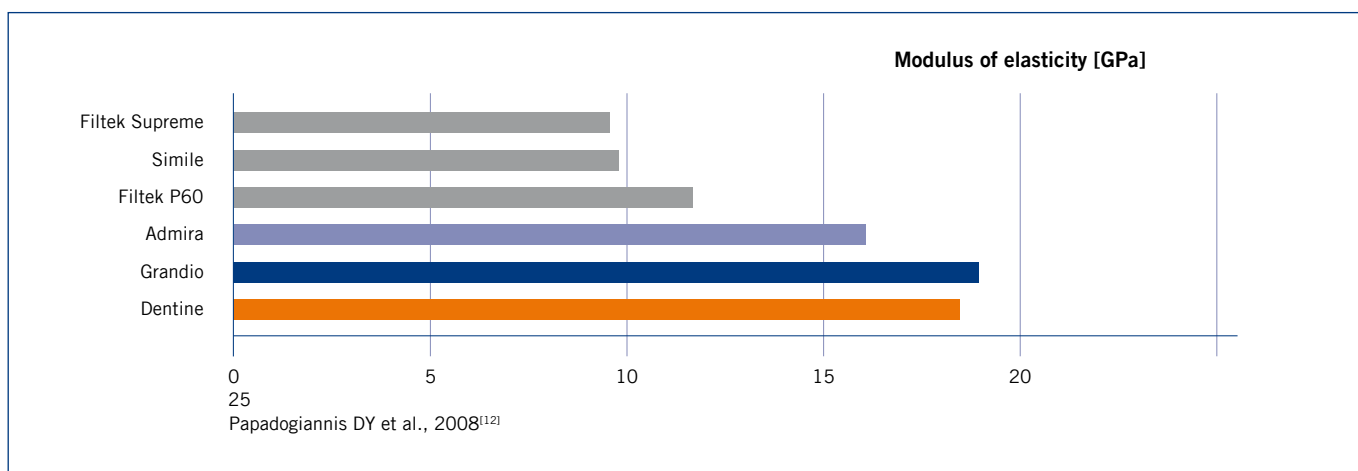
Modulus of elasticity and flexural strength

Particularly in restorations that feature thin layers and/or are supported only by little or no tooth substance, high twisting forces arise. The flexural strength of a material indicates how much force is necessary to break a test specimen. The deformation under load in the form of the modulus of elasticity is simultaneously measured during these tests. A low modulus of elasticity means high deformation which is an undesirable property in dental filling materials. If high flexural

strength is only reached through creating a material that gives way too easily and thus evades the load, then an unnatural load distribution results from the chewing strength no longer being horizontally transmitted to the periodontium. In this case, occlusal pressure constitutes a lateral tensile load on the surface which can lead to a loss of adhesion on the cavity wall and thus marginal caries. In deeper regions within the cavity, the occlusal load on flexible filling materials induces a lateral expansion which can lead to fractures in the remaining lateral tooth substance. High flexural strength in combination with a toothlike, high modulus of elasticity is thus desirable in every case.

Modulus of elasticity (University of Athens)

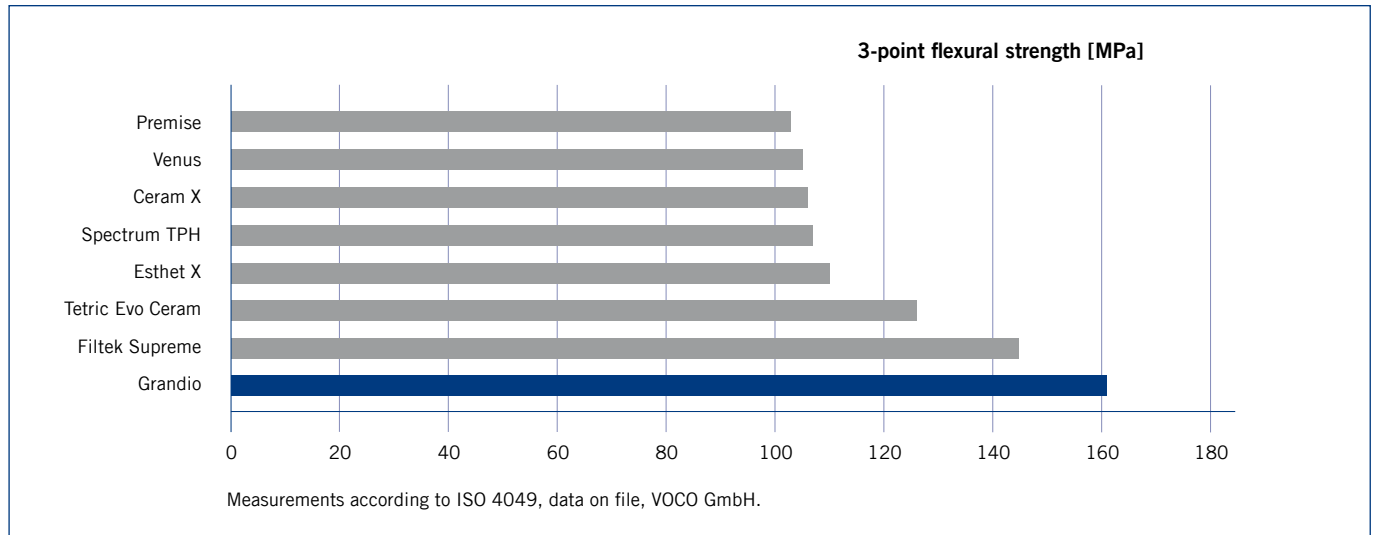
The modulus of elasticity is determined in a 3-point flexural strength test from the deformation of the material in relation to the applied force.



3-point flexural strength (internal study)

The force necessary to break a defined rectangular specimen block

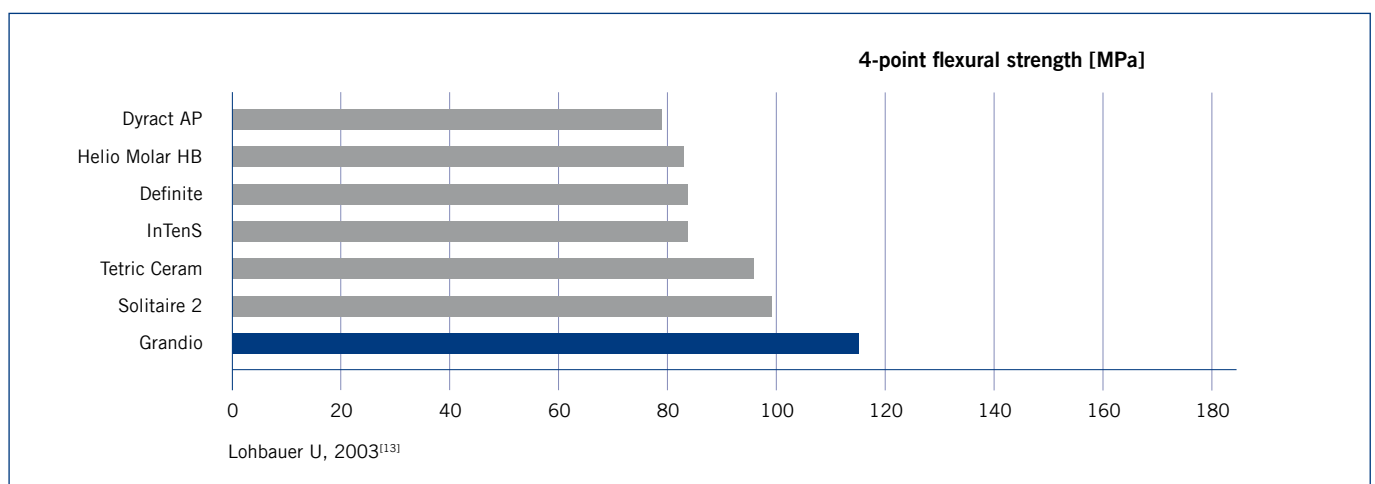
that is supported on both sides by applying force to its centre is determined in a 3-point flexural strength test.



4-point flexural strength (University of Erlangen)

In contrast to the 3-point flexural strength test, the testing force during the 4-point flexural strength measurement is simultaneously applied to 2 adjacent points, whereby higher local flexural loads do occur in the material.

The absolute values of both methods therefore cannot be compared, although the trend within both methods is similar. The 4-point flexural strength of several materials was tested in a study at the University of Erlangen^[13].

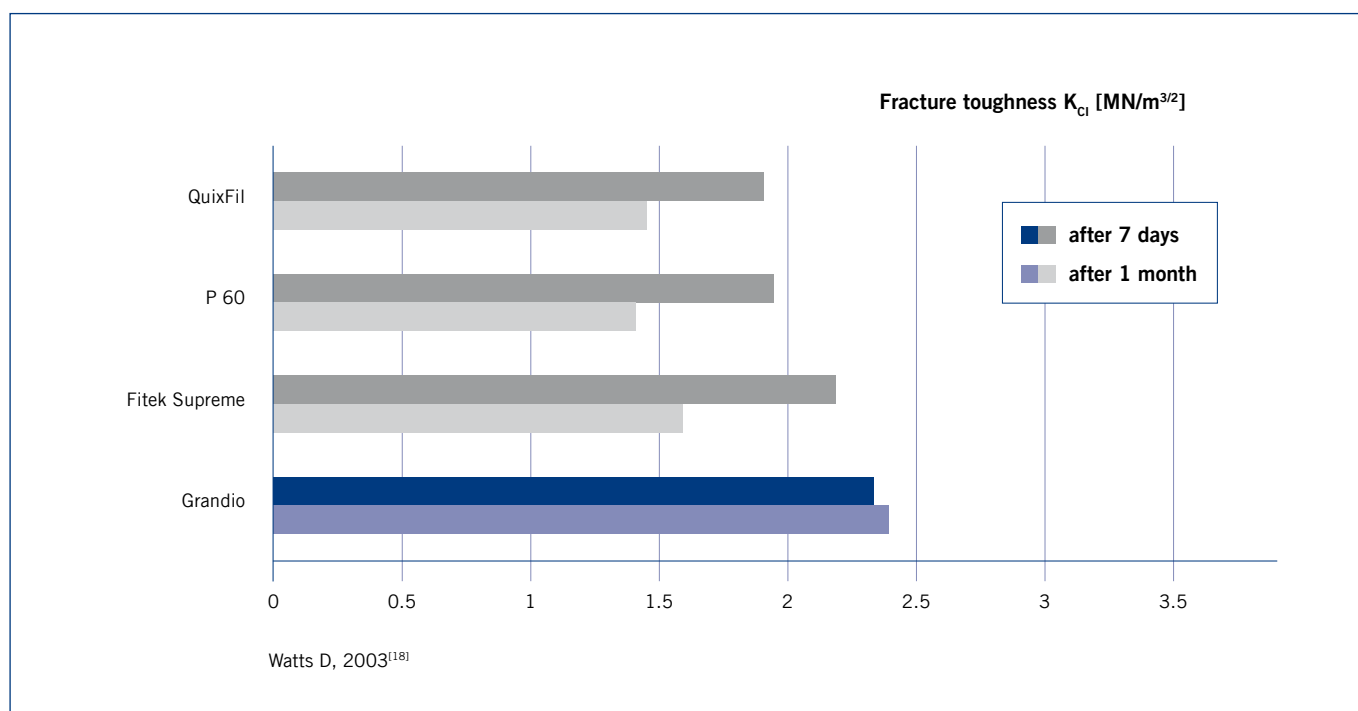


Conclusion: The external examination confirms the results of the 3-point measurement. Similar results are produced independently of the varying requirements: Grandio exhibited the highest flexural strength of all tested materials. The modulus of elasticity is close to the average^[8] for dentine (18.5 GPa), and within the range of the values for enamel^[15,16,17] (12-80 GPa), i.e. the material functions like the remaining tooth substance under stress. Considering this aspect, Grandio is ideally suited for posterior teeth.

Fracture toughness (University of Manchester)

Fracture toughness indicates the force that is necessary to achieve extension of fractures in an already fractured moulding. Long-term tests with interim water storage are designed to further substantiate that the physical properties of dental materials are not negatively modified by moisture absorption.

The University of Manchester tested the fracture toughness of several different materials after storage in water^[12]. The measurements were conducted after a week and again after one month to provide a more accurate long-term prognosis.

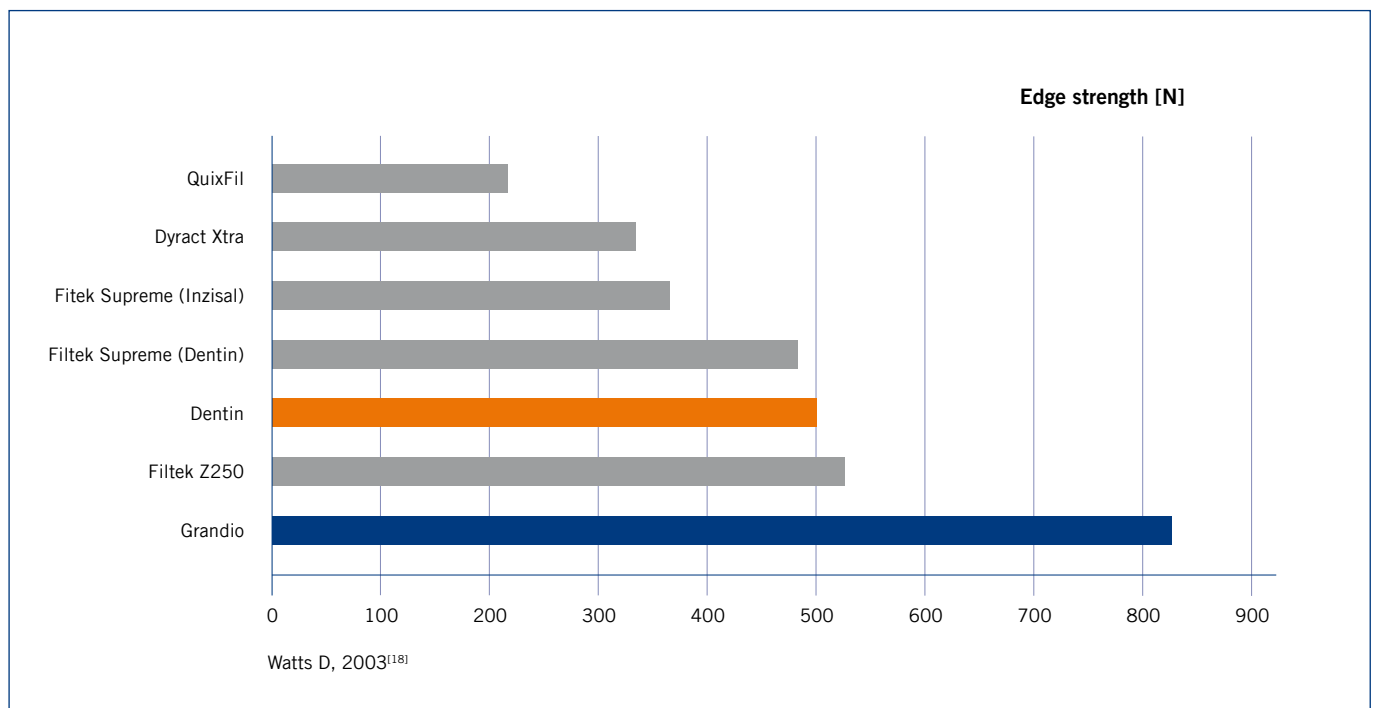


Conclusion: Grandio exhibits the highest fracture toughness of all the materials tested. The finding that the fracture toughness remains the same over a longer period of time is even more important. This long-term stability can be attributed to Grandio's extremely low water absorption, which in turn is a result of the extremely high filler content and excellent cross-linking of the resin matrix.

Edge strength (University of Manchester)

This test simulates an extreme load in the mouth as it would occur when biting through particularly hard foods. A metal point placed near the edge of the specimen is loaded and the force necessary to fracture the specimen or chip the edge

of the composite is measured. The University of Manchester examined different materials for these characteristics.



