Scientific Manual

TPH Spectra® ST

Universal Composite Restorative

Dentsply Sirona

Research

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1 Introduction

Dentsply Sirona shows an ongoing commitment to the development of superior dental materials which use innovative technologies. A major milestone was achieved by introducing **SphereTEC™**, Dentsply Sirona's advanced granulated filler technology, to the new universal composite restorative **TPH Spectra ST**. It is indicated for anterior and posterior direct restorations as well as for the fabrication of inlays, partial crowns and veneers. As with the clinically well-established predecessor TPH Spectra, two different viscosities (high and low) are available. Based on the patented SphereTEC™ filler technology, TPH Spectra ST provides unprecedented handling properties, fast and easy polishing and outstanding gloss for composite restorations with natural esthetics. TPH Spectra ST is designed as a single translucency system that matches the color of the surrounding tooth structure with only five shades covering the whole VITA® color range of 16 shades.

1.1 Classification of TPH Spectra ST

Contemporary dental composites may be classified according to their **consistency** ('flowable', 'universal' or 'packable'), chemistry of the **resin matrix** (methacrylate-, acid-modified methacrylate-, inorganic polycondensate- or epoxide based) or constitution of the **filler system** (by filler-size: nanofills to macrofills and mixtures thereof, so called 'hybrids').

Regarding its **consistency**, the high viscosity version (HV) of TPH Spectra ST offers an intermediate consistency, comparable to e.g. Filtek™ Supreme Ultra (Figure 1, Figure 2). By comparison, the low viscosity version (LV) contains a slightly lower filler load in order to reduce the viscosity without affecting the physical properties of TPH Spectra ST.

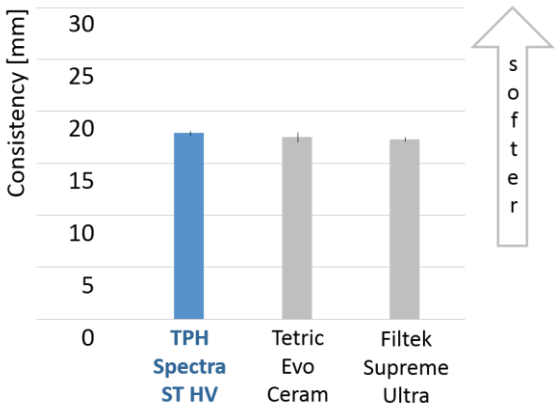

Figure 1 Consistencies of dental composites in mm diameter at **room temperature** (data for the propagation of a cylindrical sample of initially 7 mm diameter at 23°C and under a weight of 575 g for 120 s).

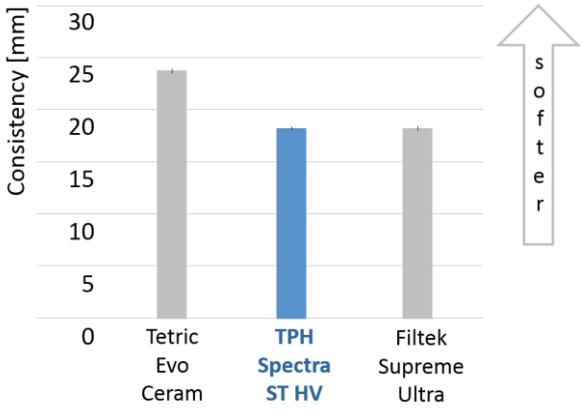

Figure 2 Consistencies of dental composites in mm diameter at **body temperature** (data for the propagation of a cylindrical sample with initially 7 mm diameter at 37°C and under a weight of 575 g for 120 s).

Regarding its **resin matrix**, TPH Spectra ST is based on a slightly modified version of the original TPH Spectra composite resin matrix. By incorporating an optimized photoinitiator system, the result is a durable, low-leaching methacrylate resin matrix.

The **filler system** of TPH Spectra ST is a blend of spherical, pre-polymerized SphereTEC fillers ($d_{3,50}$≈15 µm), non-agglomerated barium glass and ytterbium fluoride. Depending on the shade, the filler load ranges from 78-80 weight-% or 60-62 volume-% for the HV version and 76-78 weight-% or 57-60 volume-% for the LV version, respectively. Furthermore, the resin matrix contains highly dispersed, methacrylic polysiloxane nano-particles, which are chemically similar to glass or ceramics. In conclusion, TPH Spectra ST can be classified as a nano-hybridcomposite with pre-polymerized fillers.

1.2 SphereTEC Filler Technology

In general, high filler load supports mechanical strength and reduces polymerization shrinkage of a composite. Maximum filler loads can be achieved by combining particles of different size categories, so that large particles form a pre-packed grid and smaller ones can occupy the space in between (Figure 3). This approach is widely used in dental composites and, depending on the size of combined filler particles, different types of hybrid composites are produced.

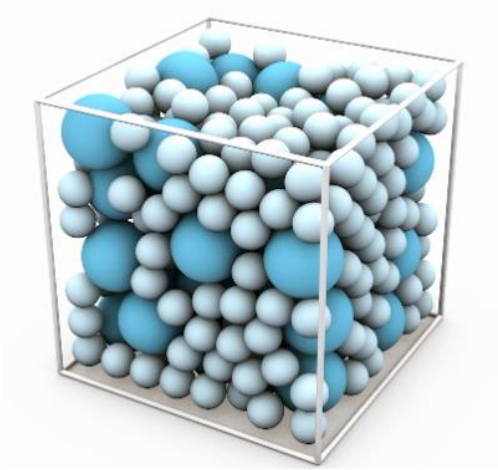

Figure 3 Simulated, random packing of spherical particles with two different sizes.

More specifically, **large fillers > 10 µm** facilitate high filler loads due to their lower surface area and corresponding lower energy to wet the particles with resin. Yet, at the same time, they impair esthetical properties like a materials' gloss by being torn out under mechanical strain, leaving significant surface defects.
On the other hand, smaller, i.e. **sub-micron particles** are favorable to obtain superior esthetics and polishability, but are more difficult to wet, limiting the maximum possible filler load.

To overcome the described technical conflict, the new generation of TPH Spectra is equipped with SphereTEC filler, the latest development in the field of composite filler technology. SphereTEC labels the process of manufacturing µm-scaled, well-defined superstructures, essentially built from sub-micron particles. Hence, when combined with isolated sub-micron particles, SphereTEC fillers allow the maximization of filler load in a composite by using primary particles of < 1 µm only.

SphereTEC fillers are produced via spray-granulation. The process roughly contains three steps (Figure 4). First, by atomization at specific pressure and temperature, small droplets of barium-glass filler particles are produced, surrounded by activated resin and solvent. Dictated by surface tension in the gaseous phase, the droplets then form spherical shapes of a well-defined size distribution and the solvent is evaporated. Finally, by travelling through hot processing zones, the resin is cured and completed, and solid SphereTEC fillers are collected.

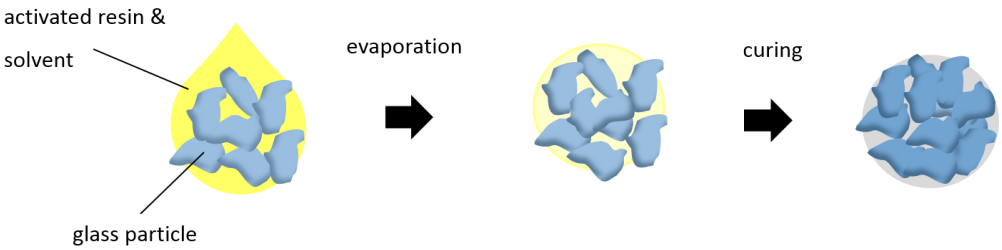

Figure 4 Schematic of the SphereTEC filler manufacturing process. From left to right: 1. Atomization of a slurry comprising finely dispersed barium glass, activated resin and solvent; 2. Forming spherical shapes and evaporation of solvent; 3. Curing to obtain pre-polymerized, spherical fillers.