Conclusion: Grandio demonstrates very high edge strength as a result of the excellent cross-linking, which particularly increases the load capacity of cusp structures and incisal edges.

Surface hardness and abrasion

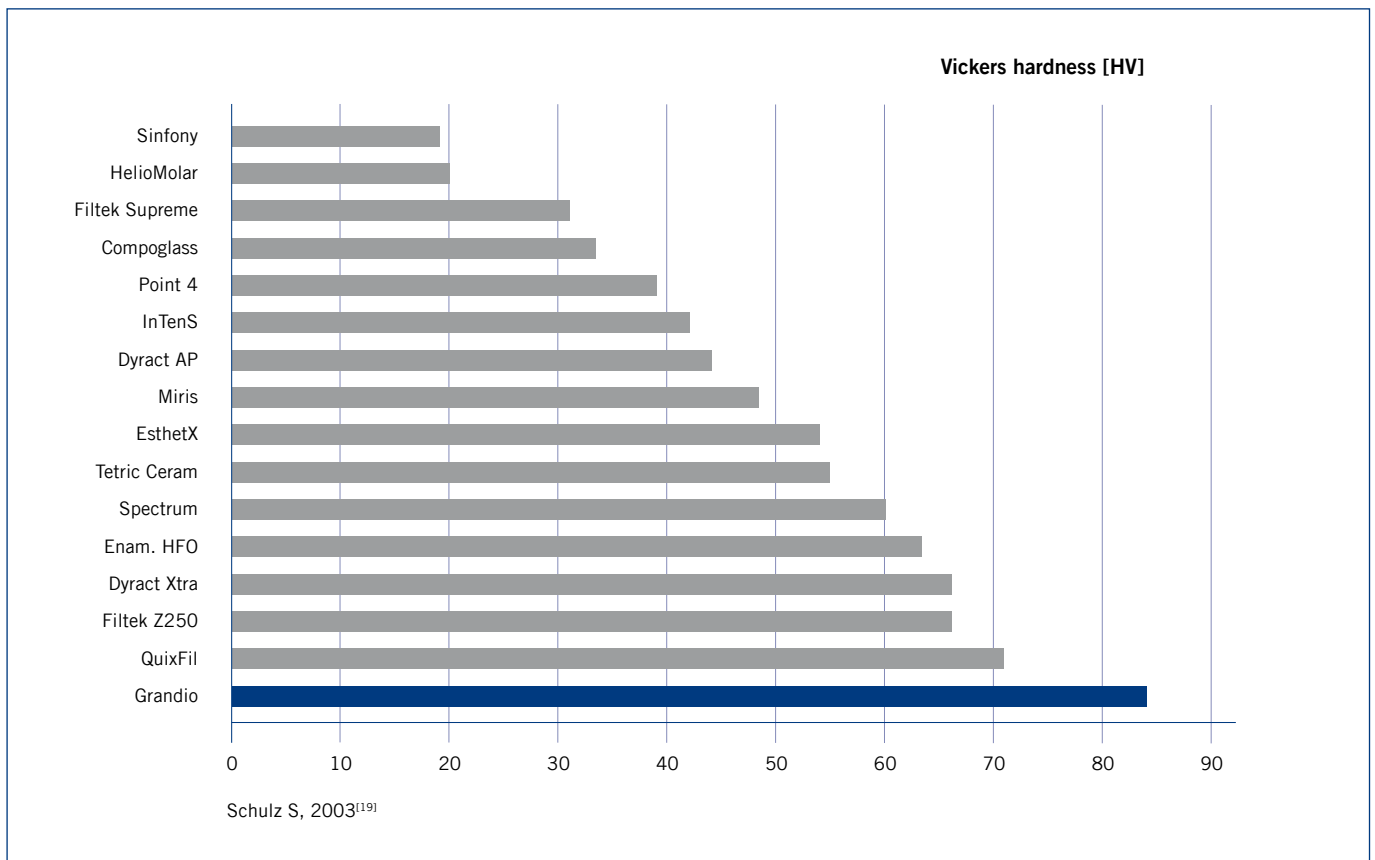
The abrasive wear caused by chewing load continues to be a central aspect of the durability of restorative dental materials. High abrasion rates in posterior teeth lead to edge fractures and loss of the occlusion. Abrasion in the anterior teeth leads to loss of lustre, which makes the restoration appear dull and unaesthetic. It is thus a fundamental goal of the development

of restoratives to optimise hardness and abrasion resistance. This goal was achieved in the nano-hybrid restorative Grandio by utilising new fillers finely coordinated with each other. The extremely high filler content and spherical nano-particles provide Grandio with an exceptionally hard surface that is superior to conventional composites.

Vickers hardness (University of Regensburg)

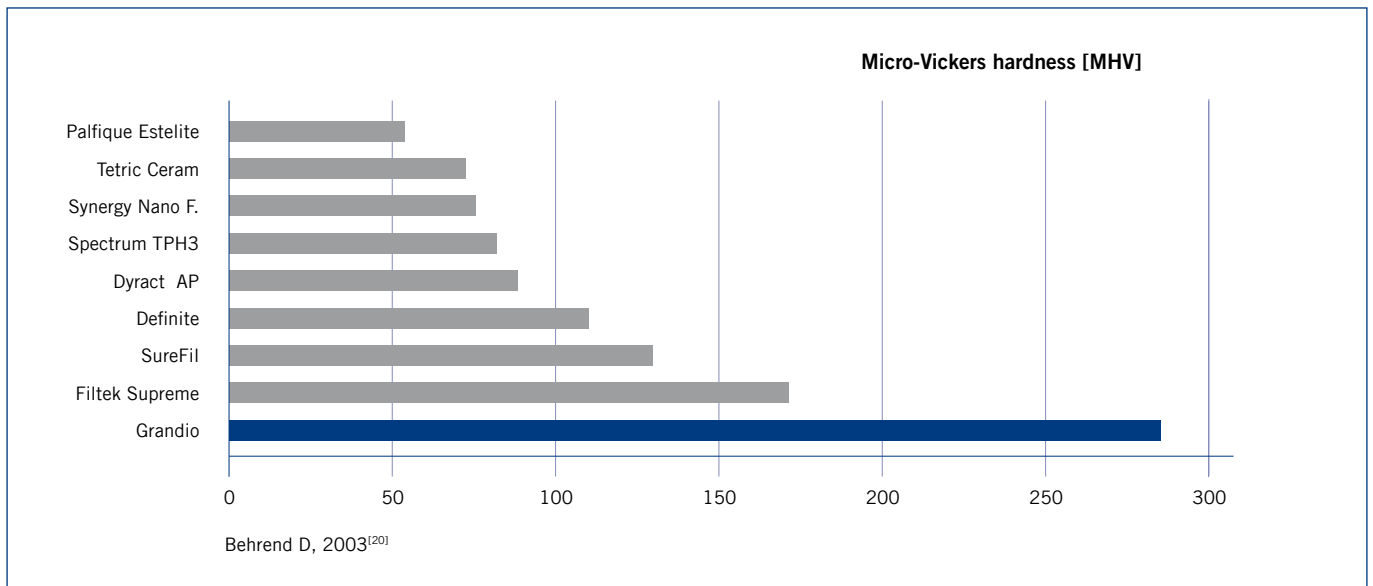
The penetration depth of a standardised pyramidal diamond point is measured under defined load and duration for the measurement of hardness according to Vickers (HV). The resulting impression left in the material is measured and the hardness subsequently calculated. Whereas the diamond point is standardised, it is important that the same conditions

are present concerning load pressure and loading period to ensure comparability of the different measurements of Vickers hardness. The following examination was conducted according to the DIN 50 133 industry standard at University of Regensburg:



Micro-Vickers hardness (University of Rostock)

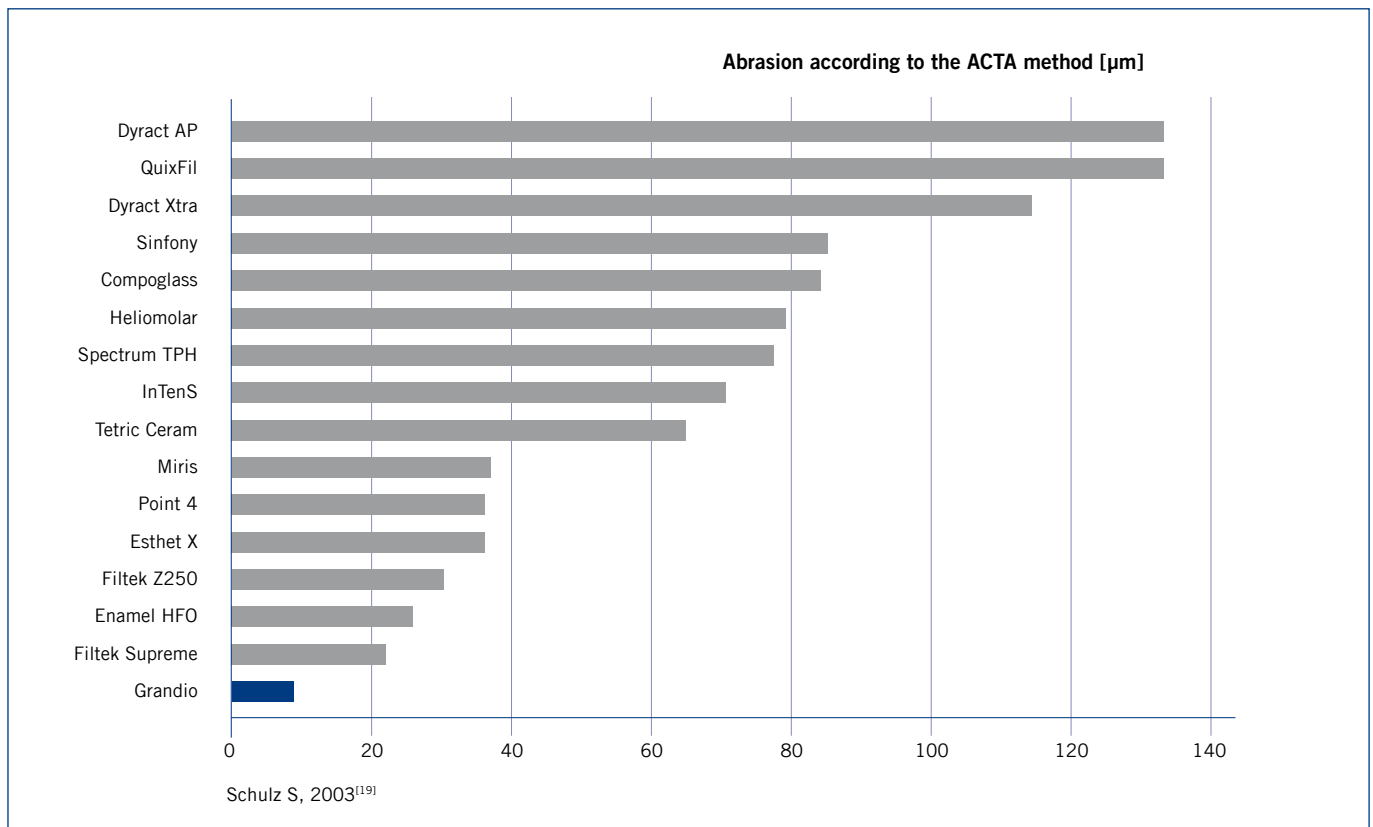
The measurement of the Micro-Vickers hardness is nearly identical to that of the normal Vickers hardness, except that the loading pressure and load duration are reduced. Micro-Vickers hardness (MHV) is often used as an alternative measuring method. Several different restorative materials were compared at the University of Rostock using this method^[20].



Three-body wear (University of Regensburg)

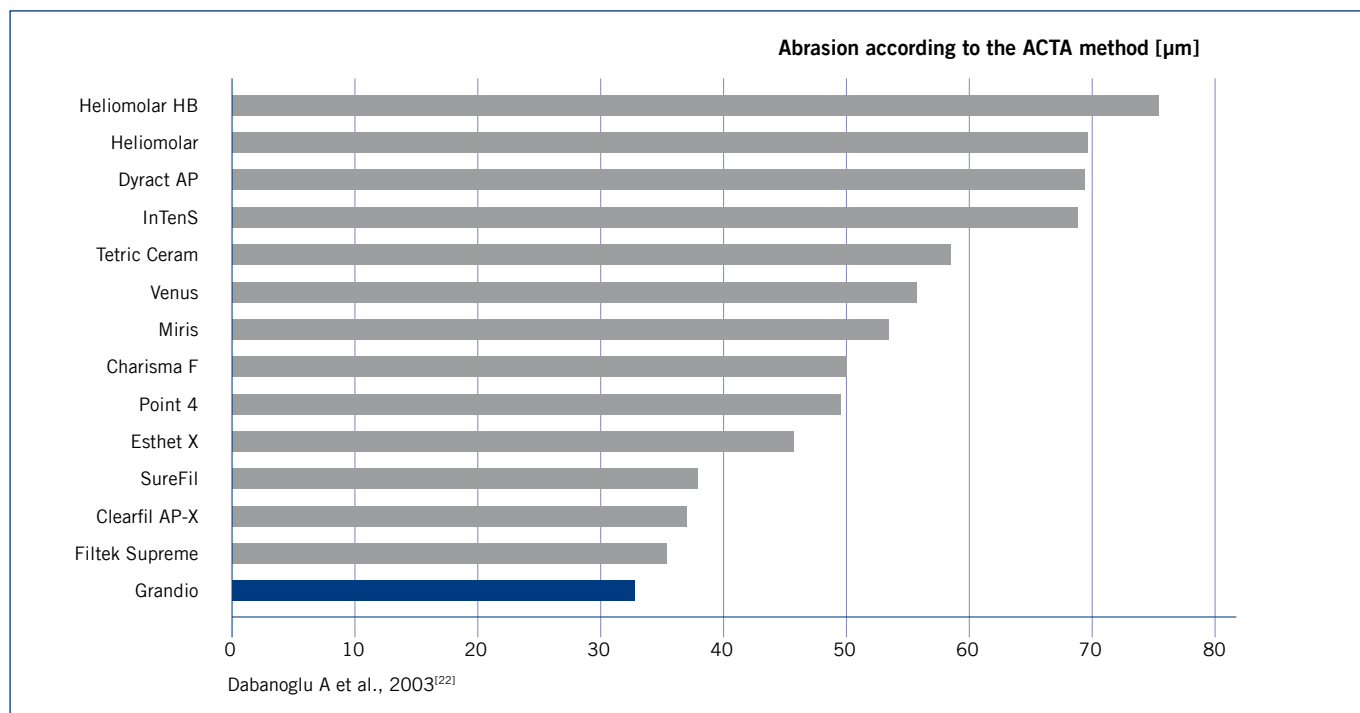
For the three-body abrasion test according to ACTA^[14], composite test specimens are placed on a rotating wheel and moved against another wheel moving one revolution per second with a contact pressure of 15 N. A pulp made from ground rice and millet seeds is used as an abrasive between the two wheels.

For the ACTA test, just as for all other studies presented here 200,000 cycles are run and then the material removal is measured. The abrasion resistance of composites by different manufacturers was investigated at the University of Regensburg.