SphereTEC fillers are virtually perfectly spherical (see Figure 5) and have a distinct, microstructured surface (see Figure 6), which distinguishes them from other pre-polymerized fillers.

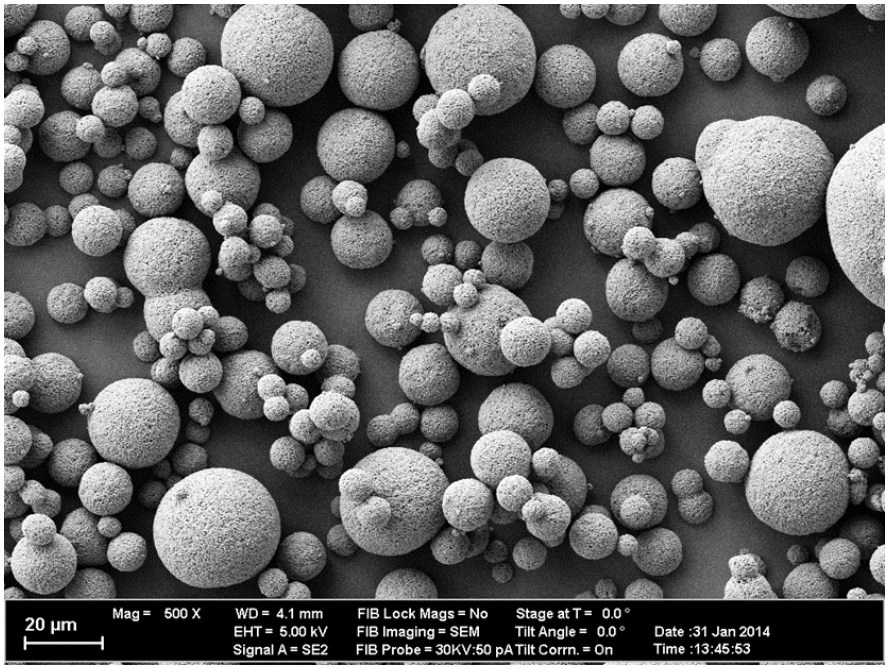

Figure 5 Typical SEM-pictures of SphereTEC fillers (Hagner M 2014).

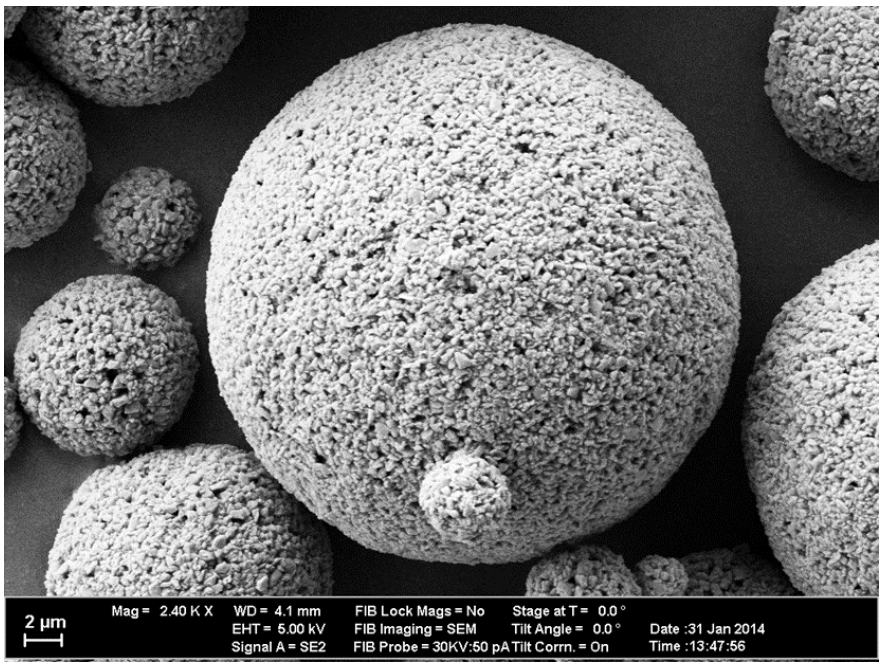

Figure 6 Typical SEM-pictures showing the microstructured surface of a SphereTEC™ filler (Hagner M 2014).

When used in the new TPH Spectra ST, they are thoroughly impregnated with resin, fully blended in the overall composition, and not distinguishable from other parts of the filler system, i.e. isolated submicron glass particles (Figure 7).

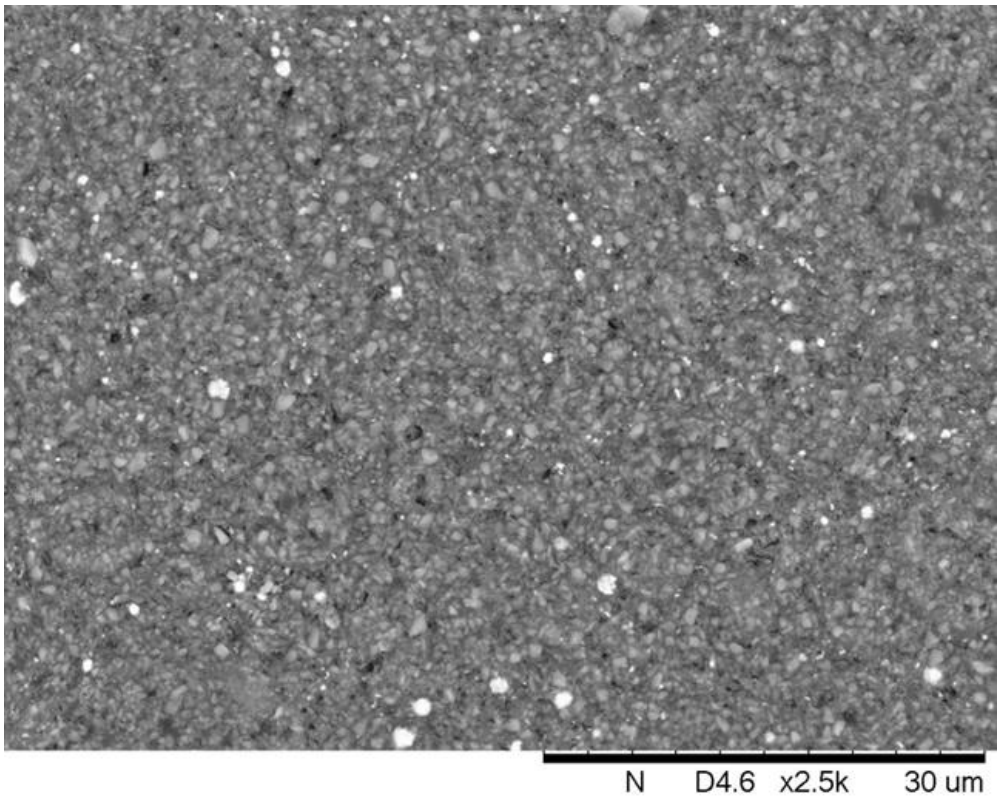

Figure 7 SEM picture of an abraded (see also Figure 27) surface of TPH Spectra ST with homogenously embedded SphereTEC filler particles (Latta MA 2015).

Due to their specific morphology, SphereTEC fillers lend unique features to the new TPH Spectra ST.

Most notably, they reduce the intrinsic friction of TPH Spectra ST when under shear stress. This is achieved by inhibited interlocking of the filler particles as SphereTEC fillers have a relatively smooth, concave surface facilitating easy application from the Compule® Tips as well as excellent sculptability by hand instruments (cf. chapter 0.1.3).

At the same time, when left unagitated, the combination of SphereTEC fillers with irregularly shaped, sub-micron particles leads to the distinct slump-resistance of TPH Spectra ST.

Because of the low active surface < 2 m^2/g and its distinct microstructure, SphereTEC fillers also reduce the amount of resin needed in a composite and thus minimize the stickiness to metal instruments (see chapter 2.1.2).

Finally, in vitro data on finishing and polishing shows that SphereTEC fillers, although ~15 µm in size, facilitate high gloss of the new TPH Spectra ST. Upon polishing SphereTEC fillers, embedded sub-micron primary fillers are removed layer-by-layer providing a smooth surface (see chapter 4.3.1).

1.3 Rheology of TPH Spectra ST

The above described novel SphereTEC filler lead to favorable thixotropic properties of the TPH Spectra ST composite during placement and sculpting.

Thixotropy describes a time-dependent shear thinning and recovery. Generally speaking, viscoelastic materials, like dental composites, show both viscous (fluid-like) and elastic (solid-like) properties when undergoing deformation. The portion of each characteristic can be determined by dynamical mechanical analysis and expressed by the loss modulus G'' for viscous portions, the storage modulus G' for elastic portions and the phase angle tan δ for the ratio of viscous to elastic portions: $\tan \delta = \frac{loss\ modulus\ G''}{storage\ modulus\ G'}$. Figure 8 shows the δ-values over three states of low- to high- to low shear stresses for TPH Spectra ST, Filtek™ Supreme Ultra and Tetric EvoCeram®. As can be seen, TPH Spectra ST not only displays the lowest δ for low shear stresses but also the fastest recovery after the stress has been reduced. Translated into the clinical context, TPH Spectra ST can be easily extruded from the Compule Tip, adapted to the cavities' walls and sculpted with the hand instruments (high shear stress → high δ >45°) but remains slump-resistant when left unagitated

(low/no shear stress → low δ <<45°). This unique property is a direct result of the novel SphereTEC filler system and was validated by handling tests (cf. chapter 2).

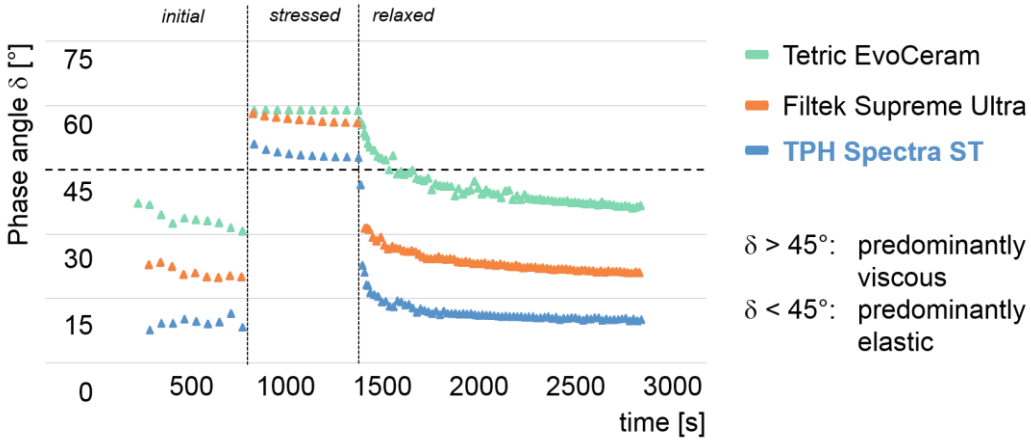

Figure 8 Phase angles of dental composites under step-wise change from low ('initial': $\tau = 2 \cdot 10^{-3}$ %rel. deflection, $\omega = 1$ Hz) to high ('stressed': $\tau = 10$ %rel. deflection, $\omega = 1$ Hz) to low shear stresses ('relaxed': $\tau = 2 \cdot 10^{-3}$ %rel. deflection, $\omega = 1$ Hz) at 30 °C.

2 Handling Properties

When choosing a composite product, clinicians not only focus on performance regarding esthetic properties, long-time marginal quality or resistance to fracture and wear. Equally important features for selecting a composite restorative are handling properties in terms of

- Viscosity of choice
- Secure adaptation of the composite paste to cavity floor, walls and margins
- Easy shaping of the uncured composite into the desired anatomical form
- Fast finishing and polishing procedure to achieve surface luster

With this in mind, the handling properties of TPH Spectra ST were validated in a user evaluation.

2.1 Evaluation of application properties by general dental practitioners

Preferences and acceptance of handling properties of TPH Spectra ST were evaluated by a large-scale User Evaluation under the condition of daily practice:
131 general dental practitioners (GDP) throughout the US, 97 of them existing TPH Spectra customers, 34 of them using another universal hybrid composite, applied TPH Spectra ST for routine treatment placing at least 10 restorations each. In total, more than 2,200 restorations were placed during the test period and served as a basis for the rating of the application properties and the immediate postoperative performance of the restorations.
With TPH Spectra, two viscosities are available – namely low viscosity (LV) and high viscosity (HV). Current users of TPH Spectra were provided with their preferred viscosity. All other GDPs received both viscosities of TPH Spectra ST.
TPH Spectra ST was rated in comparison to the composite of choice of each GDP and the findings were reported by means of questionnaires. Following graphs show results relative (percentage) to the total number of answers per question.

2.1.1 Viscosity

Clinicians have a personal preference regarding viscosity, which in some cases might even depend on the clinical situation (e.g. posterior class II compared to class IV). Typically, a composite is chosen that fits best this personal preference. Overall the majority (56 %) of the answering GDPs described TPH Spectra ST as offering a better viscosity compared to their current choice of composite. Details are given in Figure 9.

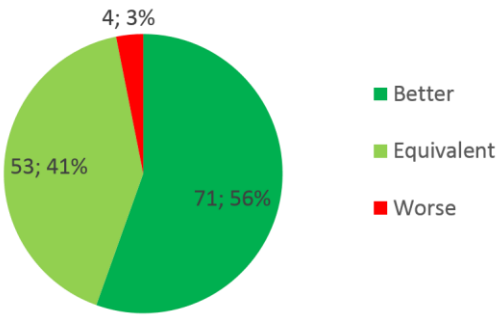

Figure 9 Overall rating of the viscosity comparing TPH Spectra ST to the current choice of composite.

2.1.2 Stickiness and adaptability

Market research showed that stickiness to hand instruments is regarded as the key challenge during direct filling therapy. To secure adaptation of the composite paste to cavity floor, walls and margins while manipulating the composite with hand instruments, stickiness needs to be as low as possible without losing the composite's ability to adapt to the cavity. TPH Spectra ST was found to be less sticky to hand instruments compared to the control composites by 66 % of the GDPs. Furthermore, adaptation of TPH Spectra ST was not found to be compromised by the vast majority of answering GDPs and rated being better (45 %) or equal (52 %) compared to their current choice of composite. Details are given by Figure 10.

Figure 10 Rating of stickiness of TPH Spectra ST to hand instruments (left) and adaptability (right) in comparison to the current choice of composite

2.1.3 Sculpting and slump resistance

Easy shaping of the uncured composite into the desired anatomical form and a low slump resistance before curing enables efficient filling therapy. The sculptability of TPH Spectra ST was rated as being better to the control composites by 63 %.

Furthermore, slump resistance was also positively rated with 43 % rating it as being better. Details are shown in Figure 11.

Figure 11 Rating of sculptability of TPH Spectra ST (left) and its slump resistance (right) in comparison to the current choice of composite

2.1.4 Polish

Regarding filler sizes, TPH Spectra ST can be regarded as a nano-hybrid composite with pre-polymerized fillers. In vitro laboratory studies under controlled conditions (see chapter 4) had shown fast finishing with Enhance® Finishers and polishing to high luster with Enhance® PoGo Polishers. Within this user evaluation a huge variety of polishing systems had been used by the participating GDPs. The majority of answering dentists did not find a relevant difference. However, about a third rated TPH Spectra ST as being better regarding speed (35 %) or quality (43 %) of polish. Figure 12 shows the detailed results.