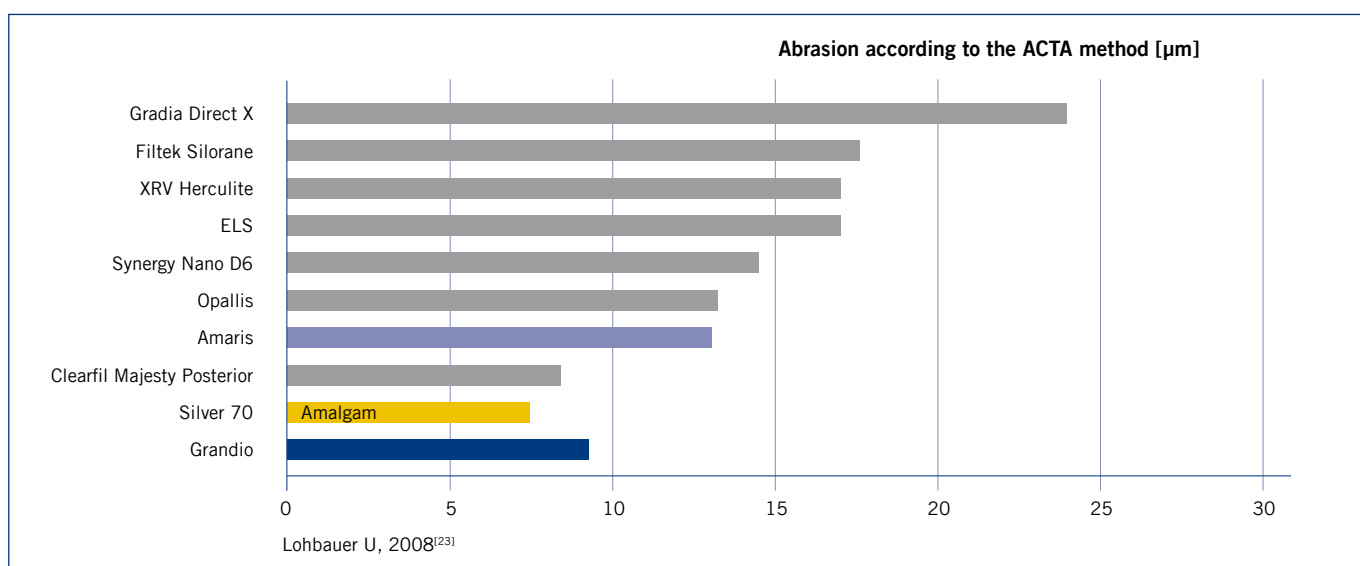
3-body wear (University of Munich)

Also in 2003, a study^[15] using the ACTA method was performed at the University of Munich, where composites by different manufacturers were examined to determine their abrasion resistance. The absolute values are different, but the trend is the same in both studies.



3-body wear (University of Erlangen)

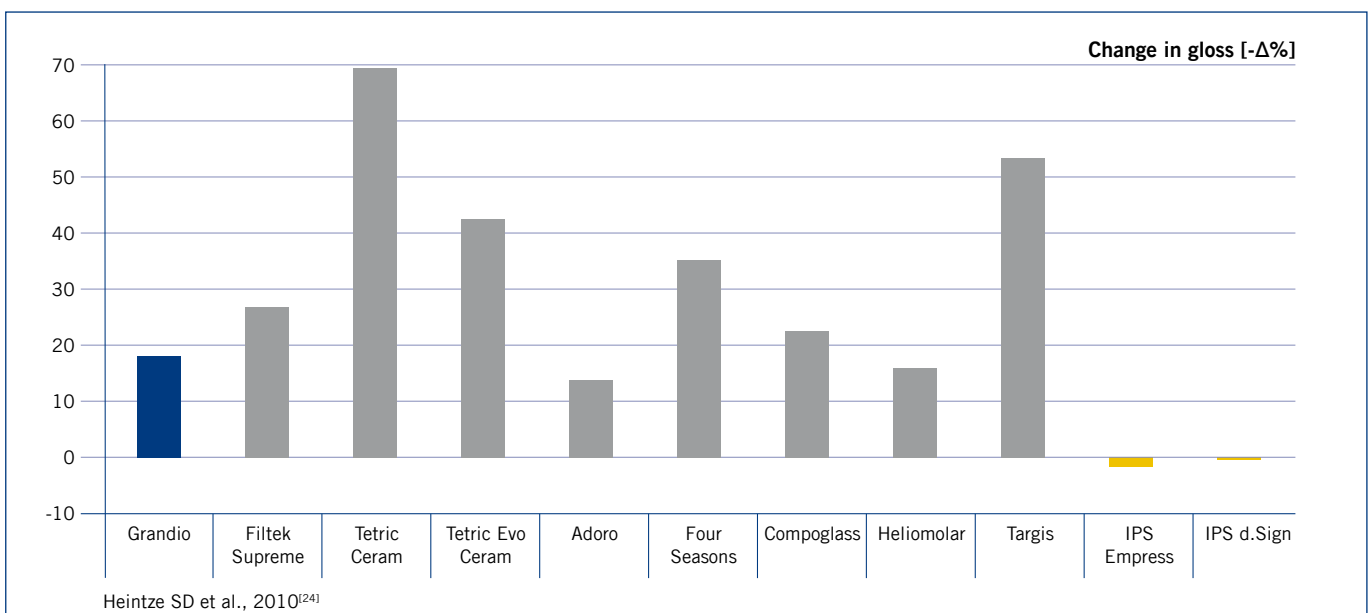
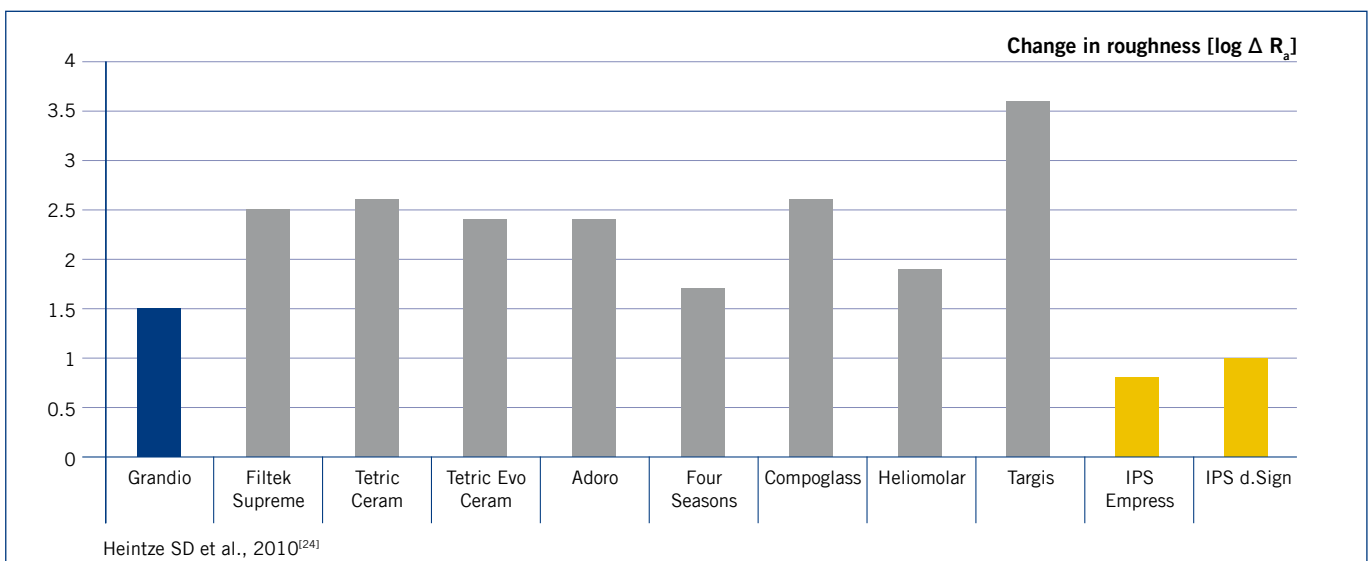
A third study was conducted at the University of Erlangen in 2008. The materials also subjected to 200,000 cycles in this study. As in the preceding studies, Grandio exhibited an excellent value.



Toothbrush abrasion

The behaviour of 9 composite materials and 2 ceramics was examined in the study presented here. Test specimens were fabricated from the materials and mechanically polished (SiC, 4000-grit). The test specimens were then mechanically brushed (10 h, 72,000 brushing cycles) with different amounts of contact pressure (100 g, 250 g, 350 g). A toothpaste with an RDA value of 75 was used in the brushing cycles.

The surface roughness (Ra) and gloss (% of reflected light) were measured both before and after the brushing cycles. The variation was observed in the comparison of both values. Grandio took first place regarding surface roughness in the group of composites; Grandio was also a top performer in the gloss retention test.



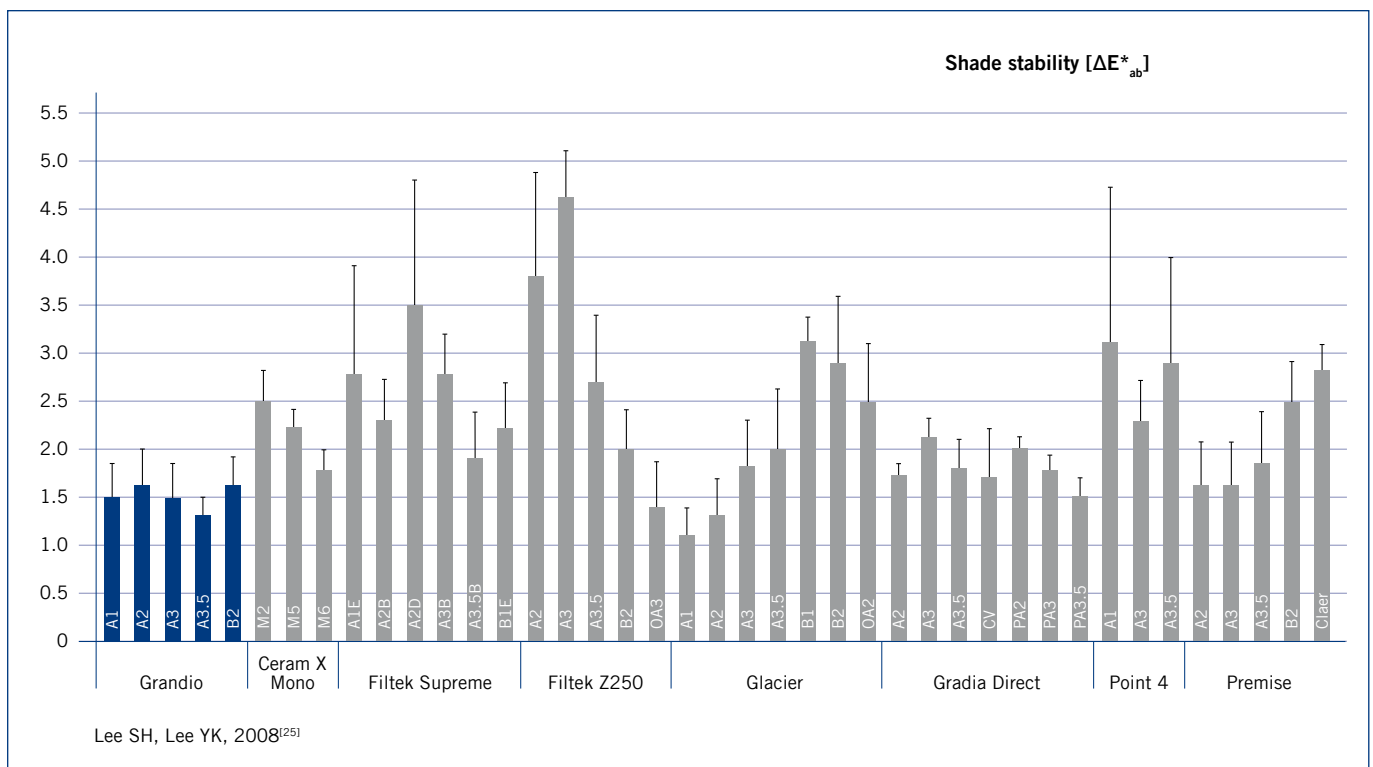
Conclusion: Grandio is an extremely hard and abrasion-resistant material. These properties are not only beneficial for the mechanical longevity of the restoration, but also for the durability of the polished material.

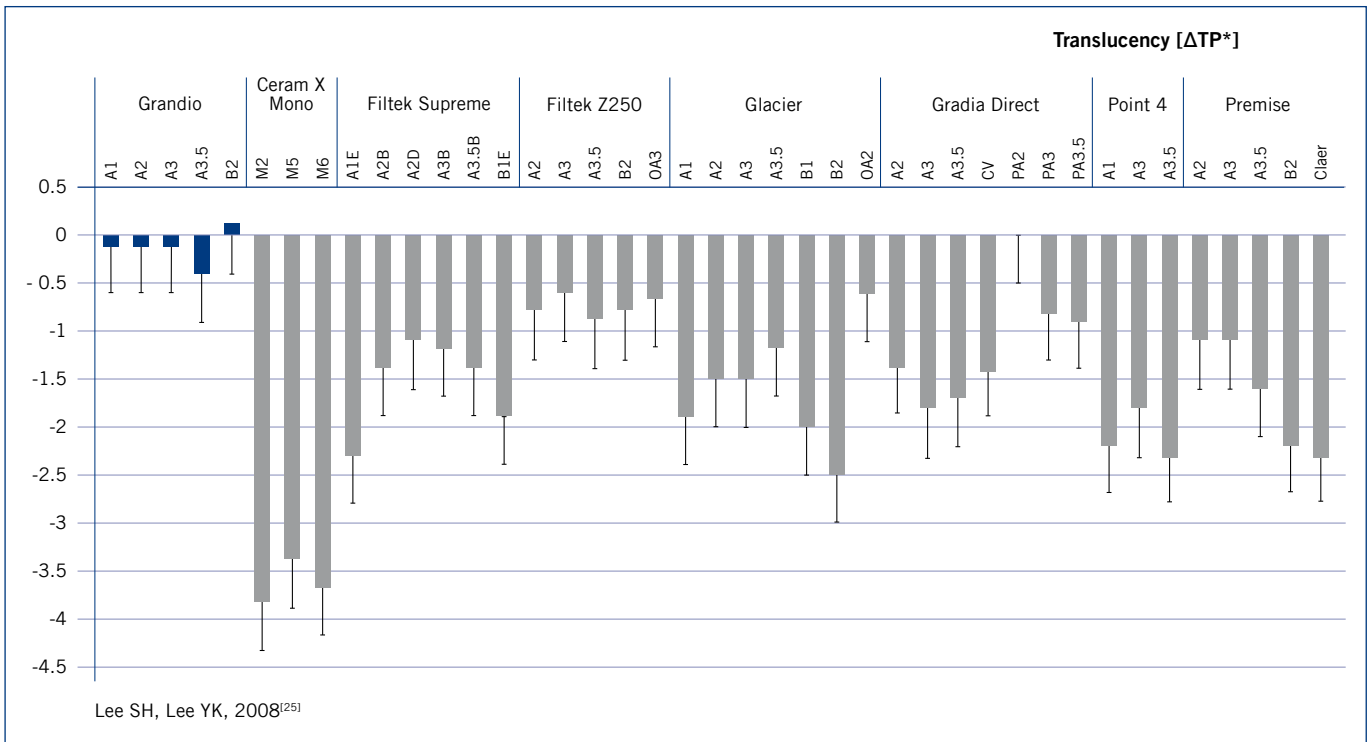
Shade stability (Seoul National University)

In this study, 8 light-curing composites in a total of 41 shades were examined. After preparation of the test specimens, these were stored for 24 hours at 37 °C and subsequently subjected to thermocycling (5000 cycles, 5 / 55 °C). The determination of the change in shade (ΔE^*_{ab}) was carried out under lighting with a standard light D65. The change in opacity (ΔTP^*) of the materials was determined by the change in shade in front of a white or, respectively, black background.

It can clearly be seen that, on average, Grandio has the highest shade stability (averaged $\Delta E^*_{ab} = 1.5$). A limit of 1.7 is set for the stability.^[26] Grandio is the only material that remains below this value. A similar picture arises on examination of the stability of the translucency parameters (Figure 2). In contrast to all other tested materials, the opacity of the Grandio test specimens only changed marginally due to thermocycling.

Conclusion: Grandio distinguished itself through significantly better shade stability in comparison to all other simultaneously tested competitive products in a study at Seoul National University. This outstanding performance relates to the retention of both colour and translucency.