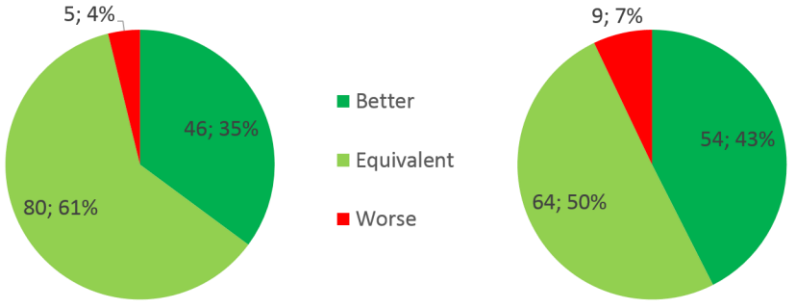

Figure 12 Speed (left) and quality (right) of polish for TPH Spectra ST using a variety of finishing and polishing systems in a clinical setting in comparison to the current choice of composite.

2.1.5 Overall handling properties

In summary, the handling properties of TPH Spectra ST were found to be better compared to their current choice of composite by 68 % of the participating GDPs (Figure 13).

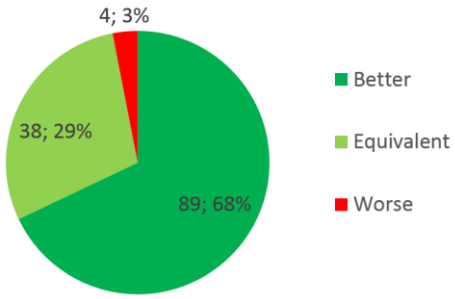

Figure 13 Rating of the overall handling properties of TPH Spectra ST in comparison to competitor products and current TPH Spectra

2.1.6 Interest in purchase

Overall, important properties determining the handling of a composite were rated being better compared to currently available composites by the majority of participating dentists in most of the cases. Against this background, it does not come as a surprise that 95 % of the participating dentists showed an interest in purchasing the product (Figure 14).

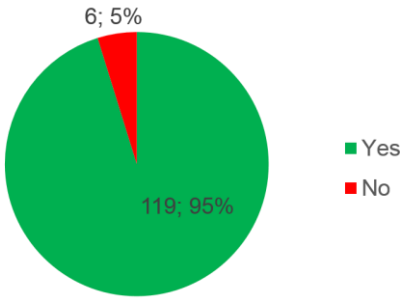

Figure 14 Interest in purchasing TPH Spectra ST either as replacement of current TPH Spectra or among competitive composite users to purchase in addition to or instead of their current material of choice.

This result indicates a very high level of customer acceptance of the product and satisfaction with its handling properties and the immediate clinical results.

3 Shade System

3.1 TPH Spectra ST

TPH Spectra ST is a single translucency system suitable for routine restorations of anterior and posterior teeth. The special features of the TPH Spectra ST shade system are:

- Five shades of moderate translucency allow restorations of all teeth within the shade range of the VITA® classical shade system (A1-D4).
- Shades are named A1, A2, A3, A3.5, and A4 - equivalent to the most common tooth shades and familiar in appearance to every dentist.
- Shades are described as CLOUD shades to reflect that each of the five TPH Spectra ST shades matches different VITA® shades, which form a 3D data cloud within the coordinates of the L*a*b* color system.

The recipe for shade selection is given by Figure 15.

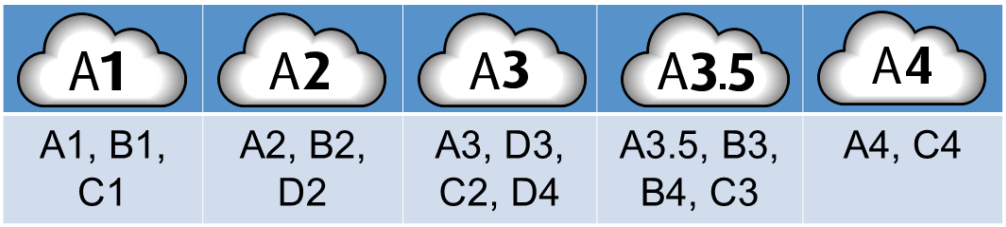

Figure 15 The new CLOUD shade concept is designed to achieve shade match with the full range of VITA® shades.

CLOUD shades cover more than one VITA® shade, because the shade of TPH Spectra ST restorations is influenced by the color of the surrounding tooth structure. This phenomenon is called *chameleon effect.* The distinct chameleon effect of TPH Spectra ST enables each TPH Spectra ST shade to match several VITA® shades.

In addition to the five CLOUD shades, a further shade is especially designed for restoration of bleached teeth. This shade (BW) is lighter than B1, the lightest VITA® shade, thus, being beyond the VITA® shade range and not considered to be part of the CLOUD shade concept.

Along with the package comes a self-adhesive recipe label (Figure 16), ideal for fixation to the rear side of the VITA® shade guide, providing a quick survey over the VITA® dedicated TPH Spectra ST CLOUD shades.

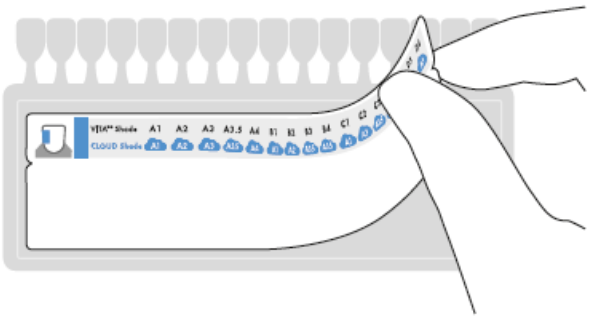

Figure 16 i-shade label for VITA® reference to TPH Spectra ST CLOUD shades

3.2 Shade selection

For shade selection, two tools and methods can be used as follows:

3.2.1 The TPH Spectra ST shade guide

The TPH Spectra ST shade guide consists of composite shade tabs, which are manufactured based on TPH Spectra ST. For shade selection, remove individual tabs from the shade guide holder. Use the shade tabs of the TPH Spectra ST shade guide to select the CLOUD shade closest to the shade of the area to be restored.

3.2.2 The VITA® classical shade guide in combination with the i-shade label

The TPH Spectra ST i-shade label facilitates shade selection by assigning one of the CLOUD shades to each of the 16 VITA® shades.
To make sure that the i-shade label is available at chairside, we recommend sticking it on the rear side of the VITA® classical shade guide.
Select the VITA® classical reference tooth, the central part of which best matches the area of the tooth to be restored. Use TPH Spectra ST i-shade label (Figure 16) to determine the CLOUD shade of TPH Spectra ST matching the selected VITA® shade.

3.3 Light-curing

Each increment of TPH Spectra ST is light-cured with a suitable curing light such as SmartLite® PS or SmartLite® Focus.
TPH Spectra ST must be used with a compatible curing light. The curing light must be able to cure materials containing camphorquinone (CQ) initiator and the peak of its spectrum has to be in the range of 440-480 nm.
Depending on light irradiance the curing time for 2 mm increments is between 10 and 20 seconds (Table 1). A curing time table for TPH Spectra ST also appears on all outer packages to facilitate sufficient light curing.

Shade			
TPH Spectra ST shades	≥ 500	20	2
	≥ 800	10	

Table 1 Curing time table for TPH Spectra ST. Check minimum light irradiance.

3.4 Instructions for Use

The up-to-date version can be found in multiple languages on www.dentsplysirona.com.