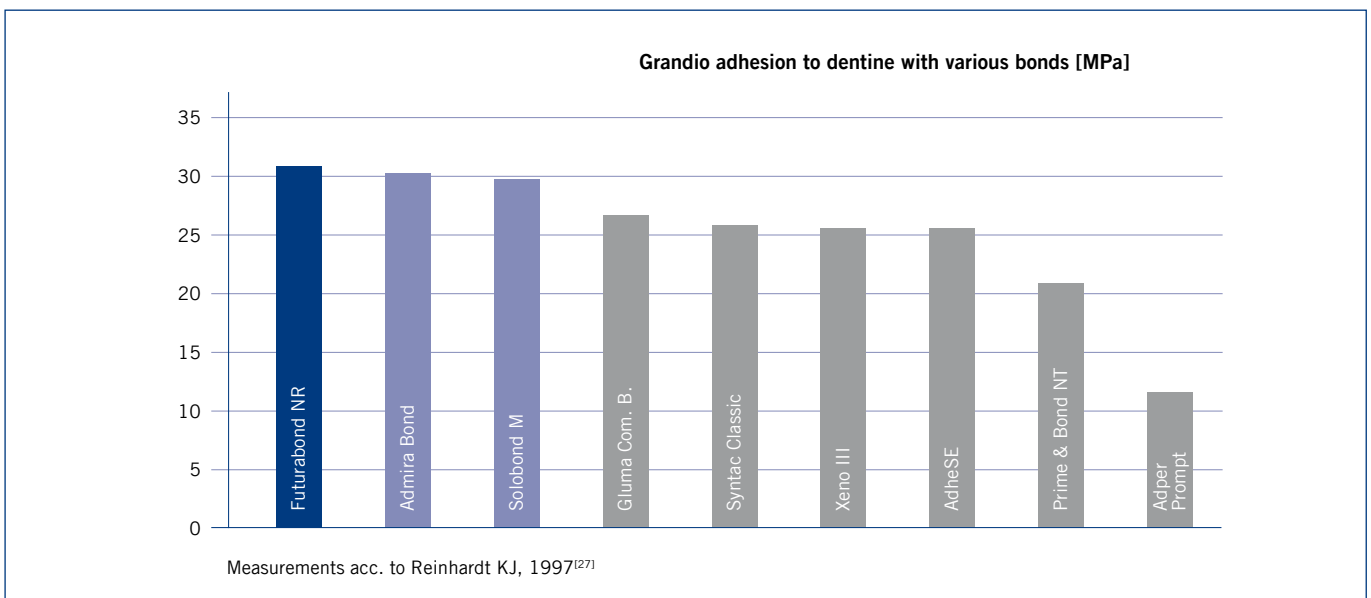




Bond strength values on dentine

The development of composites and bonds is inseparably interconnected; as inseparably as both materials should also be connected to each other. Their interaction must function perfectly to achieve this goal, since even the best bond is disturbed by a restorative with high shrinkage, and the best

restorative is useless if it cannot be permanently bonded to the tooth. The proven VOCO bonding materials served as the standard for the development of Grandio, but its compatibility with other systems was also verified ^[27] in order to fulfil the objective of a universal restorative.



From a technological perspective, a nano-reinforced bond such as Futurabond NR is the ideal bonding system for a nano-hybrid composite. As a self-etch bond, Futurabond NR also ensures problem-free application and effective treatment, especially in the SingleDose version. Adhesive values of 30.2 MPa

on enamel and 30.9 on dentine provide technical security. The Ormocer®-based and particularly biocompatible Admira Bond and the classic, 5th generation total-etch system Solobond M also have adhesive values of around 30 MPa. Bonds by other manufacturers also provide secure adhesion with Grandio.

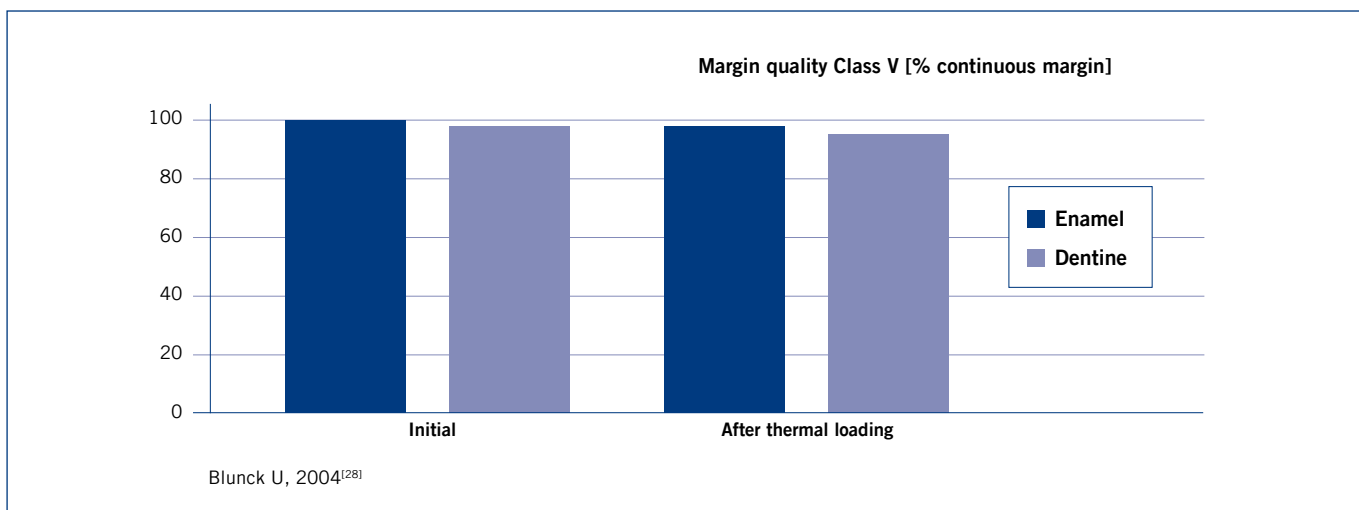
Conclusion: Grandio is compatible with all conventional self-etch and total-etch bonding systems, and always achieves adequately high dentine and enamel adhesion values.

Margin quality

Limited polymerisation shrinkage and good adhesion are essential for a lasting marginal seal between the restorative and cavity wall. Several independent institutes have confirmed that these characteristics result in a tight marginal seal.

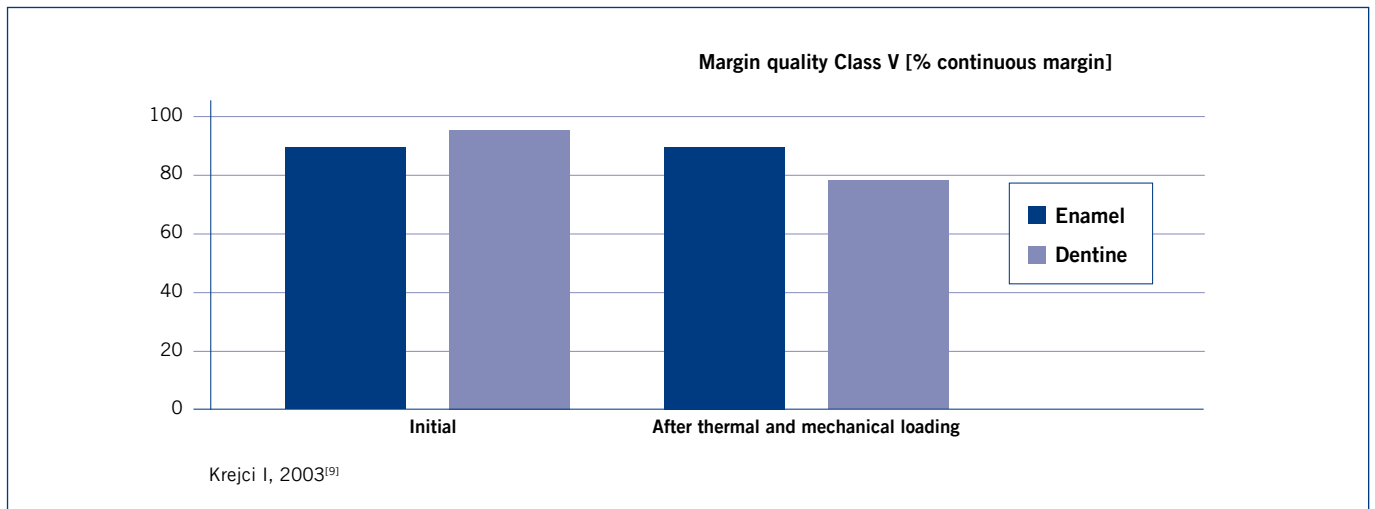
Margin quality Class V (University of Berlin and University of Geneva)

The margin quality of the combination of Grandio and Futurabond NR on enamel and dentine was examined^[28] before and after thermal loading at the University of Berlin (Charité) in 2004. In both cases, the percentage of specimens with the result “continuous margin” was over 95%.



In an additional study at the University of Geneva, test teeth were subjected to thermal and, additionally, mechanical

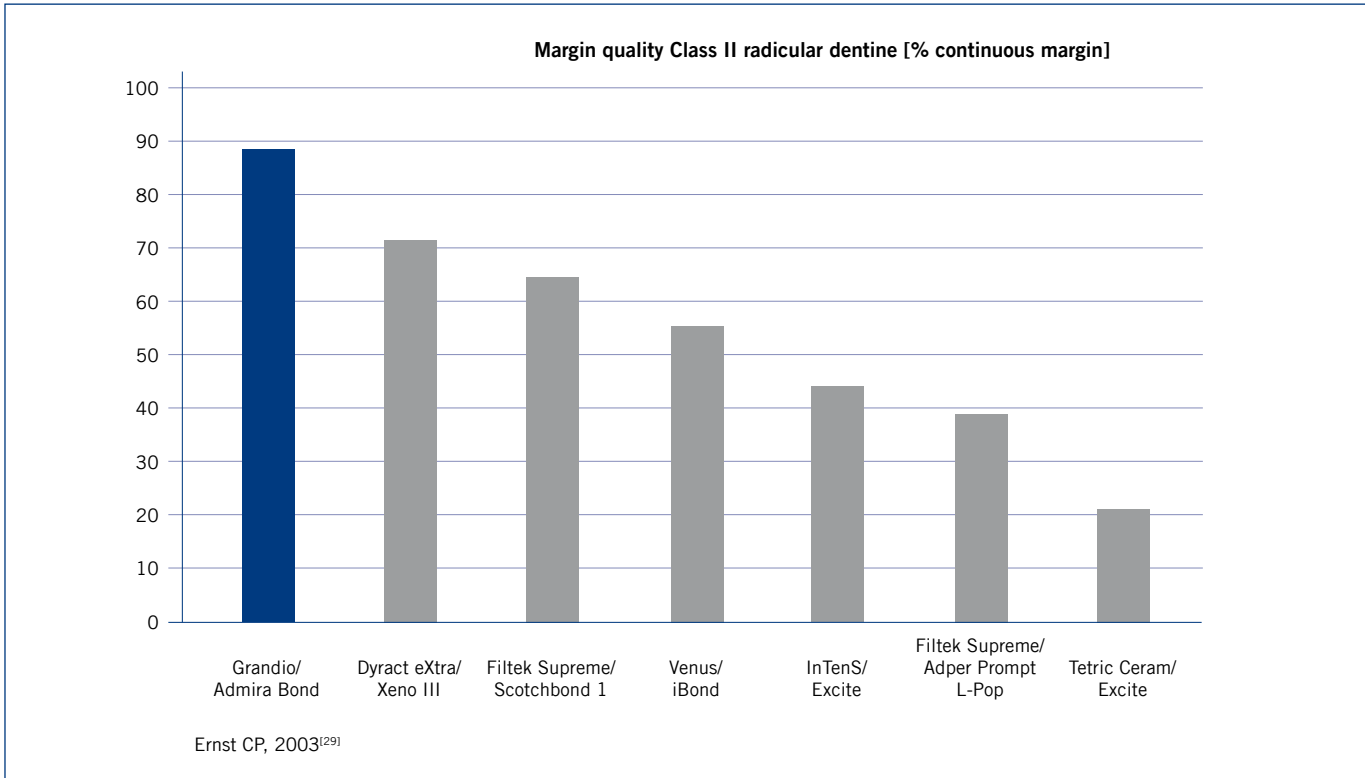
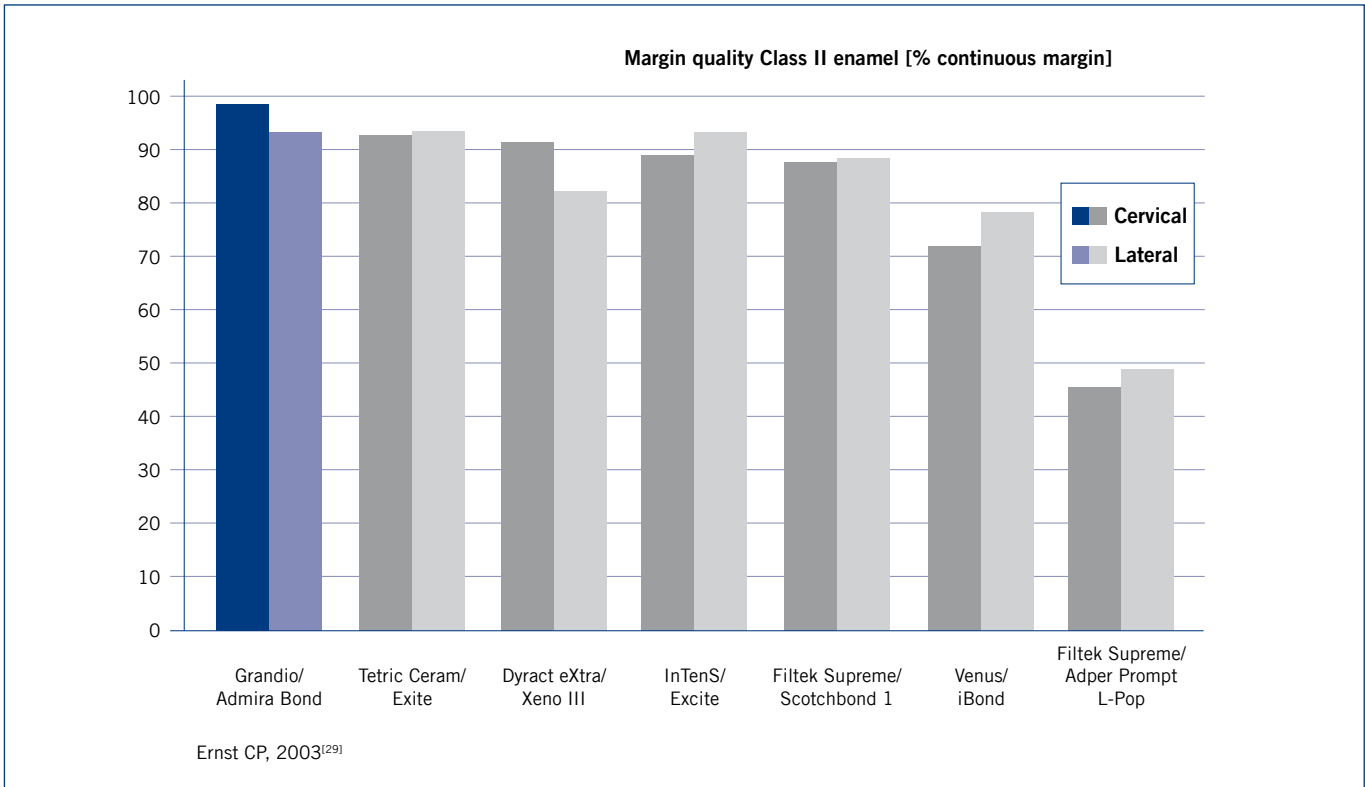
loading to examine margin quality in Class V cavity restorations with Grandio (Solobond M being used as adhesive).