4 Material properties and in vitro studies

Developing a new filler technology and formulating a new composite requires a number of in vitro investigations to ensure sufficient performance in the intended indications. Primarily, mechanical strength and wear resistance need to be tested to support the use in permanent stress bearing posterior restorations. Polishability is an important factor when the material is used for restorations with high esthetic demand.
Following properties had been investigated and results from in vitro studies are reported in this chapter:

- Mechanical strength
- Wear resistance
- Surface quality and shade stability

4.1 Mechanical strength

Lohbauer U and Belli R, University of Erlangen (Germany)

4.1.1 Flexural strength

15 specimens (2 x 2 x 25 mm) were made following ISO 4049 and stored in distilled water at 37°C for 14 days. Flexural strength was tested with a crosshead speed of 1 mm/min in a four-point bending test as shown in Figure 17 with 10 and 20 mm distance between the upper and lower support, respectively. Four-point bending allows challenging a larger portion of the bending beam compared to three-point bending described in the ISO 4049. Therefore, the resulting values are typically lower.

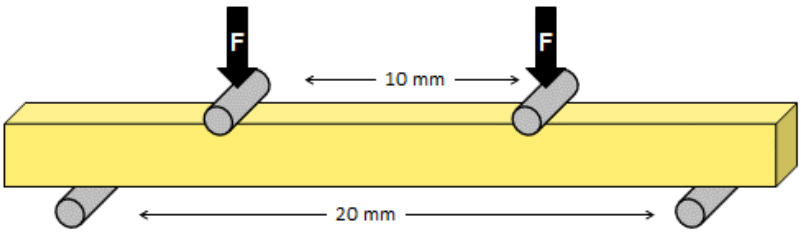

Figure 17 4-point bending test for flexural strength

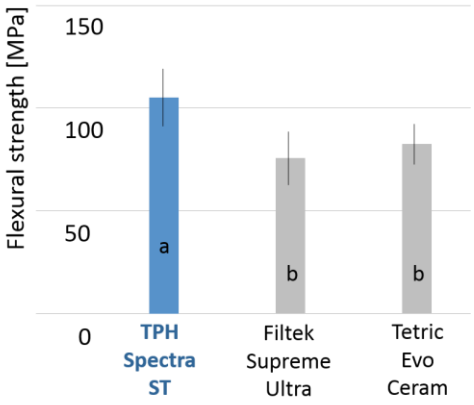

Figure 18 Flexural strength in four-point bending test (Lohbauer U and Belli R, 2015)

Mean flexural strength of TPH Spectra ST surpasses 100 MPa – the threshold for indirect restorations according to ISO 4049 – even under four-point bending as shown in Figure 18.

4.1.2 Flexural fatigue strength

While flexural strength represents the strength at maximum load, fatigue tests are needed to determine the behavior under subcritical loads and may allow a better prognosis of the long-term behavior of a material. Flexural fatigue strength was measured using 25 specimens per group in a stair-case approach starting at a level of 50% of the flexural strength and 10'000 cycles at a frequency of 0.5 Hz in water at 37°C.

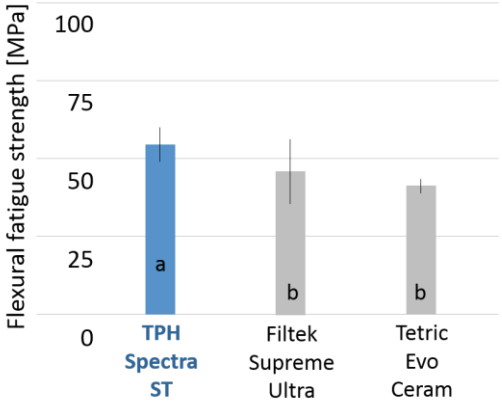

Figure 19 Flexural fatigue strength (Lohbauer U and Belli R, 2015).

TPH Spectra ST showed a high flexural fatigue strength which supports its use in permanent stress bearing restorations in posterior teeth (see Figure 19).

4.1.3 Fracture toughness

Fracture toughness (K_{Ic}) describes the resistance to catastrophic failure of an existing crack in a material. Following ISO 13856 15 specimens were prepared in a mold with an integrated V-shaped notch as shown in Figure 20 and stored dry at 37°C for 14 days.

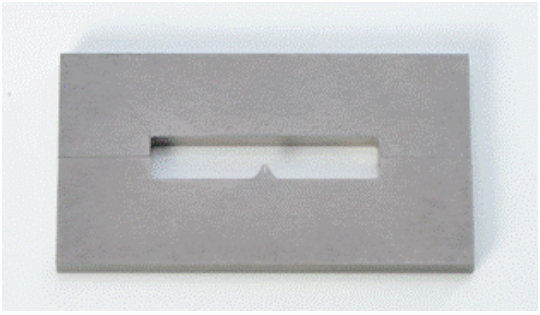

Figure 20 Mold with integrated V-shaped notch (Lohbauer U)

The notch was further sharpened using razor blades in a device allowing controlled movement parallel to the specimen as shown in Figure 21.

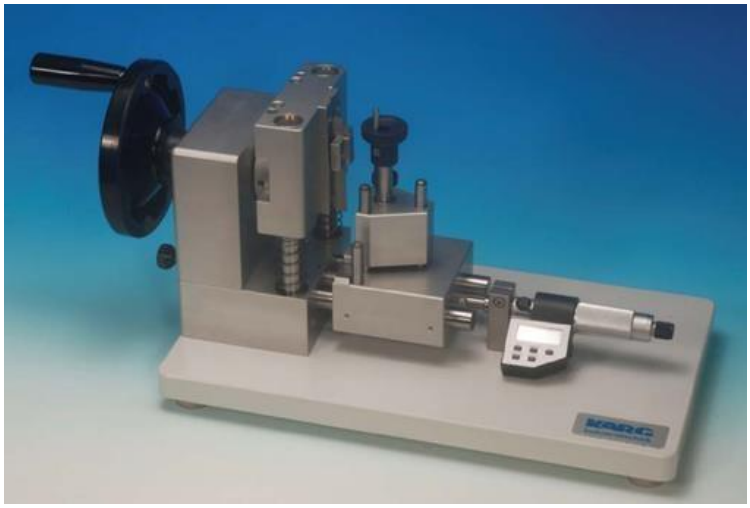

Figure 21 Notching device for parallel movement of the razor blade (Lohbauer U)

Specimens were loaded at a crosshead speed of 10 mm/min in a three-point bending test with an additional extensometer to precisely record strain during testing (see Figure 22).

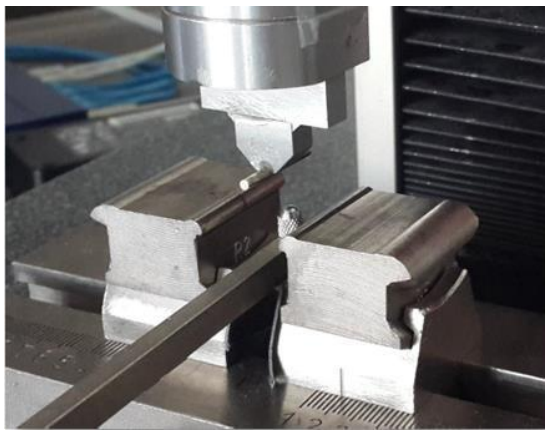

Figure 22 Three-point test set-up with extensometer (Lohbauer U)

To calculate fracture toughness the precise size of the crack-specimen size ratio is needed and was determined under a light microscope.

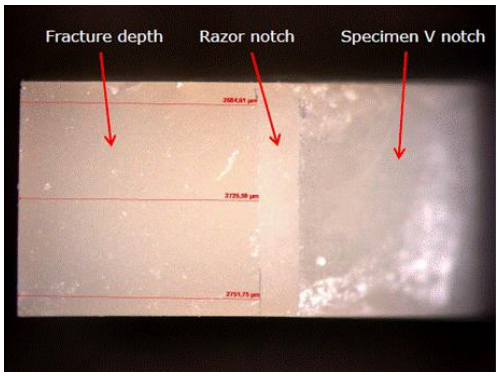

Figure 23 Determination of crack length (Lohbauer U)

Figure 23 shows a microscopic view on a cracked specimen with a clearly visible distinction between the "fracture depth", the "specimen V notch" originating from the mold, and the "razor notch" from sharpening with the razor blade, respectively.