Margin quality Class II (University of Mainz)

In posterior teeth (Class II), a distinction is made between two different case scenarios: cavities surrounded only by enamel and cavities surrounded by enamel and dentine. A study conducted by Prof. Dr. Ernst^[29] from the University of Mainz documented that Grandio takes first place among the more recent restoratives, with over 90% continuous margin in both

dentine and enamel. These studies show that Grandio achieves a permanently tight marginal seal in both enamel and dentine fillings, due to its minimal shrinkage and favourable thermal expansion coefficient. In combination with its exceptionally high mechanical stability, this means that Grandio delivers all the technical requirements for the long-term success of a treatment.



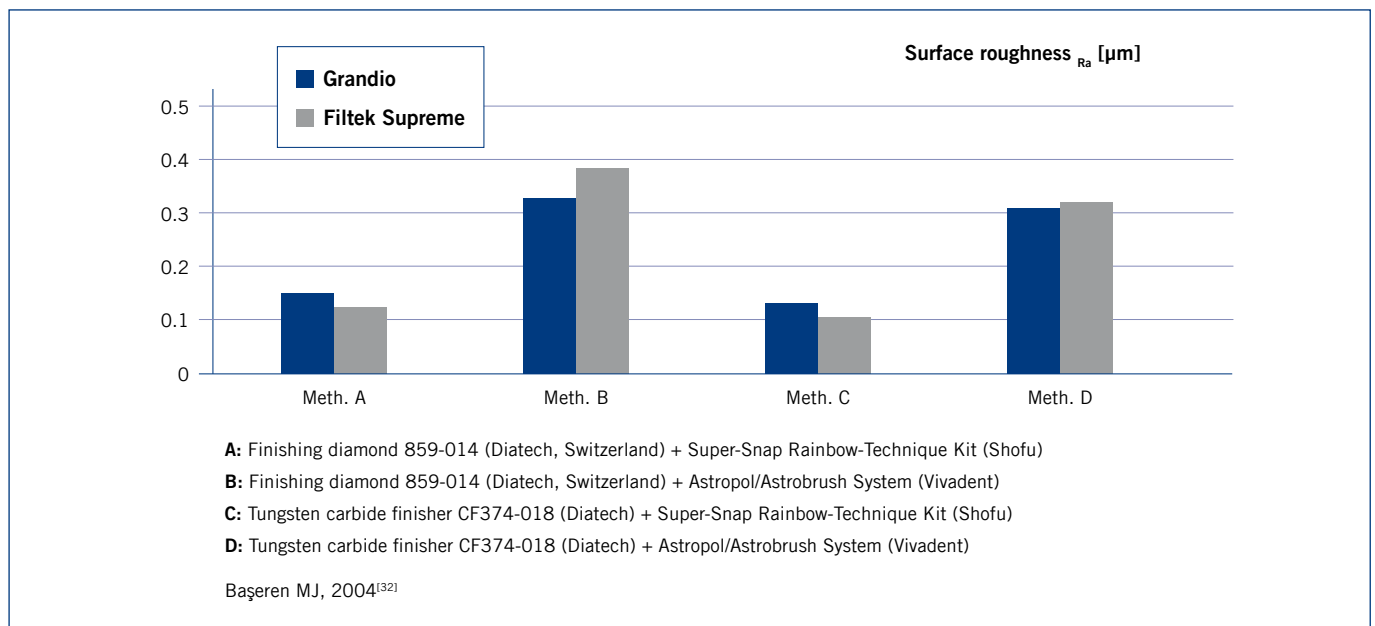
Conclusion: Grandio allows for high margin quality on enamel and dentine due to its low shrinkage.

Polishability (Hacettepe University of Ankara)

The polishability of composites describes both the characteristic of being able to achieve an aesthetically appealing result and the physical condition of the surface. The latter is physically and objectively quantifiable as surface roughness. It should be noted, however, that this value alone does not provide adequate information about the luster or about how toothlike the appearance is in humid conditions. The subjective impression depends on additional factors. Regardless of this, a smooth surface should be aimed for, since this inhibits the formation of plaque and bacterial colonisation. The fact that it is Grandio's surface finish that effectively and non-toxi-

cally inhibits colonisation by bacteria and plaque is discussed in the chapter "Toxicological data" (page 38).

The surface roughness after polishing depends on the type, grain and rpm of the polishing tool being used^[30, 31], but also on other factors. A study was conducted at Hacettepe University of Ankara^[32] which compared the surface roughness of Grandio and Filtek Supreme after processing with different polishing methods. The goal was to determine to what extent the composite material itself influences the polishing result.



The study shows that the quality of the polish mainly depends on the polisher being used, even for composites of differing hardness. There were no significant differences in the surface quality of Grandio and Filtek Supreme. Both diamond and tungsten carbide finishers are suitable for finishing Grandio. Lightly abrasive polishing discs such as Shofu Super-Snap are better suited for polishing the hard Grandio surface than soft silicone polishers like Astropol from Ivoclar Vivadent.

Many filling materials can easily and quickly be polished to a high gloss simply because they are not particularly hard. Aesthetics at the expense of durability, however, is not a good compromise. These materials lose their shine again within a short period of time anyway due to poor abrasion resistance. The counter-argument that a physically solid material is not polishable is plain incorrect. Even a diamond can be beveled and subsequently exhibits an extremely scratch-resistant surface.

Conclusion: Grandio's high physical strength ensures not only the durability of the restoration, but also a high abrasion resistance of the polished surface.

Practical tip: A hard material such as Grandio presents special challenges for the polisher. Therefore, VOCO has tested current polishing systems and compiled a list of the fastest and most

effective products for use on Grandio. In addition to VOCO's "Easygloss" polisher, the following products are suitable for yielding a very good polishing result.

Name	Manufacturer	Order no.
Dimanto	VOCO	2381 (small point, 10 pcs.), 2382 (large point, 10 pcs.), 2383 (small cup, 10 pcs.), 2384 (large cup, 10 pcs.), 2385 (lens, 10 pcs.), 2380 (set 5 pcs. mixed)
Ceramaster	Shofu	0121 (cylinder), 0122 (lenticular), 0123 (cup), 0124 (point)
DiaGloss	Edenta	19032RA (large point), 19033RA (mini-point), 19034RA (large cup), 19035RA (cup), 19038RA (disc), 19039RA (mini-cup)
Diapol	EVE Ernst Vetter	EVE Diapol W11D (mini-point), EVE Diapol W16D (small flame), EVE Diapol W2D (large flame), EVE Diapol W17D (small cup), EVE Diapol W7D (large cup), EVE Diapol W18D (lenticular), EVE Diapol W17DG (disc)
Identoflex Porzellan/Keramik NG	Kerr HAWE	ID 7271/12 (flame), ID 7281/12 (cup), ID 7291/12 (point)
Luster	Meisinger	2660 (assortment, 9 pieces), HM135 (cone), HM379 (flame), HM246 (point)
Occlubrush	Kerr HAWE	2520 (assortment, 15 pc.), 2503 (cup), 2504 (small cup), 2505 (point)
OptiShine	Kerr HAWE	2513 (cup, 3 pc.), 2514 (cup, 10 pc.)
PoGo	Dentsply	662025Y (assortment, 30 pc.)

All products can be sterilised (updated 10/2011).

Repair (University of Groningen)

A total of four restoratives were examined: Grandio (VOCO), Tetric Evo Ceram (Ivoclar Vivadent), Filtek Supreme XT (3M ESPE) and Quadrant Anterior Shine (Cavex). 160 test specimens were fabricated, which were divided into four groups:

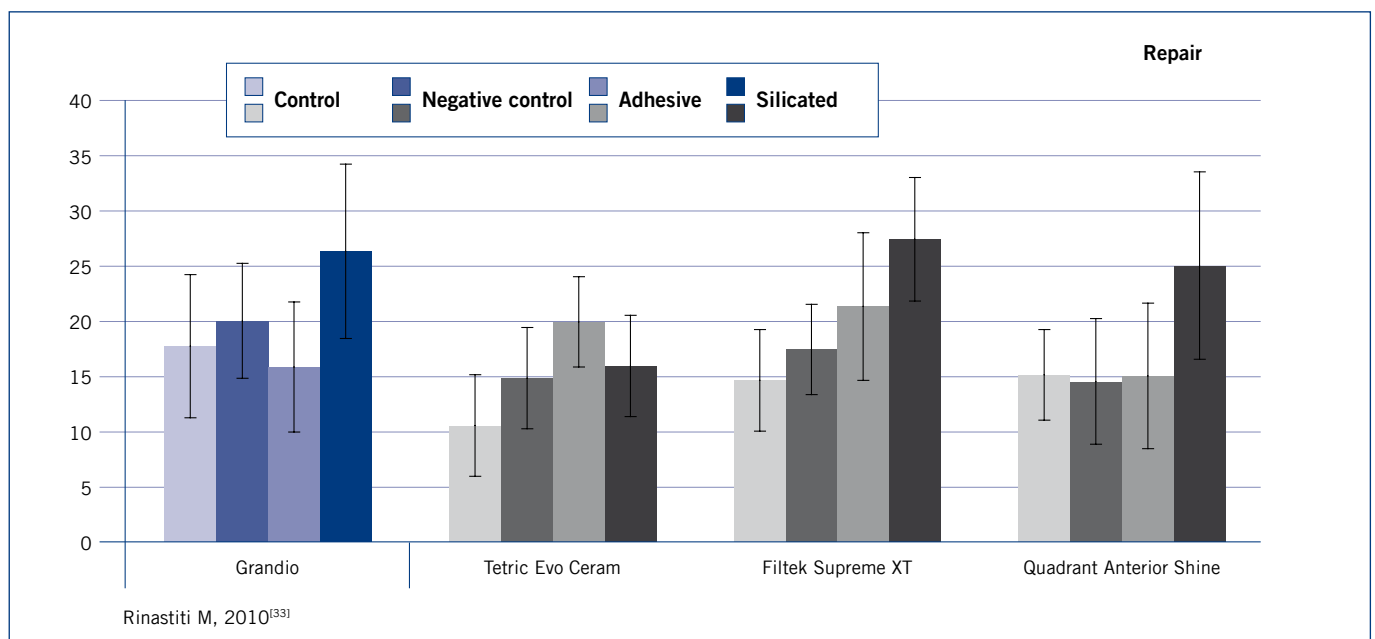
Positive control: Test specimens with inhibition layer

Negative control: Test specimens without inhibition layer (light-curing through Mylar strips)

Adhesive: Test specimens without inhibition layer using an adhesive system

Silane: Test specimens without inhibition layer, silicated (Co-jet, 3M ESPE) with silane coupling agent (ESPE-sil, 3M ESPE)

The following bonds were used in the „adhesive“ group: Solobond Plus (Grandio), Multilink (Tetric Evo Ceram), Adper Scotchbond 1XT (Filtek Supreme XT) and Quadrant Unibond (Quadrant Anterior Shine). An additional layer of composite was applied to each of the prepared test specimens and subsequently light-cured. The adhesive bond was determined with a shear test. The high adhesive value in the negative control of Grandio is especially interesting. This value shows that repairing Grandio without time-consuming pre-treatment leads to excellent results.



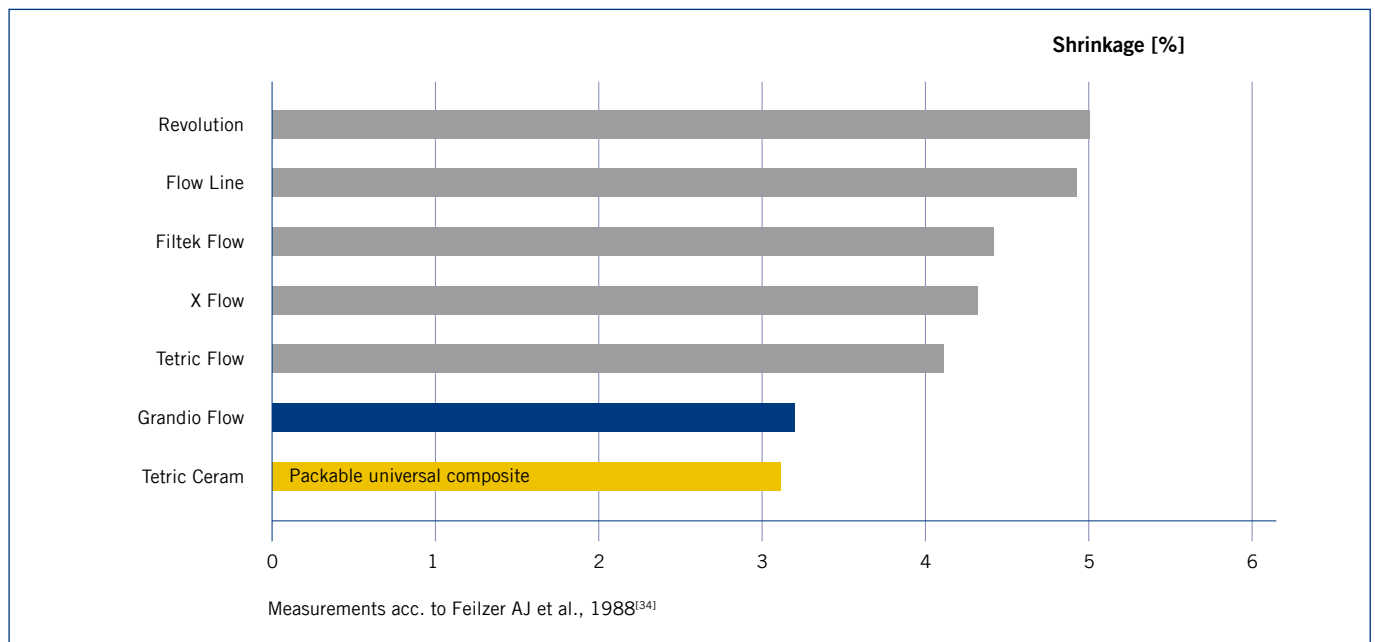
Conclusion: Repairing Grandio, even without pre-treatment, exhibits an excellent adhesive bond between the old and new composite layer. The treatment procedure thus is considerably simplified in cases involving the repair of a restoration or its revision.

Physico-chemical analyses Grandio Flow

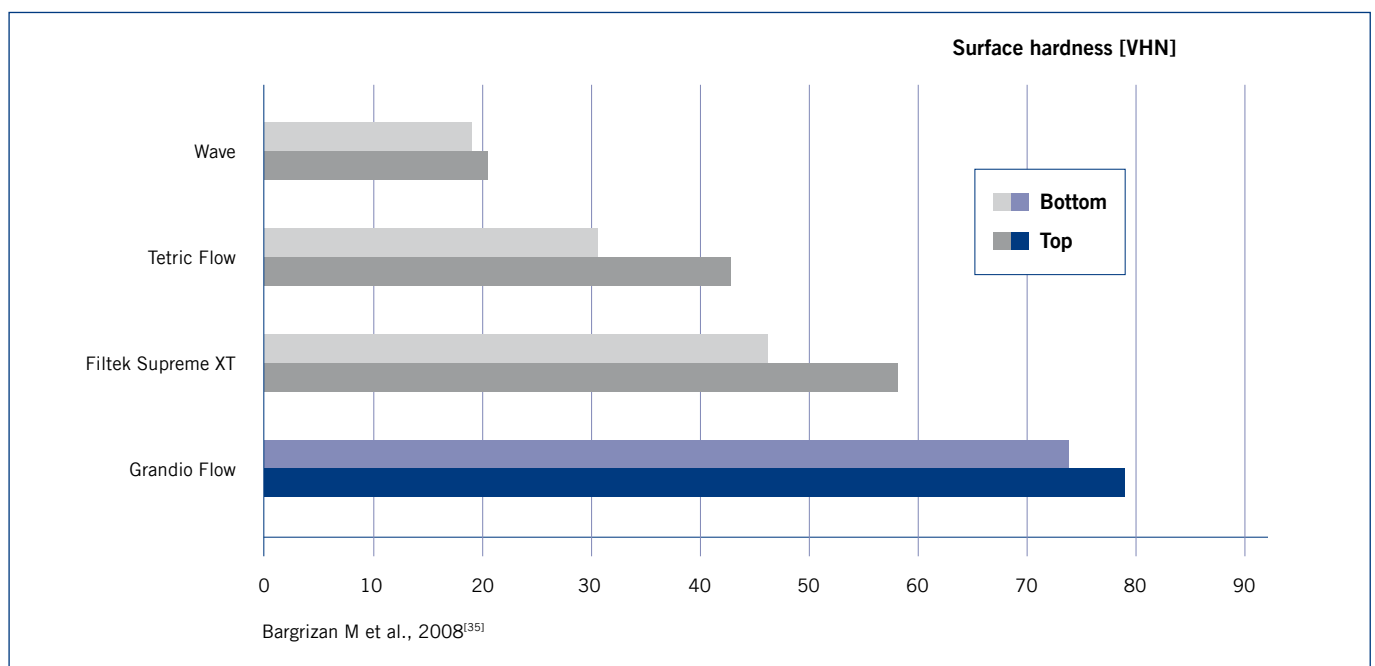
Flowables are particularly suited for restoring smaller cavities for which a normal composite is too viscous. Flowables are also appropriate for combined methods like lining or the CBF technique. The disadvantages of conventional flowables are their low filler content and the resulting somewhat higher shrink-

age and reduced physical hardness. The filler technology in Grandio permits the manufacture of a flowable that possesses the filler content and physical characteristics of conventional non-flowable composites.