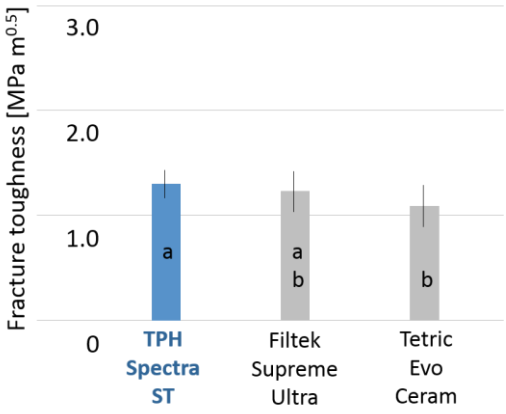

Figure 24 Fracture toughness after 14 days dry storage at 37°C (Lohbauer U and Belli R, 2015)

TPH Spectra ST shows a good fracture toughness comparable to other control materials as shown in Figure 24.

4.2 Wear resistance

Wear resistance is a key property for restorative materials used in stress bearing posterior restorations. To investigate different aspects of wear a variety of different methods have been employed for testing the wear resistance of TPH Spectra ST.

4.2.1 ACTA wear

Kleverlaan CJ and Werner A, University of Amsterdam (The Netherlands)
The three body wear simulator (see Figure 25) developed at ACTA (Academic Centre for Dentistry Amsterdam) and described by DeGee et al. in 1994 uses a spring loaded antagonist wheel which abrades the materials to be tested with a slip of 15% in a suspension of rice and millet seeds. As the spring load is constant during the wear run, this method rather simulates abrasion processes as in grinding a bolus than forces and impulses from chewing.

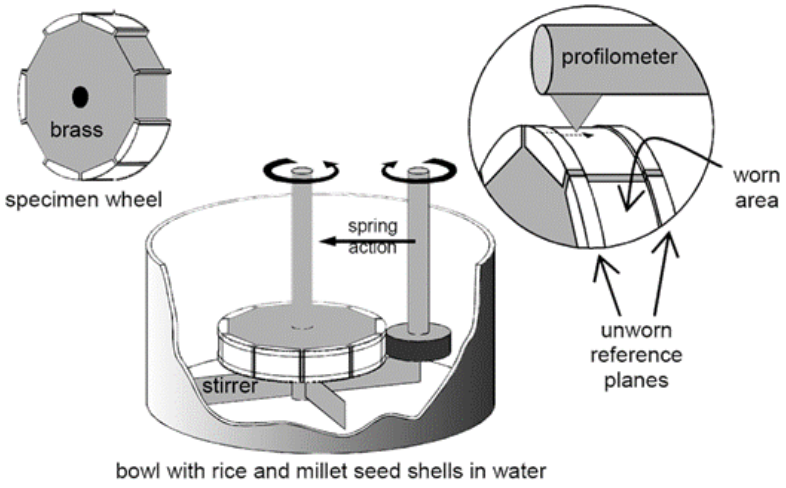

Figure 25 Three body wear simulator developed at ACTA

Results from 1 day up to 2 months are shown in Figure 26.

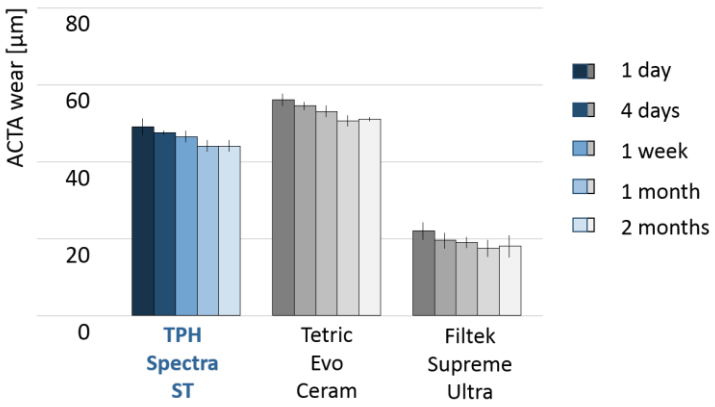

Figure 26 ACTA wear up to 2 months (Kleverlaan CJ and Werner A, 2015).

TPH Spectra ST showed good resistance to abrasive wear (Figure 26).

4.2.2 Leinfelder wear

Latta MA, Creighton University Omaha, NE (United States)

Wear in the oral cavity is a multifactorial process. Besides abrasion during grinding movements different wear patterns are generated during forceful occlusal contacts. Furthermore, localized wear in the occlusal contact area (OCA) might be different from generalized wear induced by chewing the food bolus without direct contact to the antagonist. Therefore, the so called "Leinfelder Wear Machine" allows testing both situations – localized and generalized wear.

In the generalized wear mode a steel piston is pressed through slurry of acrylic glass (PMMA) beads onto the specimen without touching it while rotating 30°. Parameters for the experiment and typical wear pattern are shown in Figure 27.

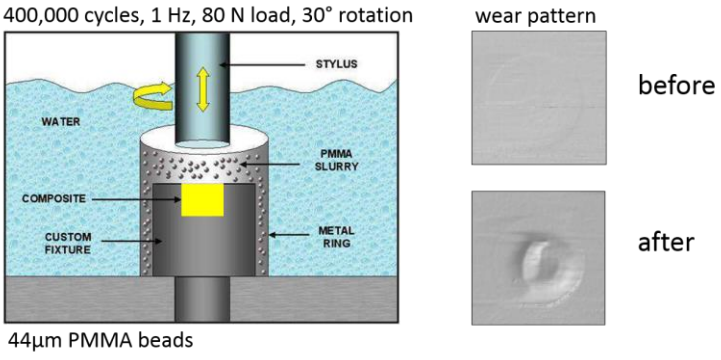

Figure 27 Generalized wear mode and typical wear pattern (Latta MA)

Figure 28 shows the volume loss of the total surface under generalized wear.

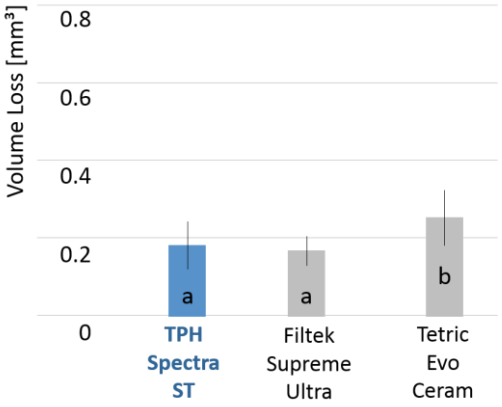

Figure 28 Volume loss under generalized wear (Latta MA, 2015)

TPH Spectra ST showed very good resistance to generalized wear as shown in Figure 28.

To simulate wear in the occlusal contact area the stylus is modified as shown in Figure 29. The resulting wear pattern differs significantly from the generalized wear test (see Figure 27).

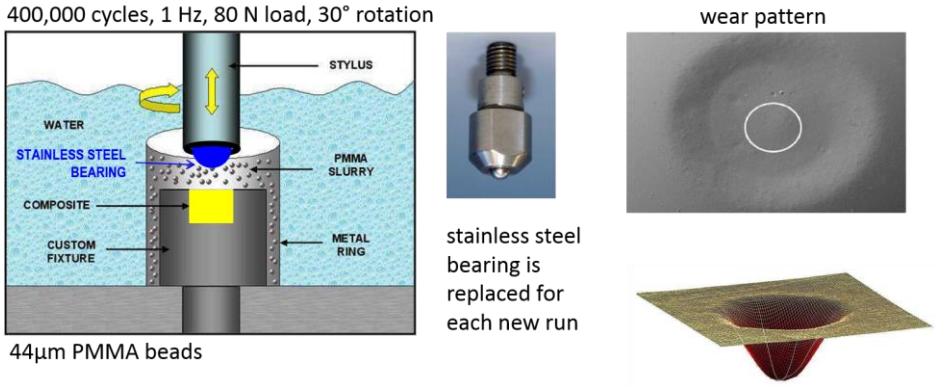

Figure 29 Localized wear mode and typical wear pattern (Latta MA)

Under the harsh conditions of localized wear TPH Spectra ST showed very high resistance to loss of height resulting in a low depth of the wear facet as shown in Figure 30.