Shrinkage



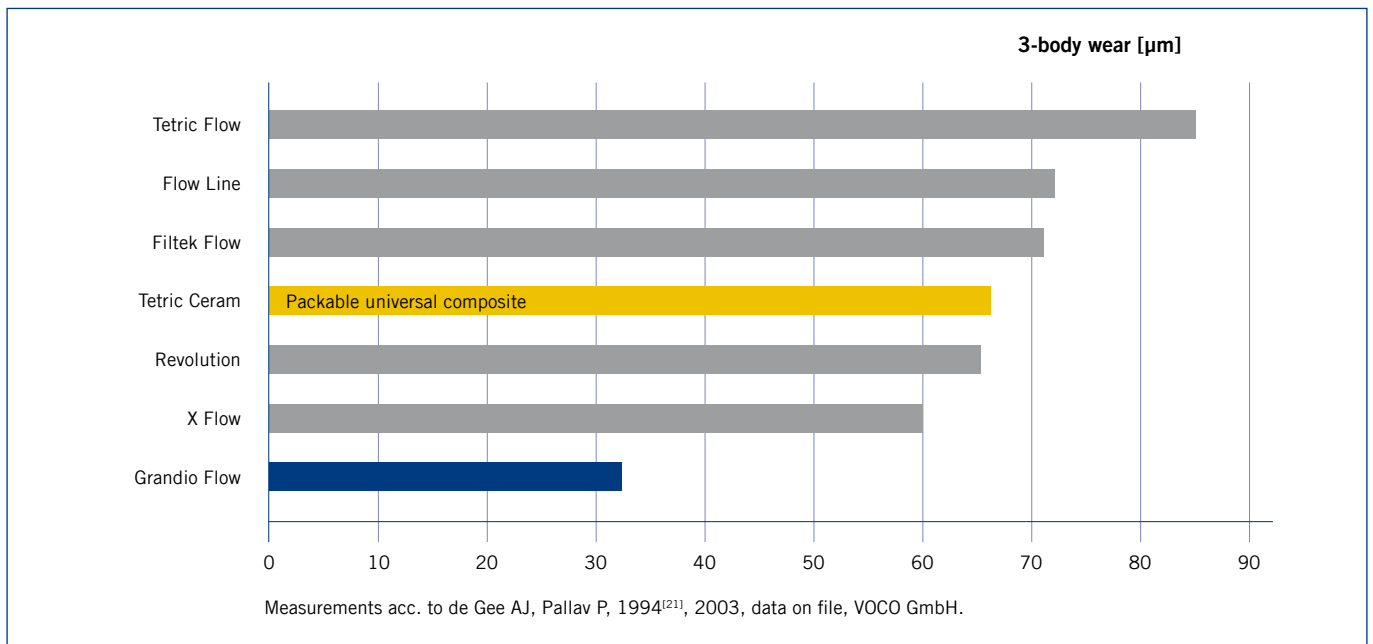
Curing depth



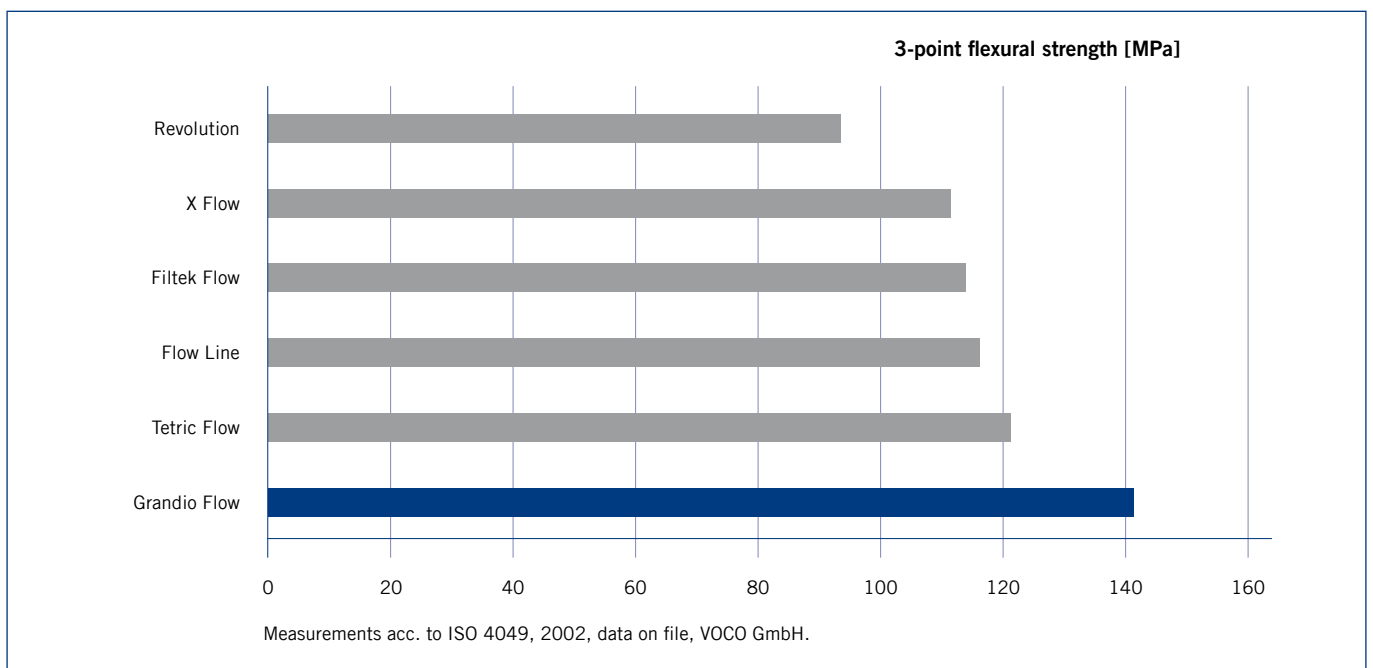
The examined test specimens were fabricated in equal size and subsequently light-cured for 40 s on one side. After 24 h of storage in water, the surface hardness on both the top (facing the light) and bottom (facing away from the light) was

determined. Grandio Flow not only received the best values in absolute numbers for the top and bottom of the specimen, it also displays the lowest reduction in hardness with only 6%.^[35]

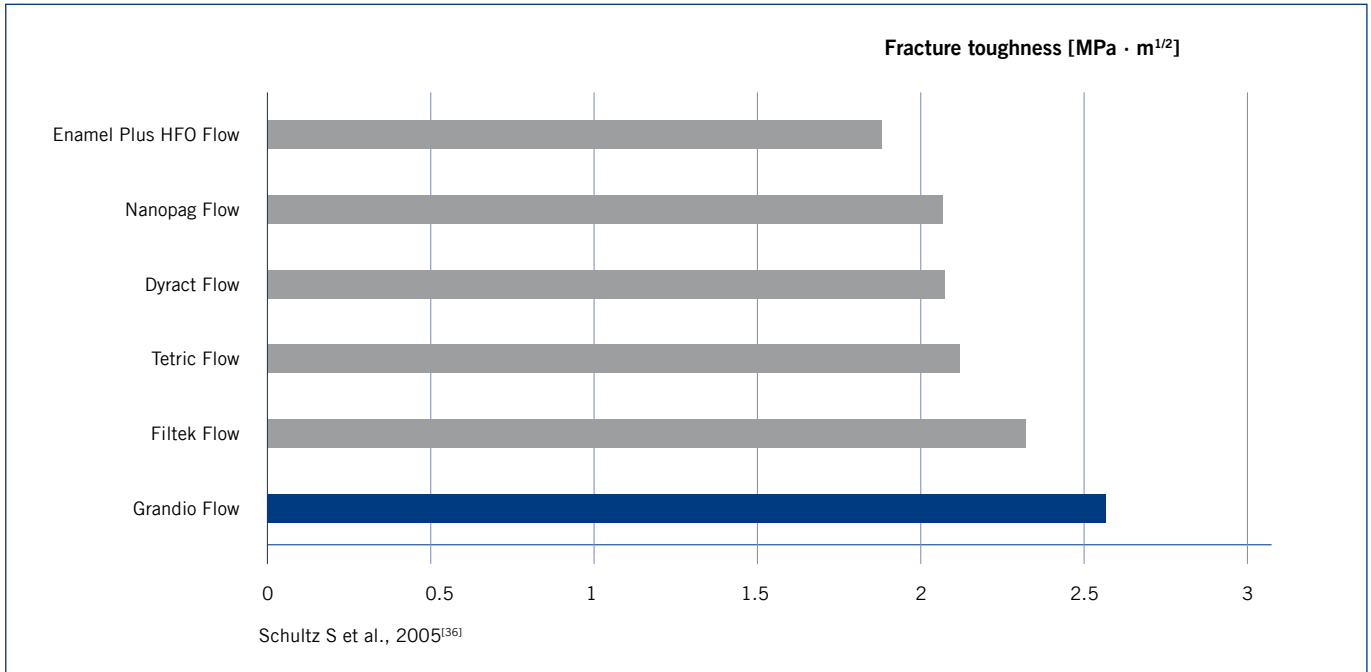
3-body wear



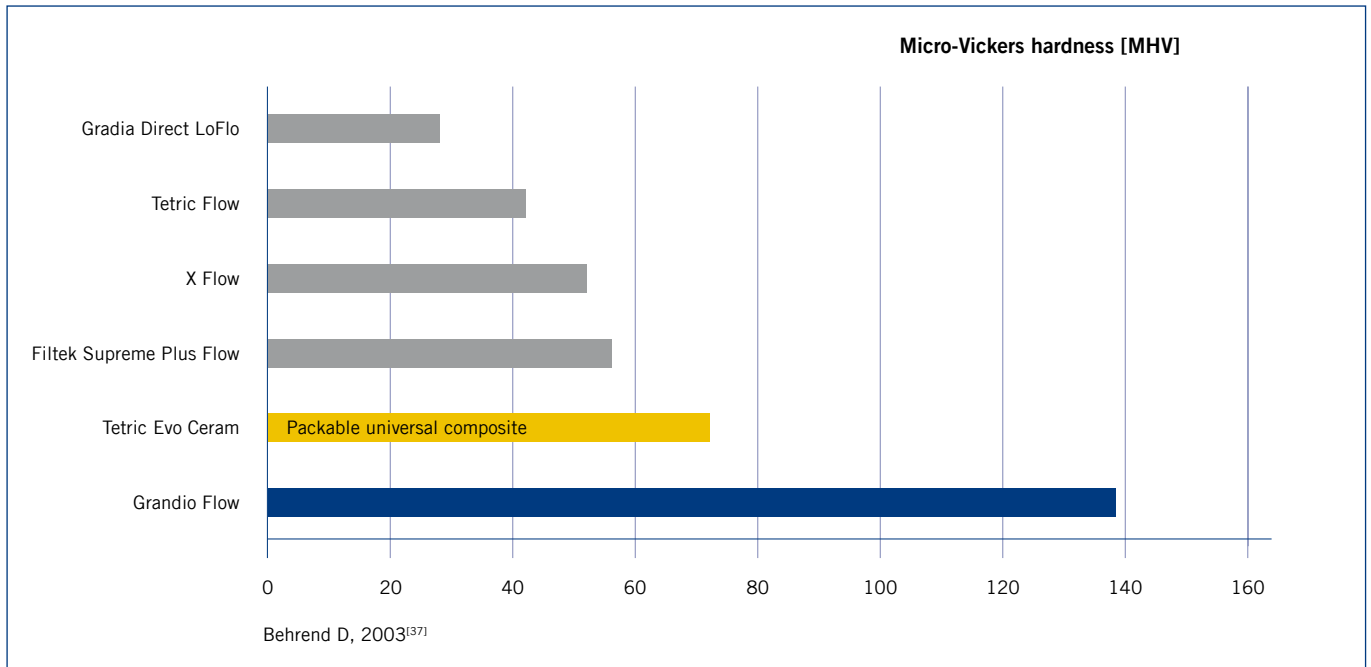
Flexural strength



Fracture toughness (University of Regensburg)



Micro-Vickers hardness (University of Rostock)



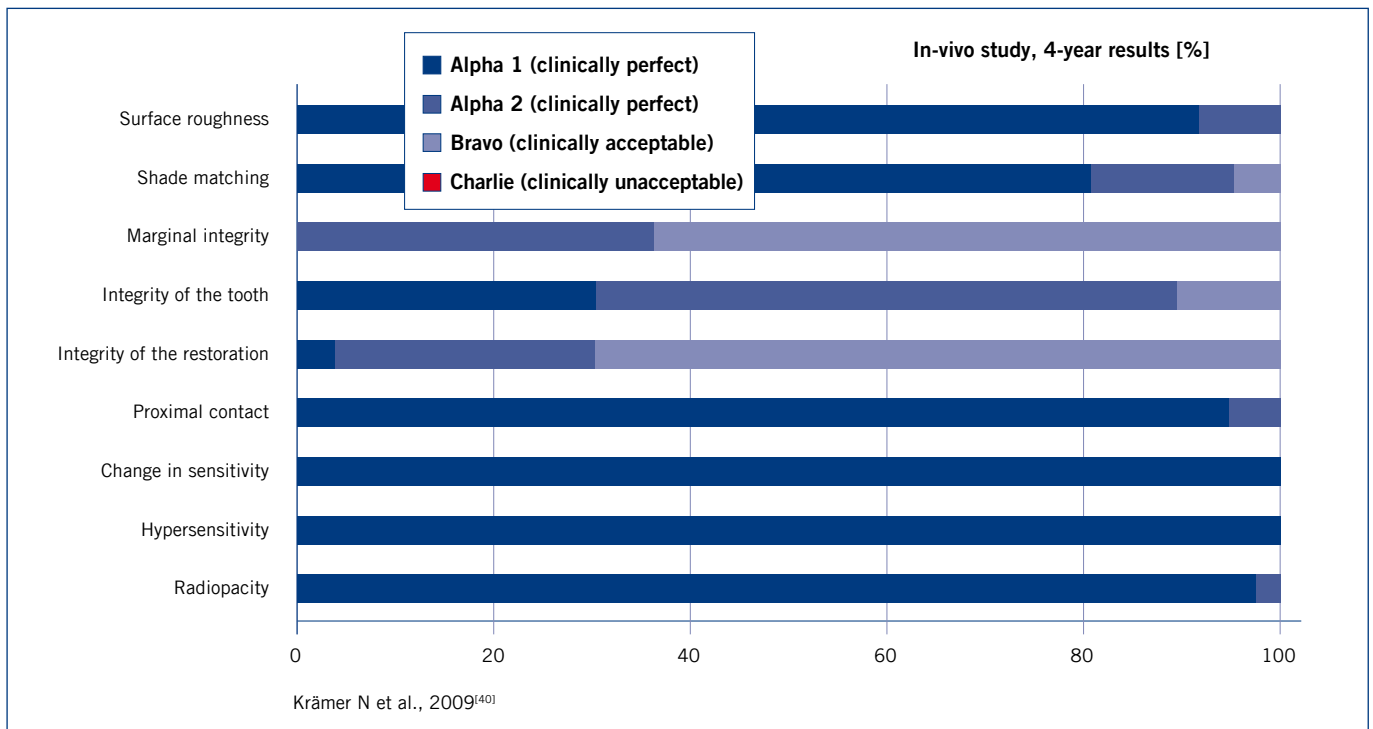
Conclusion: Grandio Flow's abrasion resistance, minimal shrinkage and excellent flexural strength are equal to those of conventional composites, yet it is flowable. Whether the material is used as a restorative for small cavities or as the flowable in the CBF technique, Grandio Flow does not require a compromise on physical properties. Technically, aesthetically and handling wise, Grandio Flow and Grandio complement each other optimally. When using Grandio Flow and Grandio in the CBF technique, the combination furthermore provides the positive effect of exactly matching shades.