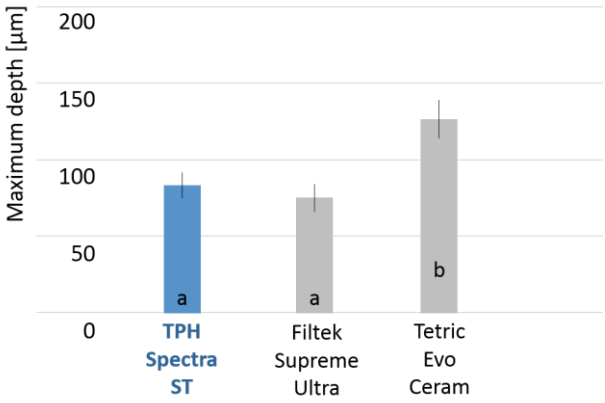

Figure 30 Maximum depth of wear facet under localized wear (Latta, 2015)

TPH Spectra ST is made with new filler technology SphereTEC as explained in chapter 1.2. For composites comprised of different filler fractions (size, type, etc.), a key question is whether wear generates a rough or smooth surface and whether any disintegration of larger particles takes place.

Figure 31 to Figure 33 show pictures from surfaces after generalized wear using a Scanning Electron Microscope (SEM).

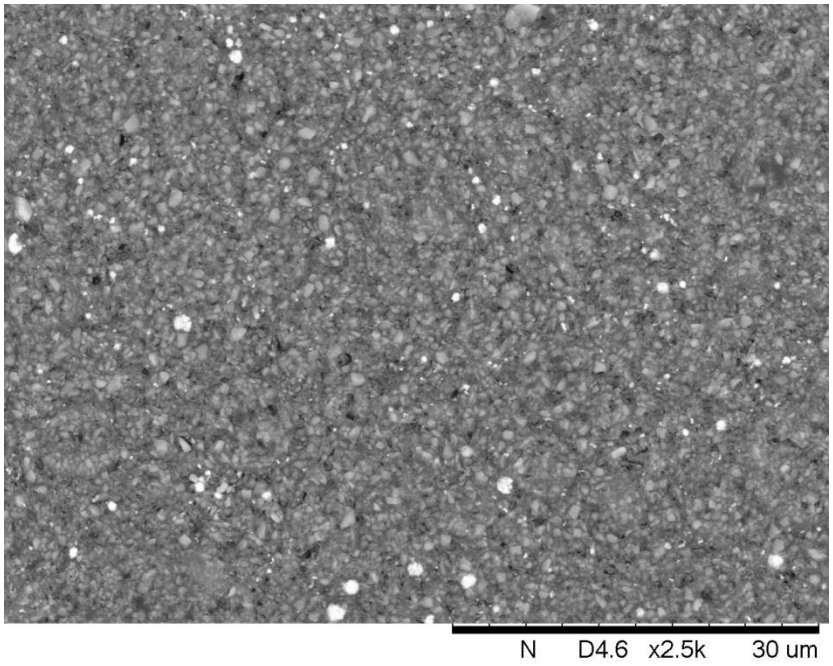

Figure 31 SEM (2500x) of TPH Spectra ST after generalized wear (Latta MA, 2015)

The abraded surface of TPH Spectra ST (Figure 31) is homogeneous and the granulated SphereTEC fillers can hardly be distinguished from the surrounding structure.

Figure 32 shows the abraded surface of Filtek™ Supreme Ultra. The clusters are clearly visible with no sign of disintegration.

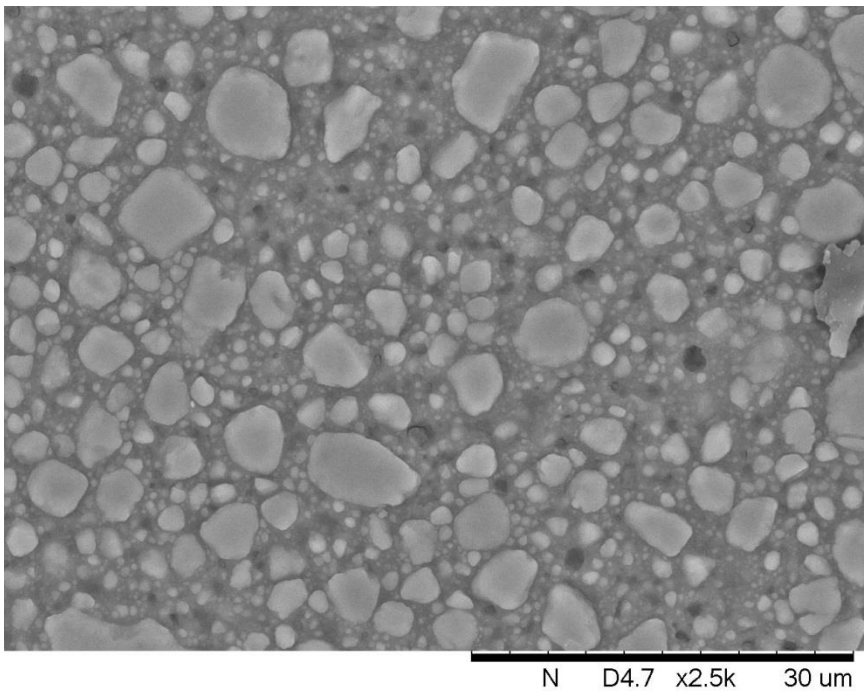

Figure 32 SEM (2500x) of Filtek® Supreme Ultra after generalized wear (Latta MA, 2015)

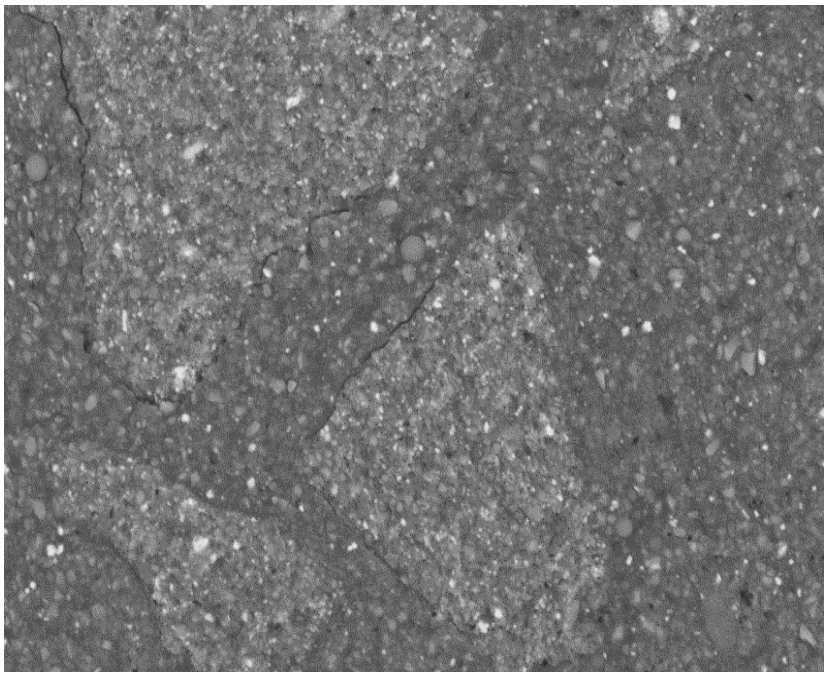

Figure 33 SEM (2500x) of Tetric EvoCeram® after generalized wear (Latta MA, 2015)

In contrast, pre-polymerized composite fillers are clearly visible on the abraded surface of Tetric EvoCeram® in Figure 33 with few signs of not perfectly smooth interfaces between composite fillers and surrounding composite.

4.3 Surface quality and shade stability

4.3.1 Finishing and polishing

Ferracane JL and Da Costa J, University of Portland, OR (United States)

Surface quality by means of gloss development while finishing and polishing a restoration is an important factor for direct restorative therapy as this procedure typically needs a lot of attention and consumes considerable amount of treatment time. Five composite specimens (5 x 12 x 2.5 mm) per group were roughened (600 grit) to obtain a standardized surface. Next, they were finished and polished by one experienced operator (da Costa J) using two different polishing systems:

- Enhance® Finisher and Enhance PoGo® Polisher – 2-step
- Sof-Lex® Finishing and Polishing discs – 3-step (M, F, SF were used)

Gloss values were periodically measured with a gloss meter on a 2x2 mm surface at an angle of 60° (see Figure 34). Specimens were repositioned after each period so that gloss from the same surface area per specimen could be followed-up over time. Gloass measurements were expressed in gloss units (GU). According to a publication of the American Dental Association (ADA), 40 GU are considered to represent a clinically accepted gloss (dotted line in Figure 37). Maximum gloss was determined after additional polishing until no further increase in gloss was visible.

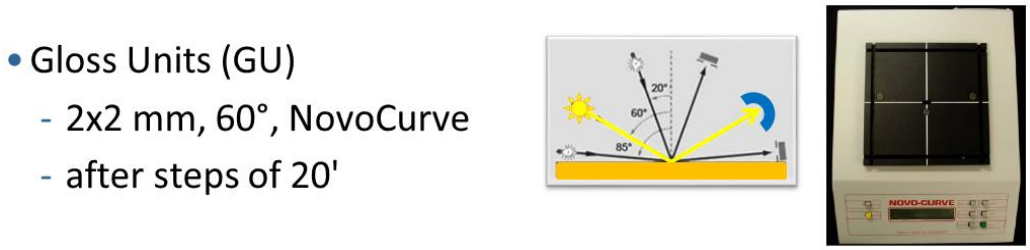

Figure 34 Parameters and equipment for gloss measurement

Figure 35 shows that **TPH Spectra ST** can be finished and polished with Enhance and Enhance Pogo to 40 gloss units in a shorter time and in fewer steps compared to the control. Moreover, the study revealed that **TPH Spectra ST** can be polished to a higher gloss above 60 GU than Filtek™ Supreme Ultra.

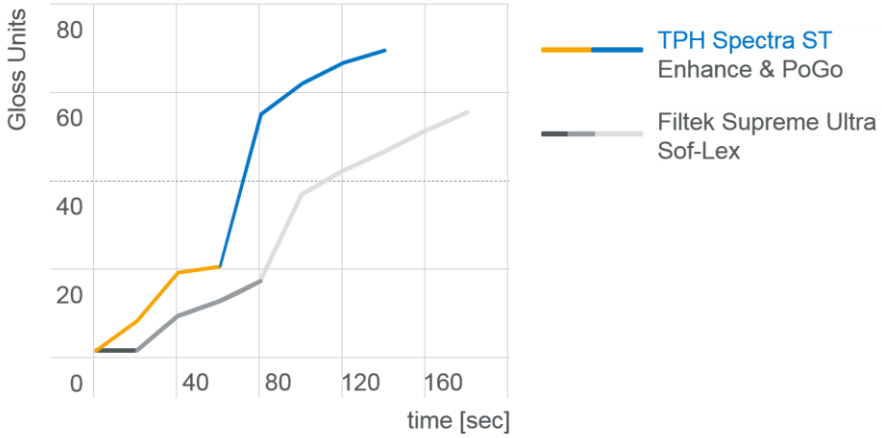

Figure 35 Gloss over time while finishing (yellow and dark gray lines) and polishing (blue and light gray lines) composites with two different polishing systems (da Costa J & Ferracane J, 2017). Clinically acceptable gloss marked as dotted line (ADA, 2010)

4.3.2 Shade stability

R&D Dentsply Sirona, Milford (United States)

Besides mechanical stability, shade stability is of importance for the long-term esthetical success of a visible tooth colored restoration. Cured composite specimens were stored in distilled water for 24 h at 37°C. Next, the specimens were soaked in 30 ml red wine side-by-side with the control composite at room temperature for 24 h. The stained specimens were thoroughly rinsed and dried. The color values (CIELab values) of each color chip was determined by spectral photometry (X-rite Color Eye) before and after the red wine staining. Results of the shade measurements expressed as the color difference delta-E are shown in Figure 36.

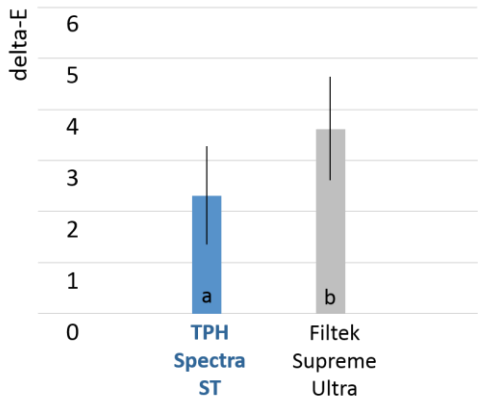

Figure 36 Mean values of color difference after staining (R&D Dentsply Sirona, 2017))

TPH Spectra ST showed significantly better stain resistance than Filtek™ Supreme Ultra.

4.4 Data sheet

Material properties specified by ISO 4049:2009 (Polymer based restorative materials) and other key material properties are listed in Table 2.

Property	ISO 4049	TPH Spectra ST
Compressive strength	-	400 MPa
Flexural strength	> 100 MPa	135 MPa
Flexural modulus	-	8.5 GPa
Vickers hardness (VH5/10s)	-	60
Filler content[1] **weight** **volume**	-	up to 79 wt.-%[2] up to 61 vol.-%
Shrinkage (Archimedes)	-	2.3 vol-%
Water sorption	≤ 40 µg/mm³	16.8 µg/mm³
Water solubility[3]	≤ 7.5 µm/mm³	-0.2 µg/mm³
Curing time 2 mm **500 mW/cm²** **800 mW/cm²**	-	20 s 10 s
Sensitivity to ambient light (10.000 lx)	> 60 s	130 s
Radiopacity	≥ 2 mm eq. Al	2.3 mm eq. Al

Table 2 Overview on key material properties (typical data).

[1] SphereTEC and conventional filler as well as ytterbium fluoride; content varies ± 2 % among shades

[2] inorganic filler content: 72-73 wt.-% / 48-50 vol-%

[3] Negative value due to very low solubility and remaining absorbed water

5 References

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De Gee AJ, Pallav P (1994). Occlusal wear simulation with the ACTA wear machine. J Dent Suppl. 1, 22:21-27.

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6 Glossary and Abbreviations

GDP	General Dental Practitioner
HV	High Viscosity
IFU	Instructions for Use
LV	Low Viscosity
OCA	Occlusal Contact Area
QTH	Quartz Tungsten Halogen
SEM	Scanning Electron Microscope
TC	Thermo Cycling / Cycles
TML	Thermo Mechanical Loading

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9 Trademarks

The following materials are not registered trademarks of Dentsply Sirona, Inc.

Brand (abbreviation(s), Manufacturer):
Filtek™ Supreme Ultra (3M ESPE)
Sof-Lex® (3M ESPE)
Tetric EvoCeram® (Ivoclar Vivadent)
VITA® (Vita Zahnfabrik)