Clinical studies

In-vivo study Grandio (University of Erlangen, 4-year results)

36 patients were monitored in this study. Class II cavities only were treated with a combination of Solobond M and Grandio. All

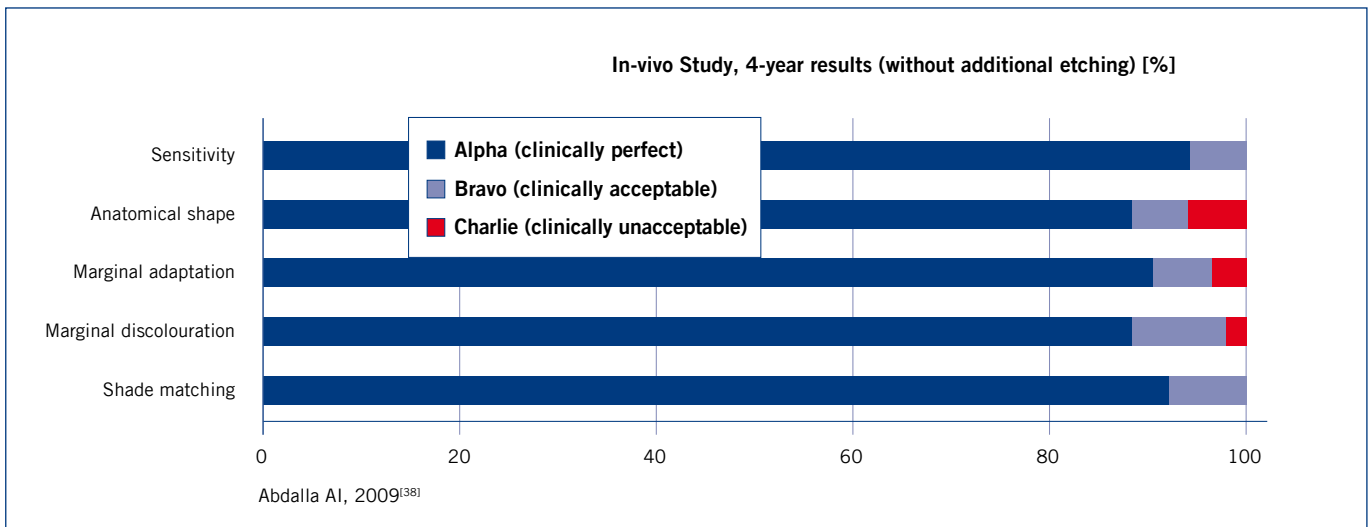
restorations were clinically acceptable 4 years later; None of the restorations was lost.



In-vivo study Grandio (University of Tanta, 4-year results)

65 Class V cavities were treated with a combination of Futurabond NR and Grandio in this study. All of the restorations were clinically acceptable 4 years later. The retention rate was 100%. Grandio exhibits excellent long-term results for the treatment of Class V cavities in this clinical long-term

study. The effect of additional etching was also examined in this study. The study came to the conclusion that additional enamel etching did not provide a positive effect. However, it was found that etching enamel and dentine (total etch) causes significant deterioration.

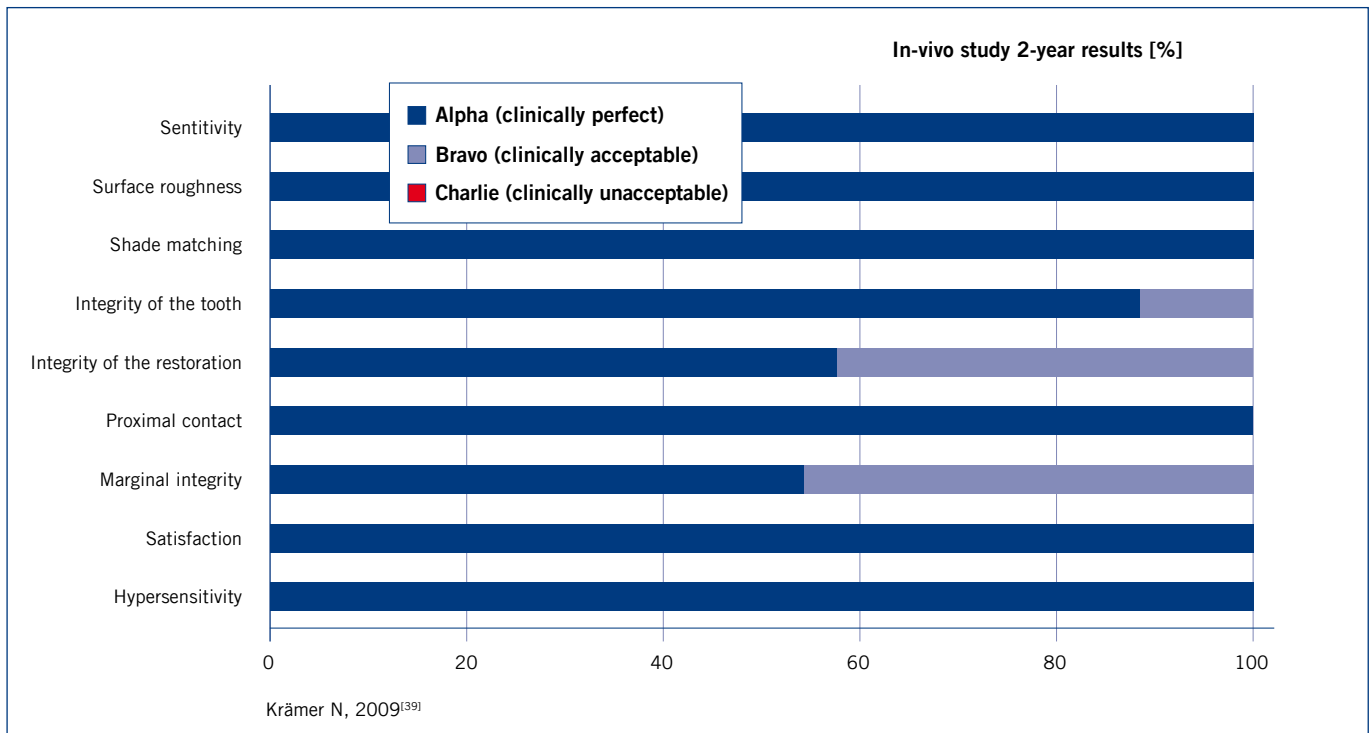


In-vivo study Grandio (University of Erlangen, 2-year results)

The suitability of Grandio as a plastic filling material for the posterior tooth region was verified in the course of a prospective clinical study under the direction of Professor Norbert Krämer in a study at University of Erlangen^[39]. 36 cavities in 30 patients were filled with Grandio in this study. All restorations had at least two surfaces and approximately one third of the cavities did not exhibit an enamel boundary in the ap-

proximal box. Furthermore, the cervical enamel boundary was estimated at a maximum of 0.5 mm in approximately half of the cavities.

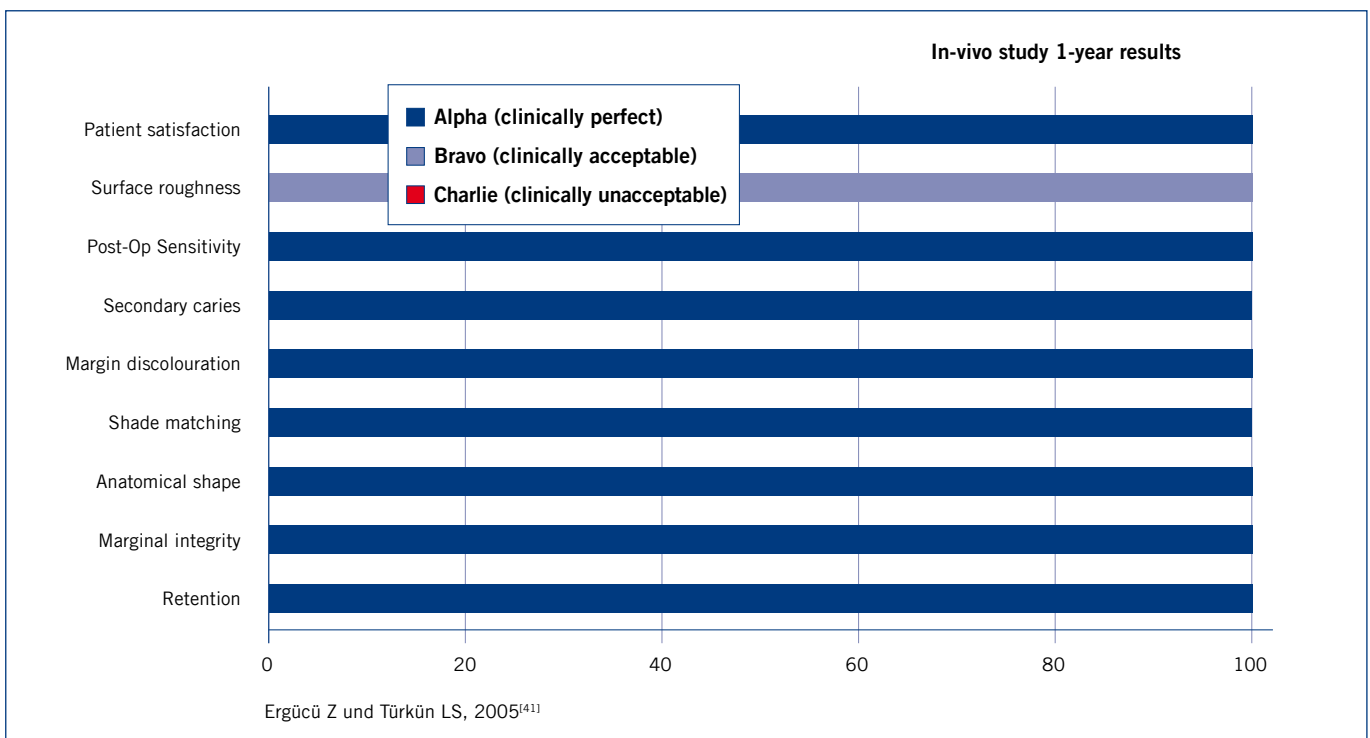
All restorations with Grandio were available for inspection after being in place for two years. All were rated clinically acceptable or excellent without exception.



In-vivo-study Grandio (Ege University of Izmir, 1-year results)

48 cavities (Class I and II) in 30 patients were treated with Grandio in a study at Ege University of Izmir (Turkey)^[41]. The cavities were prepared in a minimally invasive way and without bevelling. After bonding with a self-etching adhesive, Grandio was applied in layers according to the instructions for

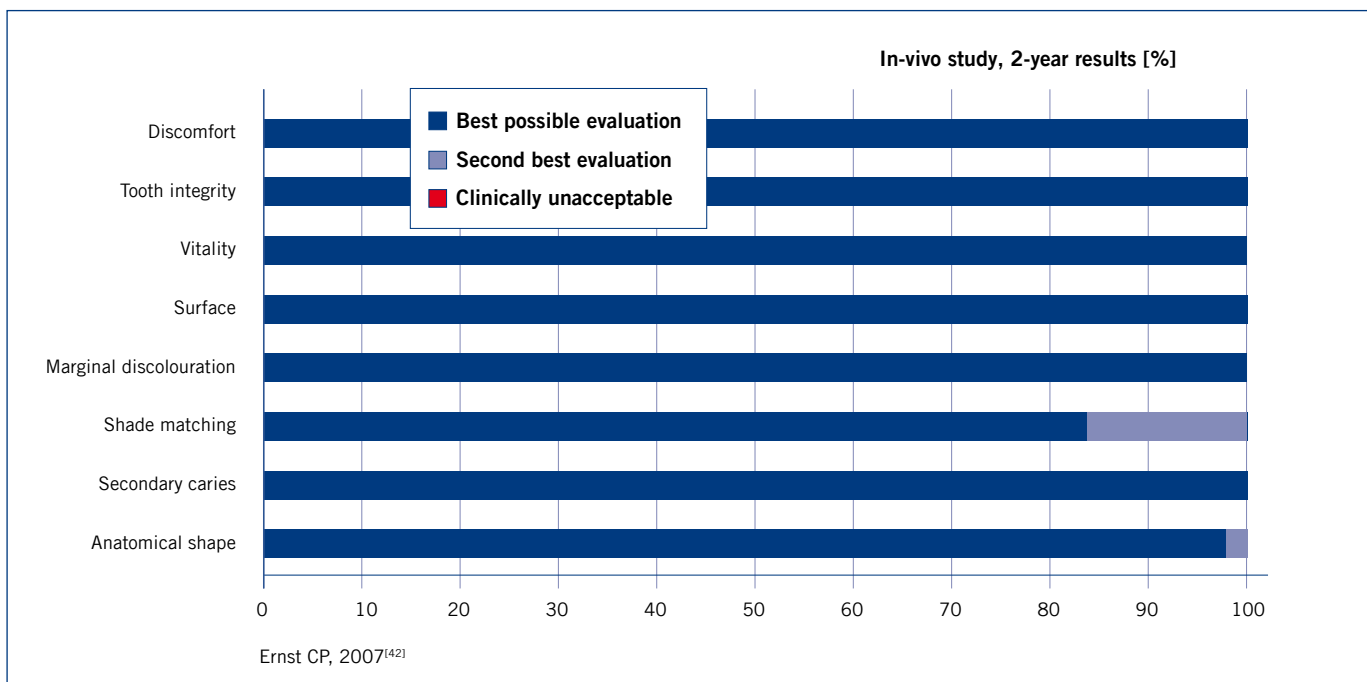
use. The polishing was not performed with the recommended materials, but with an unnamed diamond finisher, Enhance® Finishing Discs (Dentsply/DeTrey) and a Sof-Lex® Polishing Brush (3M ESPE). Here, too, all patients were available for a follow-up examination one year later.



In vivo study Grandio Flow (University of Mainz, 2-year results)

The treatment of small Class I cavities and extended fissure sealing with Grandio Flow were observed and evaluated over a 2-year time period, with Solobond M being used as the bond. The evaluation was subject to the Ryge and CDA criteria. Since the criteria for the individually observed aspects vary, the classifications “best possible value”, “second best value” (which both always represent clinically acceptable values) and “clinically unacceptable” were used in the graph.

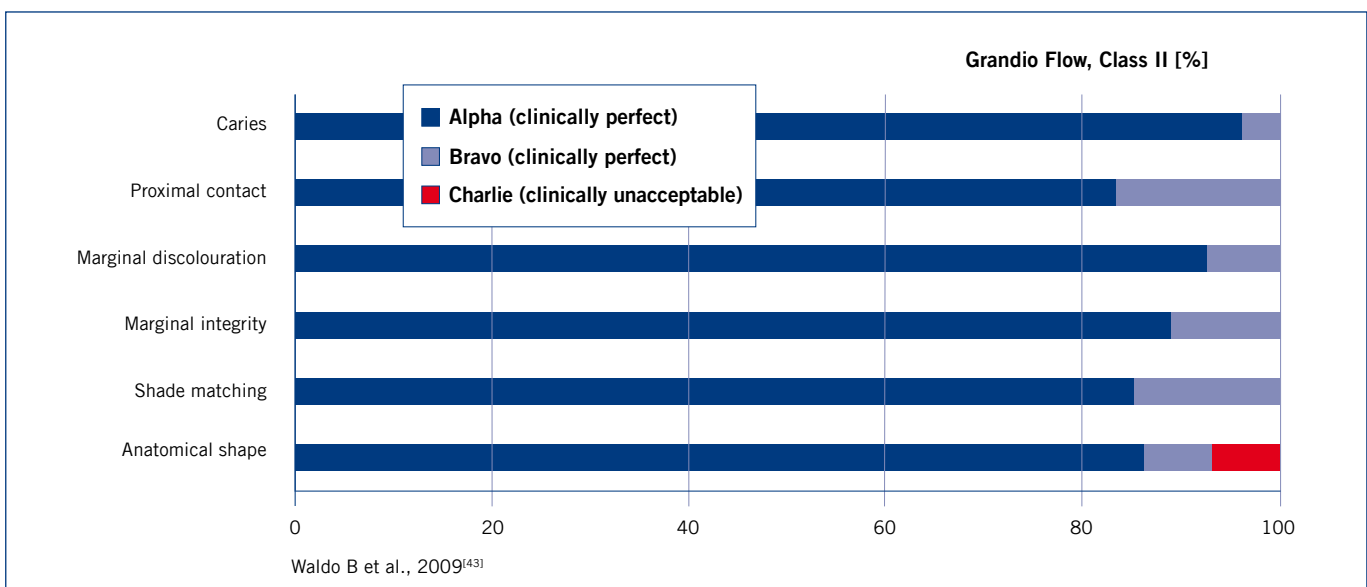
It has to be emphasized that the rating of the shade match assigned second best for even slight differences in opacity. But even these fissure sealing treatments did not deviate from the natural shade of the tooth.



In-Vivo study Grandio Flow (University of Birmingham, 1-year results)

In this study, 32 patients with moderately-sized, Class II cavities in the proximal area were selected. The cavities were then restored with the flowable Grandio Flow (32 restorations). This illustration shows the results of the examination after 12 months. The evaluation was carried out using the Ryge criteria.

The study shows outstanding results present after 12 months, which do not differ from those of packable composites.



2-year rating by The Dental Advisor™

Practising clinicians in the United States evaluated Grandio in a field study over a period of two years for „The Dental Advisor“ testing institute. 132 restorations were performed on 76 patients during the evaluation. 88 restorations in 53 patients were available for a follow-up examination two years later (Class I 36%, Class II 40 %, Class III 5%, Class IV 5%, Class V posterior 11%, Class V anterior 3%). The following criteria were evaluated by the dentists:

Fracture toughness

No damage at all could be detected in 90% of the restorations after two years. Five posterior restorations had small chips that did not require repairing and only two adjacent class IV restorations displayed an interproximal space which was easily repaired.

Shade matching and aesthetics

In addition to the material's high stability, the dentists praised its excellent aesthetics and precise matching of the tooth shade. All restorations were accomplished by using only one shade for each case, and their appearance was still rated as excellent. The clinicians found the material to be particularly user-friendly because of its easy application and absence of a complicated and time-consuming multilayer shade technique. The surface quality was likewise given a very good to excellent rating.

Margin discolouration

Discolouration at the composite-tooth interface is evidence of micro-leakage and indicates the risk of marginal caries. The frequency of margin discolouration is affected by the composite itself and also by the adhesive technique being applied, as

well as the adhesive itself and the finishing. Several different techniques and materials were used for bonding in this study. In contrast to the other materials, Grandio proved not to be influenced by this, with 94% of all Grandio restorations showing absolutely no margin discolouration after two years, which can most definitely be attributed to its excellent shrinkage behaviour.

Wear resistance

All restorations received an „excellent“ rating. 93% of restorations had no visible signs of wear, the remaining 7% exhibited minor visible traces of abrasion, but were still clinically acceptable without exception.

Clinicians' comments about aesthetics

„The restorations harmonise with the tooth substance.“

„The shades are stable and exhibit a nice mixture of opacity and translucency.“

„Restorations look great – many are undetectable.“



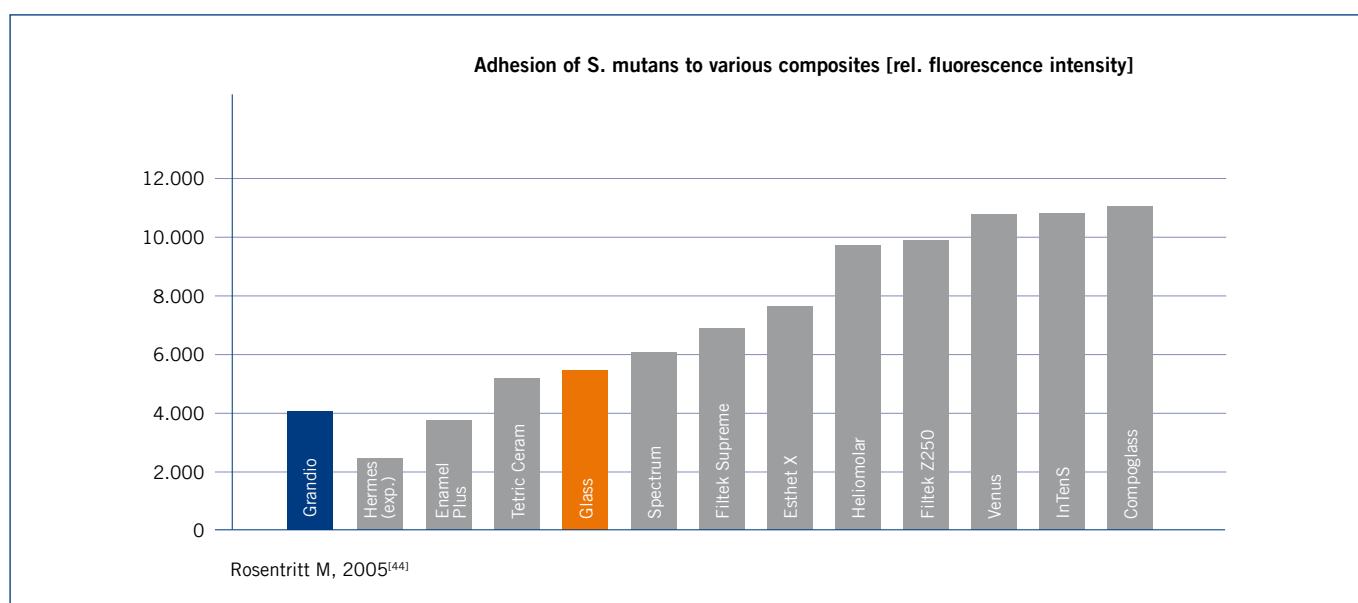
Toxicological data

Bacterial colonisation and cytotoxicity

Water absorption and the condition of the surface are closely linked to bacterial colonisation of a composite. Ideally, a dental restorative should not provide more fertile breeding grounds for germs than the surrounding teeth. While amalgam easily achieves this with its cytotoxicity, the surface quality of a composite should be able to prevent increased bacterial colonisation.

Bacterial colonisation (University of Regensburg)

At the University of Regensburg, test discs were made from different composites and incubated [44] for 2.5 hours at 37 °C with *Streptococcus mutans* in the medium. The test pieces were subsequently stained with a marker and the quantity of adhering bacteria was determined by fluorescence measurement.



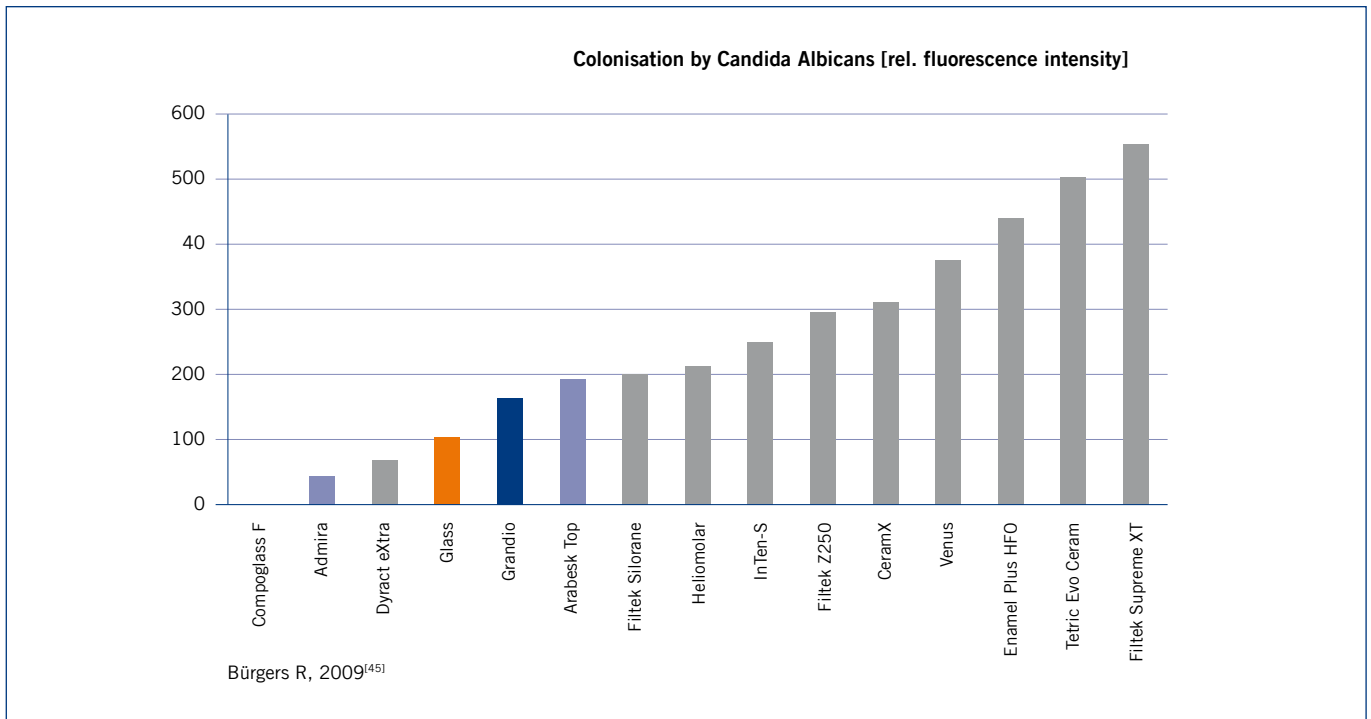
Grandio as well as Enamel Plus and the experimental material Hermes exhibited the lowest colonisation with *S. mutans*. This gives reason to expect a reduced susceptibility for the formation of plaque [44].

Colonisation by *Candida Albicans* (University of Regensburg)

15 test specimens were fabricated from each of the 14 restoratives examined in the study. The test specimens were then stored in a suspension of *Candida Albicans* for 2.5 hours at 37 °C. A bioluminescent pigment was added after rinsing the test specimens three times. The relative luminescent intensity was calculated from a comparison of the luminescence

of the untreated test specimens with that of the incubated test specimens.

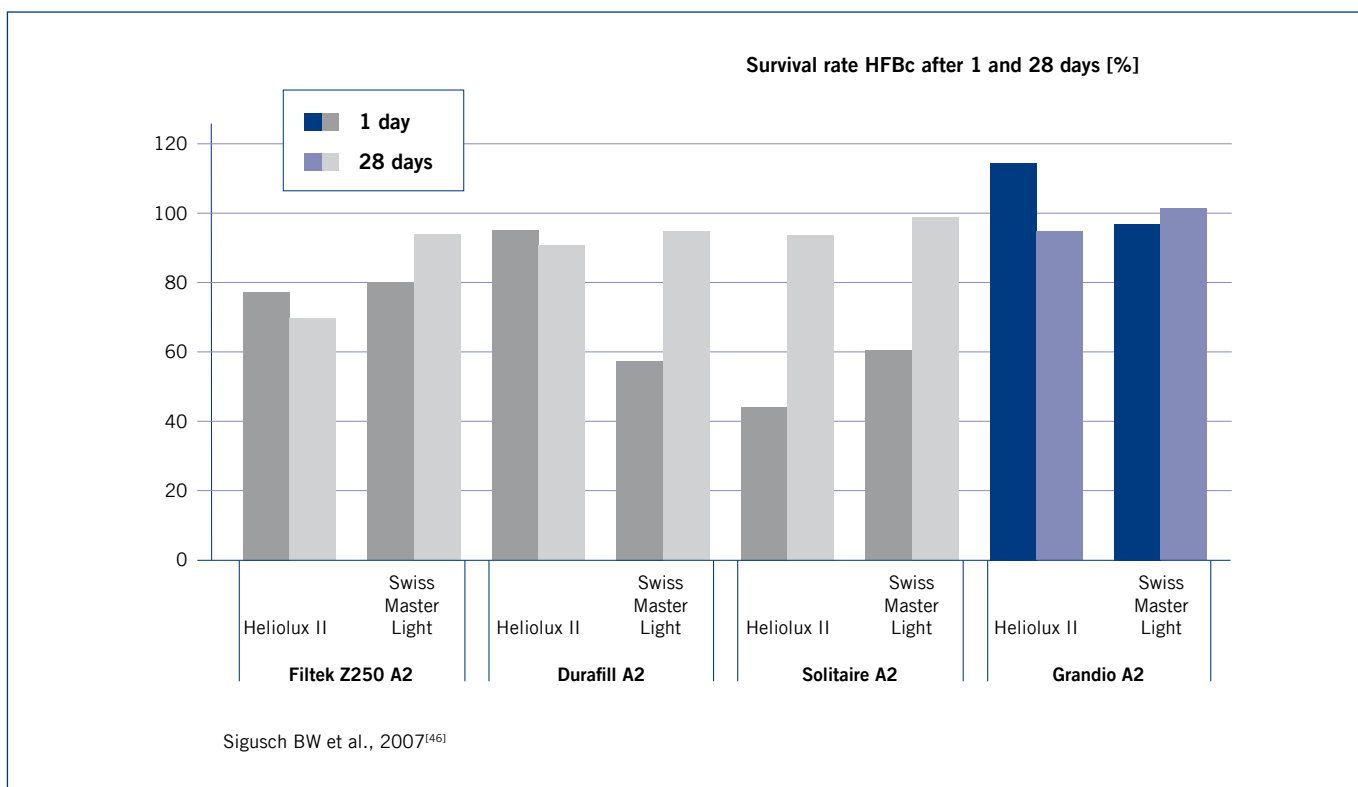
The adhesion of the pathogenic fungus *Candida Albicans* to Grandio was very low. The colonisation of the oral cavity with *Candida Albicans* is thus not promoted.



Cytotoxicity (University of Jena)

The low-level colonisation of a composite with bacteria is only a positive argument if this low rate is not caused by increased cytotoxicity. The matrix of every composite contains monomers which later polymerise by either light or catalysis. The amount of possible residual monomers on the one hand depends on the filler content of the material: the more filler, the less resin and fewer possible residual monomers. On the other hand, type and duration of the light-curing process also play a crucial role.

For this reason, various composites were cured with two different lamps (and a prototype not presented here) and subsequently stored for 28 days in a cell culture medium at the University of Jena^[46]. Cell colonies of human gingival fibroblasts (HFBC) obtained by daily sampling from the cell culture medium were incubated and their survival rate determined.



Overall, the best survival rates were achieved with Grandio. It is also noteworthy that Grandio exhibited these values from the first day on. Other materials induce a significantly lower survival rate on the first day and only after 28 days show a comparable low cytotoxicity.

Conclusion: High biocompatibility and simultaneous lower bacterial colonisation are further advantages of the Grandio technology which are beneficial not only for the longevity of the tooth, but also for the patient's satisfaction and health.

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